OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

Development and testing of behaviour change based intervention for machine related safety on farms

Candidate: Aswathi Surendran

B.Tech (Electronics and Communication), MSc (Applied Psychology)

Student number: 19240179

School of Psychology, University of Galway

Thesis submitted to the National University of Ireland, Galway in fulfilment of the requirements for the Degree of Doctor of Philosophy (Psychology)

Month of Submission: September 2023

Research Supervisors

Dr Denis O'Hora, Dr Jenny Mc Sharry, Dr Oonagh Meade, Dr David Meredith

Graduate Research Committee

Dr Anne O'Connor, Dr Helena Lydon, Dr Mark Elliott

Table of Contents

DECLARATION

I, Aswathi Surendran, declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where states otherwise by reference or acknowledgement, the work presented is entirely my own. Permission has been granted to include the publications arising from this thesis by each of the publishing journals. The contribution of the co-authors to each of these publications has been acknowledged at the beginning of each of the publication chapters.

Signature:  Date: 29 September 2023

Funding

The study is funded by the Department of Agriculture, Food and the Marine Research Stimulus Programme: Grant # 17S269.

The funding body had no role in study design, data collection and analysis, the decision to publish any of the research papers, or the preparation for this thesis.

Dedication

This thesis is dedicated to my മുത്തിയമ്മ (grandmother), whose spirit and wisdom continue to inspire me, even though she is no longer with us.

Acknowledgements

'Which is more important,' asked Big panda,

'The journey or the destination?'

'The company,' said Tiny Dragon.

- Big Panda and Tiny Dragon, by James Norbury

When I reflect on the journey that led to the completion of this PhD, it becomes clear that to say it took support, love, and friendship spanning across continents is a profound understatement. When I reflect on the blessings that have enriched my academic journey, it is not the accomplishments or achievements that come to my mind; rather, it is the normal human beings with extraordinary empathy and boundless love that I had the privilege of encountering along the way. In this moment of gratitude, I am acutely aware that there are countless people to whom I owe my deepest appreciation for their indispensable roles in guiding and supporting me throughout my PhD journey.

First and foremost, thank you to the participants who kindly agreed to take part in this work and for their valuable contribution. I am sincerely grateful to the farmers, stakeholders and safety experts who took part in the work, dedicated their valuable time and shared their insights and expertise with me.

I would like to express my sincere thanks to my supervisors, Dr Denis O'Hora, Dr Jenny McSharry, Dr Oonagh Meade and Dr David Meredith for their vision, support, and guidance in the preparation of this thesis. Dr Denis O'Hora, your patient and constructive feedback, countless hours of discussion, and commitment to excellence have greatly shaped the quality and direction of my thesis. Thank you Denis, for your faith in me and for supporting me in this journey. I am truly fortunate to have had Dr McSharry as my mentor, and I am deeply grateful for your unwavering support in helping me to navigate the methodological challenges and your commitment to ensuring the rigour of my work. Dr Meade, your presence was a significant source of confidence and reassurance, and I am truly fortunate to have had your guidance and support during the most challenging and stressful period of my studies. Dr Meredith, you provided a unique perspective and served as a sounding board for farm research discussions. Your guidance and feedback encouraged me to think critically and consider alternative viewpoints. I am also grateful to my Graduate Research Committee (GRC) members, Dr Anne O'Connor, Dr Helena Lydon, Dr Mark Elliott, for their thoughtful input and advice during annual meetings.

I would like to extend my sincere gratitude to my Teagasc advisory team, Francis Bligh and John McNamara, for their unwavering support and guidance throughout my research journey. Your insights and feedback were instrumental in shaping the direction of my research, and I am deeply appreciative of your contributions to this work.

This research was funded by the Department of Agriculture, Food and Marine Research and was carried out with the assistance of the University of Galway. I must express my gratitude to these organisations for making this opportunity possible through their funding and support.

I would like to thank the staff, researchers and fellow PhD students in the school of psychology for your support and motivation.

As a researcher who has often grappled with visa challenges while travelling the world, the COVID-19 restrictions have presented significant hurdles. Being in a new country, especially with lockdown measures in place, has not been easy. However, amidst these challenges, working with the open science community has been a true blessing. I am grateful to Hardy Schwamm for extending the invitation to join the local open science community. Becoming a part of this community and joining the Opening Door team has been a transformative experience. I would like to express my sincere appreciation to Dr Denise McGrath for taking the initiative with the Opening Doors project and for fostering an environment of open collaboration. Our discussions and interactions have been insightful, and I will always cherish the knowledge and insights gained through our writing group. I would also like to extend my gratitude to my wonderful Agape teammates. Your camaraderie and support have been invaluable in lifting my spirits during challenging times.

Even as the lockdown restrictions were lifted, the persistent hurdles posed by EU visa policies continued to hinder my participation in numerous conferences and summer schools in person. For a brief three-day event, the prospect of navigating the intricate immigration and visa procedures often left me in a state of prolonged stress and anxiety. To those immigration and visa personnel who showed kindness and empathy, those unexpected glimpses of kindness left me smiling with great joy for the rest of the day.

Paddy & Alex, Thank you for renting your house to me (and my housemates) over these past four years. In the midst of a housing crisis, finding a stable, affordable and comfortable place to live as a student can be incredibly challenging, and your support has been greatly appreciated.

Sean, your patience and encouragement played a huge role in helping me learn how to swim, even after countless failures. These days, there's nothing like a sea swim to relieve stress. When I face discouragement or failures in my academic journey, I often think back to our swimming lessons. Learning to swim was a big confidence boost for me, and it reminds me that with practice and support, even the toughest challenges can be overcome.

Nina (Coursemate/Teammate/Friend), I will always cherish our collaboration during our course and as teammates, as well as the occasional hikes we had. These shared experiences have been a source of joy and camaraderie that I will forever hold close to my heart.

Thank you, Sarah, for becoming a vital source of support during these last three months of the writing phase. Sharing this journey with you has been invaluable, especially as we had the same day as the deadline. Working alongside you most of the time has made this challenging period more manageable, and your positive spirit and encouragement have been truly appreciated.

Sana & Wei, I am deeply grateful for your unwavering friendship and encouragement, which have made all the difference in my PhD experience. Wei, Your friendship has been a guiding light throughout this journey. When I struggled to find the strength to be productive, you shared your wisdom and tirelessly encouraged (pestered, as you say) me to make plans and set daily goals. Your insistence on my ability to do better, even when I doubted myself, was a constant source of strength. Despite your demanding schedule, you managed to carve out

time for virtual Zoom calls when you can’t be here in person. I can't thank you enough for being there when I needed it most.

Sana, our journey as housemates has been marked by a multitude of shared experiences that have played a pivotal role in sustaining me throughout these four years. Your unwavering support during both the high and low points of this challenging journey has been my steadfast anchor. Your deep empathy and patience have made an immeasurable difference. I couldn't express my gratitude enough for your friendship, which has played a major role in making our house a home away from home and a place where I've felt truly at ease during my academic pursuits.

Finally, to my family, Achan, Muthachan, Kathu, and Ary, who have supported me in countless ways throughout my years of study. Amma, you've stood by me, offering your support and love. I'll forever be grateful for your unwavering belief in me.

For any early career researcher who happens upon these acknowledgment section, I've shared my experiences here because there was a time I used to think that both the academic Twitter meme creators and I were the only ones facing challenges during our PhD journeys. If you find yourself in a similar boat, please know that you're not alone in this journey.

Abstract

Background

Farm machinery-related injuries are a growing concern worldwide, posing serious risks to farmers' safety and leading to severe disabilities or fatalities. As the farming population ages and farming machinery evolves, the need to address long-term safety becomes crucial. Research has demonstrated the effectiveness of behaviour change interventions in improving farm practices. To ensure the successful adoption of safe farming practices, understanding the factors that contribute to farmers' behaviour is important. This understanding allows for developing and tailoring behaviour change interventions to the specific needs and challenges faced by the target population. However, there has been limited work on developing theory-driven interventions to increase machine safety among farmers. This thesis aims to develop and test a behaviour change-based intervention focused on enhancing tractor-related safety on farms, with a particular focus on Irish farmers. The research involved collaboration with Irish farmers, experts in agricultural safety, and relevant stakeholders to ensure the intervention's relevance and practicality.

Aim

The aim of the project was the systematic development and feasibility testing of a behaviour change based intervention to increase machine-related safety on farms.

Methods and Results

This thesis encompassed four interlinking studies guided by the Behaviour Change Wheel framework for developing behaviour change-based interventions.

Study 1 (Systematic Review): The systematic review (Chapter 3) employed the Behaviour Change Wheel (BCW) framework and the Behaviour Change Technique (BCT) taxonomy to investigate machine-related farm safety interventions comprehensively. This review revealed gaps in addressing demographic factors, specific machine-related behaviours, and intervention complexity. Additionally, it emphasised the need for tailored interventions and rigorous reporting and evaluation of the active ingredients of the intervention. Further analysis highlighted the significant role of tractors and quad bikes in farm accidents, vulnerability among older farmers and children, and the limited attention to older farmers in safety initiatives. This foundational study informed subsequent research directions, providing essential insights into farm machine safety interventions.

Study 2 (Focus Group Discussions): This qualitative study explored the perspectives and experiences of older Irish farmers concerning farm machinery safety, with a particular focus on tractors and quad bikes. Utilising the Capability-Opportunity-Motivation-Behaviour (COM-B) model, the focus group discussions identified a range of high-risk behaviours associated with machine operation and safety. The study identified the barriers and facilitators influencing the adoption of safe machinery operation practices. This study also explored farmers' attitudes towards behaviour change techniques (BCTs) identified in the systematic review. These insights highlighted the need to tailor interventions for specific demographic groups and the significance of promoting age-appropriate safety measures for older farmers.

Study 3 (Co-design workshop): This study aimed to tailor farm safety intervention to the unique needs of older Irish farmers. Two co-design workshops with international farm safety

experts and stakeholders were conducted to achieve these objectives. These workshops identified potential target behaviours, barriers, enablers, and intervention components and delivery methods. A web-based rank order survey was used to prioritise target behaviours, and findings from the survey guided discussions during the workshops. Subsequently, with the Teagasc Advisory Team, a feasibility screening to finalise the selection of target behaviours, behaviour change techniques, and modes of delivery based on predefined criteria and empirical evidence.

Key target behaviours identified were (i) allocation of attention to machinery operation and the local environment and (ii) installing and using appropriate safety devices on machinery. Barriers included limited knowledge, while facilitators included peer support. The BeSafe tractor safety intervention strategically incorporated BCTs such as 1.1 Goal setting (behaviour), 1.4. Action planning, 4.1. Instruction on how to perform the behaviour, and 13.1 Identification of self as a role model. The study highlighted the importance of tailoring farm safety intervention to different farm types and age groups. Collaboration with the Teagasc Advisory Team ensured practicality, enhancing real-world applicability.

Study 4 (Feasibility trial): Study 4, the final stage of this research, involved the feasibility trial of the BeSafe tractor safety intervention. The trial assessed the acceptability, feasibility, and fidelity of the intervention components and the overall intervention among Irish farmers. The BeSafe intervention, developed based on the Behaviour Change Wheel (BCW) framework, encompassed in-person demo sessions, a facilitated discussion, a personalised safety training procedure template, a demonstration kit, and an SMS reminder. The trial included both older and younger farmers, with a focus on enhancing awareness about tractor blind spots.

Results from the feasibility trial indicated a positive reception of the intervention among participants. Farmers appreciated the farmer-centric approach, actively engaging with the intervention components. Peer-to-peer demonstrations were particularly effective in promoting peer-to-peer learning and safer farm machine operation practices. This study demonstrated the potential of a theory-driven, stakeholder-informed, behaviour change based intervention to improve machine-related safety on farms.

Conclusion

In conclusion, this thesis presents a systematic and comprehensive approach for developing a theoretically driven, stakeholder-informed, and behaviour change based intervention to improve farm machine safety. This thesis describes a novel attempt in the development of machine-safety interventions, offering a documented systematic approach firmly rooted in the BCW framework and substantiated by empirical evidence. The studies included in this thesis have contributed to the literature by providing a greater understanding of safety behaviour among Irish farmers, including novel insights on the potential behaviour change strategies to raise awareness among the farming population and enhance the adoption of safer farm practices. Overall, the findings and recommendations presented in this thesis have the potential to contribute to the efforts to address the high injury and fatality rates in the agricultural industry, ultimately promoting a safer working environment for farmers.

Article-based PhD requirements

This PhD was in accordance with the guidelines for an article-based PhD, as set by the School of Psychology at the National University of Ireland, Galway. The requirements state that three articles should make up the core of the PhD, with two of these articles accepted for publication and the third submitted for review.

At the time of submission, two articles have been accepted for publication in the International Journal of Environmental Research and Public Health (published on April 04, 2023) and the Pilot and Feasibility Studies Journal (published on July 04, 2023), respectively, and has been submitted for review in the Annals of Work Exposures. Therefore, the requirements for an article-based PhD have been met.

Research Outputs

Below is a list of dissemination outputs which have stemmed from this thesis.

Accepted papers

Surendran, A., McSharry, J., Meade, O., Bligh, F., McNamara, J., Meredith, D., & O'Hora, D. (2023). Increasing machine-related safety on farms: Development of an intervention using the Behaviour Change Wheel approach. *International Journal of Environmental Research and Public Health.* https://doi.org/10.3390/ijerph20075394

Surendran, A., McSharry, J., Bligh, F., McNamara, J., Meredith, D., & O'Hora, D. (2023). Assessing the feasibility, fidelity and acceptability of a behaviour change intervention to improve tractor safety on farms: Protocol for the BeSafe tractor safety feasibility study. *Pilot and Feasibility Studies.* https://doi.org/10.1186/s40814-023-01319-w

Surendran, A., McSharry, J., Meade, O., Meredith, D., McNamara, J., Bligh, F., & O'Hora, D. (2023). Chapter 4: Barriers and facilitators to adopting safe farm-machine related behaviors: A focus group study exploring older farmers' perspectives. *Journal of Safety Research* (in-press)

Submitted Papers

Surendran, A., McSharry, J., Di Domenico, R., Meredith, D., Meade, O., & O'Hora, D. (2023). Deconstructing complex machine-related farm safety interventions to identify common behavior change techniques - Systematic review. Manuscript under review in the Annals of Work Exposures and Health.https://doi.org/10.31219/osf.io/rp9cj. (pre-print)

Surendran, A., Malone, S., Meade, O., .Meredith, D., Bligh, F., McNamara, J., McSharry, J., & O'Hora, D. (2024). The Feasibility, Fidelity and Acceptability of Besafe for Tractor Operations - a Behaviour Change Intervention Targeting Tractor Safety Among Irish Farmers: A Mixed Methods Study. Available at SSRN: https://ssrn.com/abstract=4751475 or http://dx.doi.org/10.2139/ssrn.4751475. (pre-print)

Conferences presentations

Surendran, A., Malone, S., Meade, O., Meredith, D., Bligh, F., McNamara, J., McSharry, J., & O'Hora, D.. (2022, November 23). *The Feasibility, Fidelity and Acceptability a Behaviour Change Intervention Targeting Tractor Safety Among Irish Farmerse*. BeSafe National Farm Safety Conference 2022, Dublin, Ireland.

Surendran, A., McSharry, J., Meade, O., Bligh, F., McNamara, J., Meredith, D., & O'Hora, D. (2022, November 23). *Can we improve tractor safety? Preliminary results from a pilot safety training programme*. BeSafe National Farm Safety Conference 2022, Dublin, Ireland.

Surendran, A., McSharry, J., Meade, O., Bligh, F., McNamara, J., Meredith, D., & O'Hora, D. (2022, August 23-27). *Exploring older farmers' perspectives on improving machine related safety and factors influencing behaviour change: A focus group study*. European Health Psychology Society Conference 2022, Bratislava, Slovakia.

Surendran, A., McSharry, J., Bligh, F., McNamara, J., Meredith, D., & O'Hora, D. (2022, May 19-21). *Interventions to reduce machine-related accidents on farms: A systematic review and analysis of behavioural components.* International Behavioural Trials Network Conference 2022, Montreal, Canada.

Other media dissemination

O'Brien, A. (2023, September 15). New video focuses on farm vehicle safety and blind spots. Agriland.Ie. https://www.agriland.ie/farming-news/new-video-focuses-on-farm-vehicle-safety-and-blind-spots/

"Farm Vehicle Safety and Blind Spots Video Launched". (2023, September 19). Farm Safely. https://farmsafely.ie/farm-vehicle-safety-and-blind-spots-video-launched/

"Train-the-Trainer" approach can Improve Farm Safety Culture - Teagasc | Agriculture and Food Development Authority. (2024, March 08). Www.teagasc.ie. Retrieved March 25, 2024, from https://www.teagasc.ie/news--events/news/2024/train-the-trainer.php

Statement of Contribution

The candidate was responsible for the design, data collection, analysis, and write-up of each of the four studies conducted in this research. The supervisory team, Graduate Research Committee, manuscript co-authors, and local experts advised and/or provided support in conducting the research. The contribution of the co-authors to each of these publications is detailed in each of the publication chapters.

List of Tables

List of Figures

List of Abbreviations

APEASE: Affordability, Practicability, Effectiveness and cost effectiveness, Acceptability, Side effects/safety, Equity of an intervention

BCT: Behaviour Change Technique

BCW framework: Behaviour Change Wheel framework

COM-B model: Capability-Opportunity-Motivation-Behaviour model

DAFM: Department of Agriculture, Food, and the Marine

HSA: Health and Safety Authority

MRC: Medical Research Council

MSD: musculoskeletal disorders

NFS: National Farm Survey

NIH BCC: National Institutes of Health Behaviour Change Consortium

PTO: Power Take off

ROPS: Roll Over Protection System

SPIRIT: Standard Protocol Items: Recommendations for Interventional Trials

TFA: Theoretical Framework for Acceptability

TIDieR: Template for Intervention Description and Replication

Teagasc: The Irish Agriculture and Food Development Authority

Chapter 1 Introduction

The farming landscape in Ireland is not only a crucial component of the nation's economy but also a cornerstone of its cultural heritage. However, amidst the picturesque fields and rural charm, there exists a persistent concern - the safety of Irish farmers, particularly those who belong to the older generation. This thesis embarks on a journey that delves deep into the heart of Irish agriculture, seeking to understand, address, and ultimately improve the safety practices of these dedicated, hardworking individuals.

In spite of the fact that only 7.1% of Ireland's workforce is engaged in agriculture, the sector has consistently recorded the highest number of fatal incidents, accounting for 35% to 45% of annual workplace fatalities (*Annual Review and Outlook for Agriculture, Food and the Marine 2022*, 2022). This is a cause for concern as farmers are eight times more likely to suffer fatal injuries compared to other workers (Lee et al., 2017a; M. Murphy & O'Connell, 2018a). The situation is exacerbated by the fact that older farmers, with an average age of 57 among Irish farm holders in 2020, are particularly vulnerable, constituting 41% of fatal incidents (Conway et al., 2022). Machinery, particularly tractors, is the main cause of fatalities and injuries in the agricultural sector. With tractors being responsible for 53% of vehicle-related fatalities on Irish farms and considering that the elderly and children face a heightened risk (M. Murphy & O'Connell, 2017), it underscores the imperative of directing our attention toward high-risk areas, notably tractor safety. This focus is especially crucial when considering vulnerable populations like older farmers since they constitute a significant demographic within the farming community (Hernandez-Peck, 2008; O'Meara, 2019). Additionally, despite being disproportionately impacted, existing interventions often overlook the specific safety needs of older farmers, and there is a tendency for them to disengage from safety initiatives (Nilsson, 2016).

The agricultural sector presents a distinct working environment characterised by a unique blend of cultural, operational, and environmental factors. These factors encompass diverse farming tasks, the unpredictable impact of weather conditions, and the inherent isolation often associated with family farms. As most Irish farms are family-owned enterprises, many Irish farmers work alone, relying on their own safety practices with limited oversight. This solitary work environment challenges enforcing safety regulations and ensuring the proper use of engineering solutions. Additionally, when workplace injuries do occur, the isolated nature of work often exacerbates their severity (M. Murphy & O'Connell, 2017). The situation is further complicated by the fact that many farmers continue working well past their retirement age, facing added risks due to age-related physical limitations and ailments. Farmers aged 65 and above are particularly vulnerable to musculoskeletal disorders (MSDs) and an elevated risk of severe injuries. Compounding these concerns is the cumulative effect of prolonged exposure and the physical demands of tractor-related work conditions (Alwall Svennefelt, 2019; M. Murphy & O'Connell, 2017).

While older farmers are consistently identified as a vulnerable population, research investigating their risk perception and safety practices remains limited (Nilsson, 2016). An essential aspect of safety relates to the perspectives and views of older farmers regarding their health, safety, and job-related risks, along with their experiences with previous accidents. Farmers often underestimate their disease burden, and their health status can significantly

affect work performance (McLaughlin et al., 2009). These factors drive them to perform tasks as they did many years ago, inadvertently increasing their exposure to risks and injuries (Alwall Svennefelt, 2019). Therefore, in order to improve safety among older farmers, it is important to have a better understanding of their priorities, needs, and preferences. Additionally, it is necessary to investigate the barriers, enablers, and behaviours that can increase the participation and engagement of older farmers in safety initiatives.

Recognising the urgency of the issue, the primary focus of this thesis centred on exploring the behavioural determinants that influence safety decision-making among older farmers. The overarching goal was to develop and assess behaviour change interventions that enhance awareness of safer farming practices, specifically targeting the prevalent risk-taking behaviours, especially concerning tractor safety, among older farmers and their families.

Moreover, through collaboration with diverse stakeholders within the farming community, including farmers, agricultural experts, and safety researchers, we ensured that our novel intervention is evidence-based and contextually relevant (Giles et al., 2020). Consulting with these stakeholders during the design phase allowed us to incorporate local demographic factors and address the specific needs and challenges faced by Irish farmers.

In the initial phase, the thesis focused on understanding the persistence of improper machine-related safety practices in the agricultural sector despite the educational, engineering, and regulatory strategies rolled out by various safety initiatives in the past. While existing safety research provided insights into workplace accidents and injury mechanisms, it soon became evident that it is essential to explore the specific factors influencing safety outcomes in the Irish farming context. Consequently, the next study aimed to investigate the behavioural factors influencing farmers' risk tolerance, with the goal of identifying the underlying dynamics and aiding in the creation of more effective interventions. The study recognised the significance of socio-cultural and environmental factors within the farming community. Social norms, peer pressure, and environmental factors shape farmers' attitudes towards risk-taking and safety practices (M. Murphy & O'Connell, 2017; O'Connor et al., 2022). Therefore, the research explored the influence of peer learning and social support on safety attitudes and behaviours within the farming community. This multidimensional approach aimed to provide a comprehensive understanding of the individual, social, and environmental factors that contribute to farm safety.

To attain this objective, the thesis employed a systematic and evidence-based approach, drawing from established behaviour change theories and frameworks. Specifically, it relies on the Capability-Opportunity-Motivation-Behaviour (COM-B) model and the Behaviour Change Wheel (BCW) framework (Section 2.5.3). These theoretical frameworks provide a comprehensive understanding of the determinants of behaviour and offer practical guidance for the development of targeted and effective interventions (Michie et al., 2014). By leveraging existing behavioural intervention frameworks and theories, this thesis developed and tested evidence-based interventions tailored to the specific needs of Irish farmers, with a particular focus on older individuals operating tractors.

In addition to intervention development, this thesis emphasised the importance of feasibility testing. Therefore, the last study focused on rigorous evaluation of the feasibility, fidelity, and acceptability of proposed interventions within the farming community. This ensured that

these interventions were theoretically sound but also relevant and acceptable among the Irish farming community.

In summary, this thesis aimed to explore the factors that need to change to improve machine-related safety on farms, develop and pilot test a behaviour change-based intervention, and address the local demographic factors that influenced farmers' attitudes and behaviours. By adopting a theory-driven and stakeholder-focused approach, the research sought to foster sustainable behaviour change and improve machine safety practices in the farming sector. Feasibility testing will play a crucial role in ensuring the practicality and acceptability of the proposed interventions.

Project Outline

Aim of the Thesis

The overall aim of this research was to develop and test an evidence-based behaviour change-based intervention enhancing machine-related safety on farms.

Objectives

Four objectives were identified (Figure 1):

Objective 1: Evaluate existing machinery-related farm safety interventions, including an examination of the behavioural change techniques employed, to assess their effectiveness and limitations

Objective 2: Investigate farmer attitudes and the barriers and facilitators influencing the adoption of safer farm machinery practices on farms.

Objective 3: Develop and refine a behaviour change intervention targeting farm machinery safety through co-design workshops.

Objective 4: Explore the feasibility, fidelity, and acceptability of the developed behaviour change intervention to assess its practicality and alignment with acceptability and fidelity principles.

Figure 1: Thesis objectives

Research Design

According to Creswell and Plano Clark (2017), all research requires a basis for its investigation, and researchers must be conscious of their underlying worldviews. The worldview or paradigm of a research project refers to the fundamental beliefs or assumptions that form the foundation of the inquiry and reflect the researcher's perspective on the world. These beliefs are shaped by personal experiences and cultural background and evolve over time as new experiences and ideas are encountered. The paradigm underpinning this research constitutes a thoughtful synthesis of ontological, epistemological, and methodological considerations deeply rooted in the pragmatic worldview (Cherryholmes, 1992). This choice is informed not only by the theoretical richness of pragmatism but also by the unique demands posed by the intricate landscape of farm safety research.

The ontological aspect of this paradigm recognises that reality is multifaceted, allowing for the exploration of different perspectives and dimensions of farm safety behaviours. It asserts that knowledge is shaped through experiences and interactions (Denzin & Lincoln, 2011), a notion that harmonises remarkably well with the multifaceted nature of farm safety behaviours. By acknowledging the coexistence of diverse realities within the agricultural realm, this paradigm embraces the complexity of factors influencing safety behaviours among farmers.

The epistemological dimension of this paradigm presents knowledge as a purposeful creation. In this view, knowledge is not confined to rigid categories of objectivity or subjectivity. Rather, it exists along a continuum, evolving through engagement with the world. Such an epistemological stance is particularly pertinent to the exploration of farm safety behaviours, which demand a departure from traditional boundaries and a willingness to embrace a spectrum of insights (Yardley & Bishop, 2015). This pragmatic epistemology aligns with the research's aspiration to capture the nuanced interplay of factors influencing safety behaviours.

Embedded within the pragmatic paradigm is a methodological framework that harmonises with the complexities of farm safety research. Drawing inspiration from the insights of Goles and Hirschheim (2000) and Kaushik and Walsh (2019), a mixed methods approach is adopted for the current research. This approach, fusing quantitative and qualitative methodologies, embodies the pragmatist belief in knowledge as a continuum. The choice of a mixed methods approach also reflects the pragmatic paradigm's emphasis on contextually grounded knowledge, allowing for a thorough exploration of the complex dynamics shaping farm safety behaviours. Furthermore, this methodology acknowledges the limitations of using only one research method and instead combines qualitative and quantitative techniques to leverage their strengths (Johnson & Onwuegbuzie, 2004). Therefore, the current research acknowledges and addresses the multifaceted dimensions of farm safety behaviours by adopting a qualitatively led, exploratory mixed methods design. By integrating these different approaches, the research aims to gain a comprehensive understanding of the various factors influencing farm safety behaviours.

The pragmatic paradigm serves as both a philosophical anchor and a methodological compass, guiding the current research toward its ultimate objectives. By embracing an ontological perspective that acknowledges multiple realities, an epistemological stance that embraces the spectrum of knowledge creation, and a methodological framework that marries qualitative and quantitative methods, this paradigm proves to be an ideal fit for exploring the complexities of farm machine safety behaviours.

In summary, the adoption of the pragmatic paradigm stands as a strategic choice as it not only allows for a holistic exploration of the diverse factors impacting safety behaviours but also fosters a deeper engagement with the unique context of agricultural settings. By adopting this approach, we ensure the reliability and rigour of our research findings.

The structure of the thesis

The thesis starts with an introductory chapter (chapter 2) that sets the stage for the research journey. This chapter begins with a brief examination of the global perspective on farming and farm fatalities, shedding light on the universal challenges faced by the farming community. It then narrows its focus to the unique context of farm safety in Ireland. This section provides a concise yet comprehensive overview of the farm safety landscape in Ireland, emphasising the critical issues surrounding machine-related safety on Irish farms. It also presents a compelling case for the development of a behaviour change intervention to enhance machine-related safety on Irish farms. Finally, it outlines the overall design of the current work, providing readers with a clear understanding of the systematic approach adopted throughout the thesis.

Figure 2: Summary of objectives and studies conducted

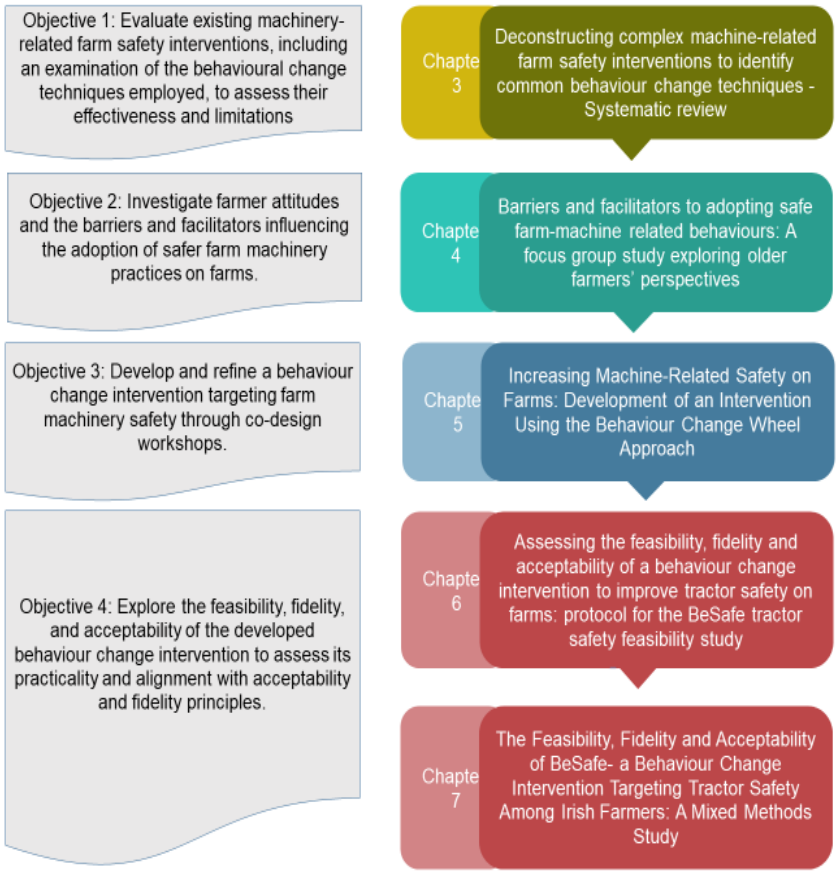


Figure 2 provides a concise visual summary of the research objectives and the corresponding studies conducted, offering an overview of the comprehensive scope of this work.

Chapters 3 – 7 are presented as independent journal articles. Chapters 5 (Surendran, McSharry, Meade, et al., 2023) and 6 (Surendran, McSharry, Meredith, et al., 2023) have been published, chapters 3 (Surendran, Mc Sharry, et al., 2023) is currently under review for publication, and Chapter 4 and 7 are a work in progress, with expected submission in October 2023 and November 2023, respectively.

Chapter 3 describes a comprehensive systematic review of farm machine safety interventions, aiming to identify key intervention components, behaviour change techniques, and outcomes. The study critically analyses existing literature to uncover gaps in the field of machine-related farm safety and emphasises the need for tailored strategies, demographic considerations, and systematic reporting of intervention. The findings underscore the importance of addressing the specific safety needs of vulnerable populations, such as older farmers, and high-risk-prone areas, such as tractors and quad bikes.

In addition to incorporating best practices from published studies, the project sought to ensure that farmers' voices were heard and that interventions aligned with their concerns and experiences. In service of this intention, Chapter 4 is a qualitative study that included four focus groups of older farmers. In this study, the attitudes, behaviours, and perceptions of Irish farmers, particularly older individuals, regarding machine-related safety were explored. Five themes were identified: 1) Capability to manage competing responsibilities; 2) Characteristics

of the farm and its work environment; 3) Availability and affordability of resources; 4) Prevailing sociocultural opportunities; and 5) Perceived likelihood and cost-benefit analysis in safety decision-making. The insights gathered in this chapter play a pivotal role in refining the direction of subsequent research phases, guiding the development of a tailored safety intervention for enhancing farm machinery safety among older farmers.

Chapter 5 outlines the systematic development of an evidence-based behaviour change intervention, guided by the Behaviour Change Wheel (BCW) and the Capability-Opportunity-Motivation-Behaviour (COM-B) model. It details the outcomes of a co-design workshop involving stakeholders, including farmers, agricultural experts, and safety researchers. This collaborative effort identified target behaviours and intervention components essential for enhancing machine-related safety on farms. This chapter provides an initial template for developing a theory-based, stakeholder-informed, behaviour change based intervention targeting farmers and reporting such developments.

Chapter 6 outlines the protocol for the feasibility trial, a critical phase in the development of the behaviour change intervention for machine-related safety on farms. It describes a systematic approach for evaluating the acceptability, feasibility, and fidelity of the intervention and its components. The chapter highlights the trial design, outcome measures, and methodology used to assess the intervention's effectiveness. It underlines the importance of aligning the intervention with the needs and suggestions of Irish farmers and emphasises a theory-driven, farmer-engaged approach to promoting safety practices.

In Chapter 7, the results of the feasibility trial are presented and analysed. The chapter discusses participant feedback on the intervention acceptability, their engagement with the intervention components, and the observed impact on machine-related safety practices. Through quantitative and qualitative analysis, this chapter offers insights into the intervention's perceived acceptability, engagement and potential effectiveness, setting the stage for broader implementation and further development.

The thesis ends with a general discussion (chapter 9). This chapter revisits the findings of the individual studies within the thesis, offering a comprehensive synthesis of the research outcomes. It then widens its scope to explore the broader implications of the PhD study's findings within the farm safety research. Moreover, this chapter discusses the practical implications of the research, emphasising how the developed intervention can contribute to tangible improvements in farm safety practices. The chapter is concluded by acknowledging the limitations of the thesis and providing a critical reflection on the approach taken in this study.

Chapter 2 Background

This chapter provides an overview of the key topics central to the study: farm safety, behaviour change, and the development of behaviour change based safety interventions. The first part of the chapter provides a worldwide view of farming, which helps to comprehend the context in which agricultural safety concerns arise globally. This leads to a discussion of Irish farming, which has its own unique characteristics and challenges. The chapter highlights the critical issue of farm safety among lone farmers in Ireland, who are a vulnerable population with distinctive safety needs. Next, the significance of behaviour change is discussed, along with the theoretical foundations that support it. The complexities of understanding behaviour change are explored, including the interplay of psychological, social, and environmental factors that affect human behaviour. The use of behaviour change theories and frameworks is also examined, with a focus on their crucial role in shaping the research methodologies used in this study. The BCW framework is a crucial framework in this study, as it provides a structured approach to developing effective interventions (Michie et al., 2014). The chapter explains the importance of the BCW and how it is practically applied in this research, highlighting its ability to drive the development of evidence-based and theory-driven safety initiatives. The chapter ends by introducing the BeSafe project and a brief overview of the intervention development process, which sets the stage for the following chapters that delve deeper into the development and evaluation of the behaviour-change-based safety intervention.

A global perspective on farm safety

Farming is an essential occupation that plays a crucial role in providing food and sustaining communities worldwide. According to the Food and Agriculture Organisation of the United Nations (FAO), the agricultural sector employs a significant portion of the global workforce, with approximately 874 million people working in agriculture internationally in 2020, making up 27% of the global workforce (FAO, 2021). It is a dynamic industry that involves various processes, machinery, and environmental factors. Agriculture involves a wide range of activities, including the use of various types of machinery, animals, plants, and products, and it takes place in diverse indoor and outdoor environments under different geographic and climatic conditions. This dynamic nature of farming contributes to its significance and the challenges it presents (Europäische Kommission, 2004; Huston, 1969; D. J. Murphy, 1992).

One significant development in farming practices occurred in the 1950s with the introduction of machinery, which revolutionised the industry. During this time, machines such as tractors, harvesters, and other agricultural equipment became more prevalent on farms. These machines brought increased power and efficiency to farming operations, allowing for larger-scale production and improved productivity. However, with the benefits of machinery also came new risks and challenges for those involved in agricultural work (Myers et al., 2009).

The nature of the work, which involves handling powerful machinery, working in diverse environments, and performing physically demanding tasks, has made farming one of the most hazardous industries worldwide, alongside mining and construction. Agricultural workers experience higher rates of adverse health effects and fatalities compared to workers in other occupations (Shortall et al., 2019). Today, farming involves the use of a wide variety of hazardous machinery and processes, such as tractors, cultivators, harvesters, and tools for

repairs and maintenance, exposing farmers and farm workers to potential injuries and accidents. Moving parts, sharp blades, and the sheer power of these machines pose significant hazards, and incidents such as cuts, burns, fractures, and amputations are not uncommon in the farming sector (Jadhav et al., 2015). Additionally, the complexity of operating and maintaining these advanced tools requires specialised knowledge and skills (Myers et al., 2009; Sorensen et al., 2017).

Farm injuries refer to accidents and incidents that occur within agricultural settings involving farm workers, non-working farm residents, and visitors. These injuries can be occupational or leisure-related and are known to be among the most severe, often resulting in fatalities and long-term disabilities. Farm injuries encompass a wide range of incidents, including those caused by machinery, animals, falls, overexertion, and other hazards commonly encountered in agricultural activities (Europäische Kommission, 2004).

Farm injuries and fatalities pose a significant risk globally, with the agricultural sector being among the most hazardous occupations. In the United States, farm injuries have a fatality rate six times higher than the average for all industries combined, and tractors are a leading cause of death, responsible for approximately 300 fatalities annually (DeRoo & Rautiainen, 2000). Older farmers face the highest risk, but youth agricultural labour force and children also account for farm occupational fatalities (Hard et al., 2016; Pickett et al., 2022).

European Union statistics indicated that in 2013, there were 1.5 non-fatal injuries per 100 workers and 4.1 fatal injuries per 100,000 workers in EU agriculture. However, it is important to note that these rates are likely underreported due to voluntary reporting by self-employed workers. The fatality rates varied greatly between countries, ranging from 0 to 51 per 100,000 workers. Chronic illnesses related to agricultural work, such as musculoskeletal diseases, respiratory diseases, and skin cancer, are also frequent among agricultural workers (Europäische Kommission, 2004).

Aside from the human toll, farm injuries and fatalities also carry significant economic costs. For example, in Australia, the economic costs of farm-related fatalities were estimated to be $650.6 million in 2008, representing 2.7% of the farm gross domestic product. These costs include medical expenses, rehabilitation costs, loss of earnings, and the impact on victims' families and farming communities (Franklin et al., 2015). Quantifying the full economic costs of occupational injury and ill health in agriculture is challenging, but it is clear that they have a substantial impact on both individuals and the agricultural sector. In summary, farm injuries and fatalities pose significant challenges globally, with agriculture ranking among the most dangerous occupations. Tractors and farm vehicles, animal-related work, and farm structures contribute to the high incidence of injuries and fatalities (Europäische Kommission, 2004; Litchfield, 1999; Sorensen et al., 2017a). The economic costs along with high farm-related fatalities, underscore the need for enhanced farm health and safety interventions to mitigate risks for those involved in agriculture.

Navigating the Solitary World of Farmers

While the preceding discussion offered an overarching portrayal of the global implications of farm injuries and fatalities, it is imperative to delve into the intricacies of farm safety within the context of lone working. The research underscores the profound influence of the solitary nature of work on safety outcomes, highlighting the diminished exposure of lone workers to social and organisational factors that promote healthy behaviours. Factors such as supportive

supervision, organisational training, and peer social modelling, which typically contribute to healthy lifestyle behaviours, are less accessible to lone workers. This deficiency in support is compounded by the hazardous nature of lone working itself. Lone workers are confronted with an increased likelihood of encountering risky hazards, often due to minimal occupational safety support. The absence of a second pair of eyes that could identify imminent dangers further exacerbates this risk. The unique structure of lone working renders hazards more likely to occur, and when they do, they tend to be more perilous. For instance, threats to health that could be mitigated by the presence of another individual, such as the effects of falls or exposure to noxious gases, may become amplified due to the incapacitation of the lone worker (O'Hora, 2014; Olson et al., 2009; Parand & FOSTER, 2008).

The absence of protective factors that are often present in group settings contributes to the heightened vulnerability of lone workers to workplace hazards. Notably, farmers working alone exhibit a heightened susceptibility to serious injuries and fatalities (Etienne et al., 2023; McLaughlin & Sprufera, 2011). This susceptibility is further compounded by numerous factors, including time constraints, financial pressures, and a culture of self-reliance, which can potentially diminish safety priorities among farmers, leading to a complex interplay between individual and contextual elements. This intricate interplay between the solitary nature of farm work, external factors, safety outcomes, and diminished exposure to supportive factors underscores the critical role played by farmers' behaviours and attitudes in shaping safety on farms (Brennan, 2015; Cole, 2002; Tone & Irwin, 2022; Wheeler et al., 2022).

Normalisation of Risks in Farming

Farming communities often accept injuries and fatalities as an unavoidable part of farming, which often leads to socialisation and normalisation of danger and conscious risk-taking in the interest of the farm business (Shortall et al., 2019). Therefore, Narasimhan et al. (2011) observed that the success or failure of each intervention was highly reliant on behaviour modification, i.e. worker acceptance and adoption. Therefore, fundamental changes must occur in the farmer's attitudes and behaviour such that those farmers stay safe. However, more often than not, interventions lose focus on the psychosocial factors and ignore their constant influence on an individual's perception of what is safe and risky (Sorensen et al., 2016).

Transitioning our focus towards addressing farm safety comprehensively demands a closer examination of the specific contexts in which it occurs. Given that farming communities often overlook safety and develop a sense of acceptance towards these risks and injuries, particularly within localised settings, the importance of tailoring interventions to address local attitudes and practices becomes evident. While the preceding section shed light on the global impact of farm injuries and fatalities, it is vital to acknowledge the inherent variations in local contexts across countries. Within the European Union (EU), regulations have been established to provide a framework for farm health and safety (Europäische Kommission, 2004; M. C. Jakob et al., 2021; Leppälä et al., 2021). However, the distinct challenges and circumstances encountered by Irish farmers necessitate a closer examination. By undertaking a thorough exploration of the Irish farming landscape, we can develop targeted interventions and strategies that are tailored to the unique characteristics of the local context. Consequently, the current study aims to delve into the experiences and practices of Irish farmers in order to gain valuable insights into the specific factors contributing to farm injuries

and fatalities, ultimately facilitating the identification of effective measures to enhance farm safety within this particular setting.

Farming in Ireland:

With approximately 135,000 farms spread across the country, Irish farming plays a vital role in the nation's economy, rural communities, and cultural heritage (Health and Safety Authority, 2020.; Farm Safety Action Plan 2021 - 2024, 2021.; Balaine, 2019). These farms predominantly operate as family-owned enterprises, with ownership and management often passed down through generations. This familial approach underscores a strong sense of tradition and a profound connection to the land that is deeply embedded in Irish agricultural practices. Moreover, the farming landscape in Ireland is marked by its diversity, mirroring the varying geographical and climatic conditions found across the island. Key farm types, including beef production, sheep farming, dairy farming, and tillage farming, represent the multifaceted nature of Irish agriculture. While each farm type typically focuses on a dominant enterprise, it is customary for farms to engage in secondary activities that contribute to overall farm output. This strategic diversification enables farmers to remain adaptable to shifting market demands, thereby enhancing productivity across different sectors (Balaine, 2019; Europäische Kommission, 2004). An additional noteworthy shift in the Irish farming demographic is the changing age composition of farmers. With a growing number of older farmers and a comparatively smaller proportion of younger farmers entering the sector (*Demographic Profile of Farm Holders - CSO - Central Statistics Office*, 2023.), the generational transition is significantly altering the landscape of Irish agriculture. By understanding the distinct features of Irish farming, from its familial tradition and diverse practices to its ageing demographics, we can better understand the complexities inherent in ensuring safety in Irish farms.

To foster effective farm safety practices in the Irish agricultural sector, it is essential to consider the specific challenges and resources present in this context. This includes recognising the predominance of small family-owned farms, addressing the needs of an ageing farming population, acknowledging the impact of isolation and high workloads, and promoting accessible safety solutions tailored to the unique characteristics of Irish farms. This understanding forms the foundation for our exploration into the factors influencing safety behaviours and attitudes among Irish farmers, with a particular focus on enhancing safety practices among older farmers.

In the following sub-section, titled 'Farm Safety in Ireland,' we delve into the unique challenges faced by Irish farmers. This investigation provides essential context for the thesis's objectives by shedding light on the complex landscape of farm safety within Ireland.

Farm safety in Ireland

The agricultural, fishing, and forestry sector in Ireland has consistently had the highest rate of work-related injuries, both fatal and non-fatal, compared to other sectors. The rate of fatal injuries in this sector is significantly higher than the average for decades. In 2015, the agricultural sector had 19 deaths for every 100,000 workers, compared to the overall rate of 2.5 deaths for every 100,000 workers across all sectors (Watson et al., 2017). Injuries on farms are underreported, with an average of just 100 non-fatal incidents reported to the Irish Health and Safety Authority per year despite the legal obligation to do so (M. Murphy & O’Connell, 2018b). The 2011 Irish National Farm Survey analysed work-related fatalities in

Agriculture from 2011 to 2020. Of the 208 fatalities during this period, 97% were men, even though women comprised 27% of the agricultural workforce. 21 victims were under 18 years old, mainly due to incidents involving tractors, machinery, or vehicles (Figure 1). Dairy and mixed farming had the highest death rates. Notably, older workers, particularly those over 65, were significantly overrepresented in fatalities, with older farmers accounting for 47% of the deaths (Figure 3). The survey also noted an increase in farm injuries, with 2,459 injuries per 100,000 farms in 2010, up from 1,815 in 2006 (Health & Safety Authority, 2021).

Vehicles, particularly tractors, are the most common cause of fatal incidents on Irish farms (Health & Safety Authority, 2021; Mohammadrezaei et al., 2022a) (Figure 2,4). Tractor-related injuries account for a significant proportion of deaths, often involving overturning, collisions, or being struck by moving parts. Tractors are also involved in non-fatal injuries, with incidents such as falls from tractors, being struck by tractor parts, or being caught in machinery (Health and Safety Authority, 2020.).

Figure 1: Work-related fatalities in Agriculture by type of incident

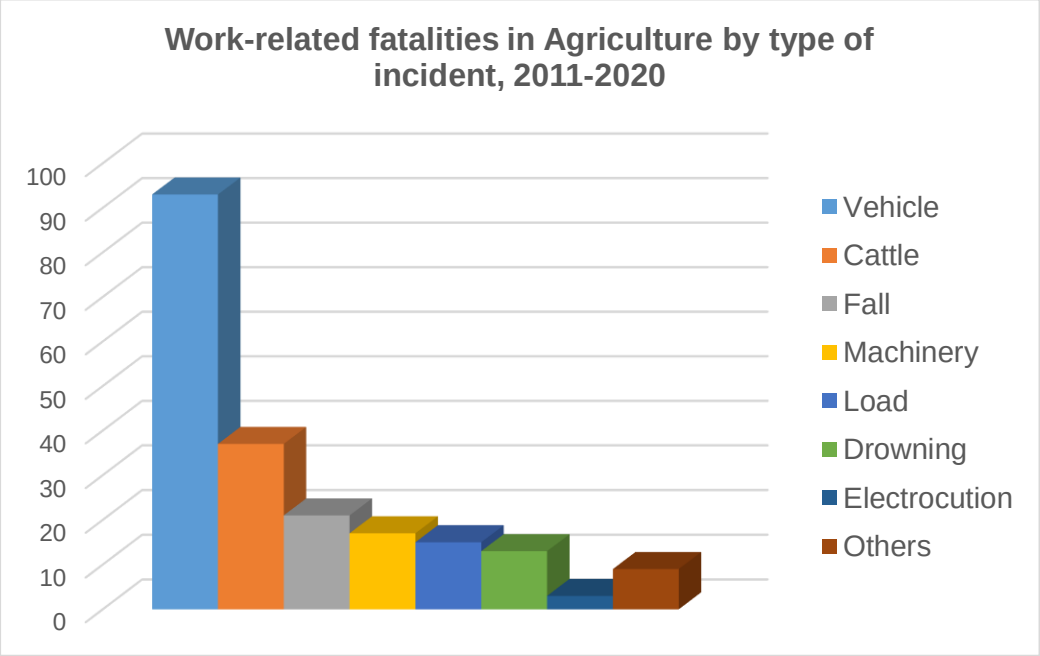


Figure 2: Work related facilities involving each type of vehicle

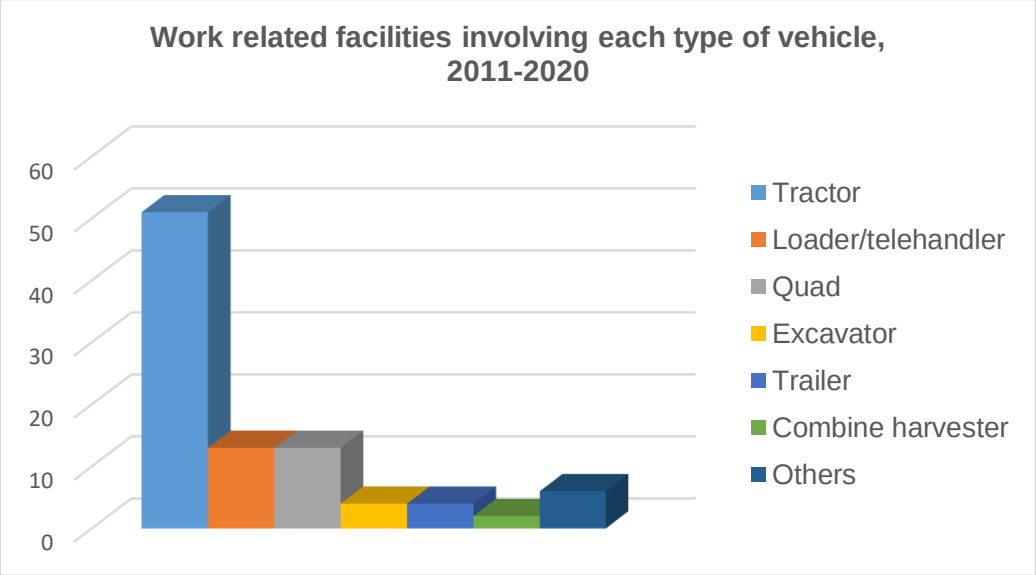


Figure 3: Work related facilities in Agriculture by age band

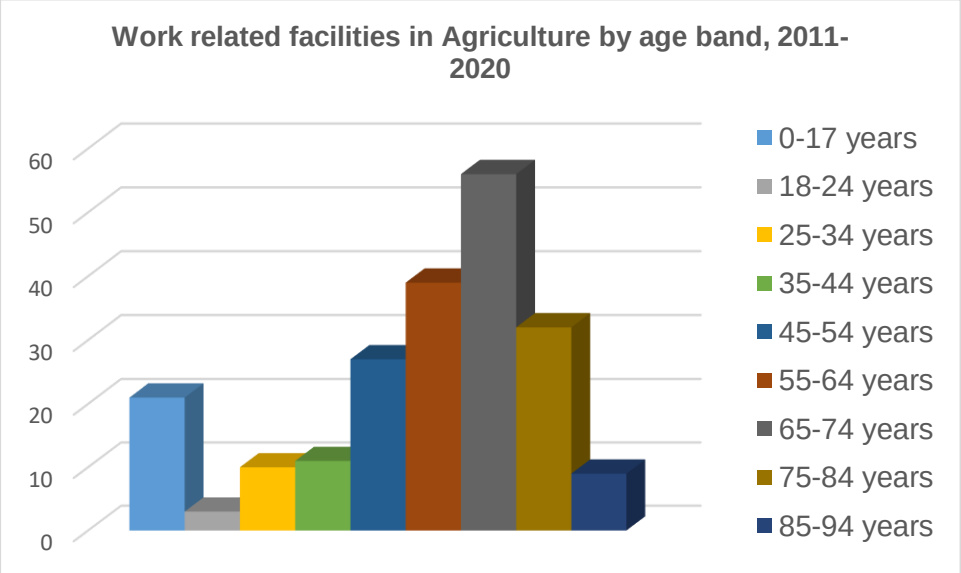
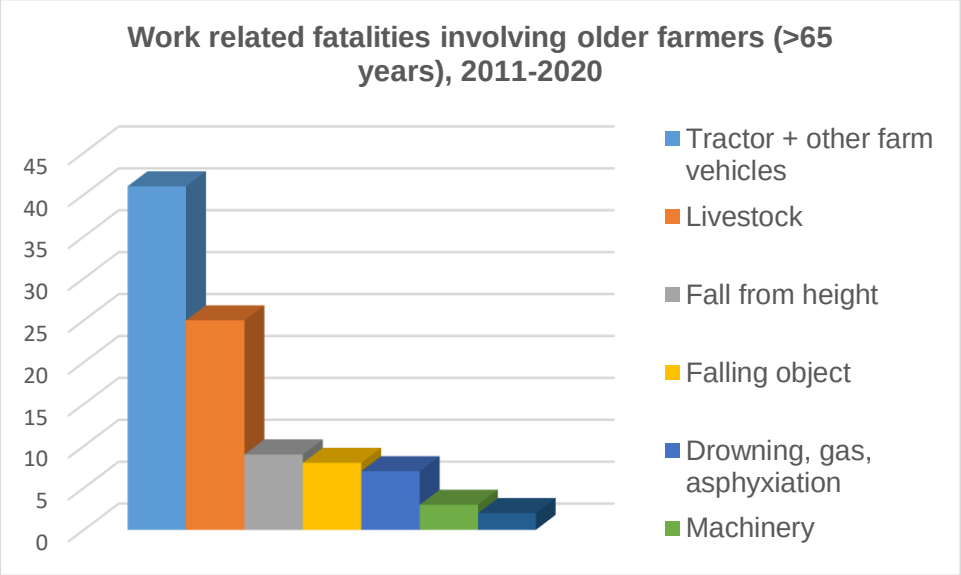


Figure 4: Work related fatalities involving older farmers



Challenges and opportunities to improve safety on Irish Farms

The structure of the agricultural sector in Ireland can significantly influence farm safety considerations. The familial management structure, where farms are family-owned and operated, presents unique challenges and opportunities for ensuring farm safety practices. The involvement of family members in daily operations necessitates a collective effort to address health and safety concerns, as the responsibility for managing risks falls on the shoulders of the farm owners themselves. This familial legacy not only shapes farming practices but also influences the transmission of attitudes and behaviours related to safety. Interventions must be cognisant of this cultural aspect, fostering a sense of shared responsibility and instilling safety practices that align with the family's well-being (Balaine, 2019; M. Murphy & O'Connell, 2017; Watson et al., 2017). This unique family-centric tradition also opens an opportunity for considering mentoring programs as a means to enhance safety. Encouraging experienced farmers to mentor the younger ones can not only pass on farming wisdom but also instil a strong safety ethos for both mentor and mentee (M. Murphy & O'Connell, 2018b; Stoneman et al., 2014).

Diverse Farming Sectors and Unique Risks

The different types of farms and activities in Ireland have unique challenges and risks that require specific interventions (Mohammadrezaei et al., 2022a; M. Murphy & O'Connell, 2017). For example, safety measures that work for dairy farming may not be relevant for tillage farming due to their different methods of operation. Therefore, it is important to have flexible intervention strategies that can be adjusted to suit each farming sector's requirements. To achieve this, intervention plans should be developed through a consultative approach that considers feedback from different farm types. This will ensure that practical and relevant approaches are tailored to each specific farming sector, aligning with their unique needs.

Engaging Older Farmers: Wisdom and Mentorship

In Ireland, the age demographic of farmers is a notable factor impacting farm safety. There has been a gradual increase in the average age of farmholders, with a higher proportion of older farmers compared to younger ones (*Farmers over 65 Years - Health and Safety Authority*, 2021.). These seasoned farmers bring invaluable insights accumulated over years

of experience. However, their mental and physical well-being may face challenges due to the demands of modern high-powered machinery and the rigours of farm work (Alwall Svennefelt, 2019; M. Murphy & O'Connell, 2018). Furthermore, despite being among the most vulnerable groups, older farmers often find themselves overlooked in intervention efforts (Nilsson, 2016). The poor retention of older farmers in these initiatives further exacerbates the issue. To address this, it is essential to actively involve older farmers in the very design phase of interventions. Their insights, needs, and challenges can be systematically incorporated, making the interventions more attuned to their specific circumstances (McCallum et al., 2022; Nilsson, 2016). Here, the concept of mentorship, previously discussed, assumes a pivotal role. Encouraging older farmers to not only embrace safer practices for their own well-being but also to serve as mentors to the younger generation becomes crucial. By doing so, older farmers can model safe behaviours and ensure the continuity of safer practices for the future farming workforce. By fostering a sense of ownership and relevance, older farmers are more likely to engage with and commit to the safety interventions. This inclusive approach not only enhances the efficacy of interventions but also ensures that the wisdom of older farmers is passed down to younger generations, forging a continuum of safety awareness and practices within the farming community (M. Murphy & O'Connell, 2017; Ramos et al., 2021).

Lone Working Challenges in Irish Farming

Lone working and the demanding nature of agricultural tasks contribute significantly to the physical and mental strain experienced by Irish farmers. Because of the financial constraints and labour scarcity, the majority of Irish farms operate with minimal employees, often relying on family members or substitute workers. The isolation of many farms, coupled with fluctuating workloads and economic pressures, can elevate stress levels and potential safety hazards (Mohammadrezaei et al., 2022a; M. Murphy & O'Connell, 2017). Furthermore, the lone-working nature poses challenges in establishing formal safety management systems. Instead, farmers frequently turn to informal networks for guidance, underlining the importance of peer-to-peer knowledge exchange and practical insights in shaping farm safety practices (Bertolozzi-Caredio et al., 2021; McCallum et al., 2022; Sutherland & Marchand, 2021a).

To conclude, the complex nature of Irish farming, which includes family traditions, diverse practices, generational shifts, economic factors, strong social bonds, and cultural nuances, requires a nuanced approach to designing interventions. By creating interventions that acknowledge these complexities and use them to their advantage, a strong culture of safety can be established. This will not only protect the well-being of older farmers but also ensure the long-term success of Irish agriculture. In summary, the changing demographics of Irish farmers necessitate a strategic adjustment of safety interventions. By recognising the vulnerable population, providing tailored mentoring and ensuring the active involvement of stakeholders, interventions can effectively improve safety practices, leading to a positive impact that benefits the well-being of older farmers and promotes safer practices for future generations.

Farm Safety Intervention Categories

This section provides a concise overview of prevailing intervention categories in farm safety research. Detailed investigation of machine safety intervention studies can be found in Chapter 3.

Farm Safety Interventions: The Three E's

Farm safety literature classifies farm safety intervention into primarily 3 E's: Engineering, Enforcement, and Education (Rautiainen et al., 2008). Engineering solutions within the context of farm safety refer to the implementation of physical modifications, equipment enhancements, and structural adjustments aimed at reducing risks and preventing accidents. The primary objective of engineering solutions is to create a safer working environment by designing and implementing measures that mitigate potential hazards associated with machinery, equipment, and farm infrastructure. The strengths of engineering solutions lie in their tangible and immediate impact on improving safety. These solutions directly address specific safety concerns by introducing physical changes that create barriers between potential hazards and individuals. By integrating protective mechanisms, such as reinforced guards, improved machine labelling, and safer workstations, engineering solutions provide robust and reliable safeguards. Their effectiveness is not reliant on individuals' behaviour or compliance, making them a proactive and consistent approach to risk reduction (Alwall Svennefelt, 2019; Jakob et al., 2021; Lower & Temperley, 2018, 2018; Pickett et al., 2022; Sorensen et al., 2017) .

One significant weakness is the potential financial burden associated with their implementation. The implementation of engineering solutions can be resource-intensive, entailing investments in new equipment, modifications, or structural alterations. The costs of designing, purchasing, installing, and maintaining safety equipment or modifying machinery can be substantial, particularly for smaller farms with limited resources. Additionally, the complex and diverse nature of farming operations often requires tailored engineering solutions for different machinery types, which can lead to variations in effectiveness and compliance. Another weakness is the challenge of addressing dynamic and evolving risks. Engineering solutions may not fully adapt to changing conditions or emerging hazards, especially in a rapidly evolving agricultural landscape. Moreover, while these solutions provide essential physical safeguards, they might not comprehensively account for human errors (Alwall Svennefelt, 2019; Jakob et al., 2021; Lower & Temperley, 2018; Pickett et al., 2022; Sorensen et al., 2017).

Enforcement-based solutions are interventions that use regulatory and legal mechanisms to enforce compliance with safety standards and regulations. The objective of enforcement-based solutions is to ensure that farms and farmers comply with safety regulations and standards to reduce the risk of accidents and injuries. In Ireland, these interventions draw upon a legal framework, often dictated by EU directives (Jakob et al., 2021) and national work environment legislation (Shannon, 2005a), which obliges employers, including farmers, to conduct risk assessments, document hazards, and inform workers about health and safety measures (Lower & Temperley, 2018; Sorensen et al., 2017).

Enforcement interventions can be effective tools for driving systemic change. They provide a platform for revising equipment standards and policies, addressing safety hazards, and promoting preventive measures. One of their primary strengths is the ability to establish clear guidelines and expectations for safety compliance. By setting enforceable regulations, these interventions establish a uniform safety culture across the farming community. Moreover, enforcement mechanisms create a sense of accountability, as non-compliance can lead to legal consequences, encouraging farmers and stakeholders to prioritise safety measures (Pickett et al., 2022; US EPA, 2016).

Enforcement interventions have certain limitations as well. There is considerably less support for imposed solutions like regulatory enforcement within the farm community. Regulation, often viewed as a contentious topic, receives little endorsement from farmers or farm advocacy groups. This hesitancy towards enforcement-based solutions can be attributed to concerns about perceived burdens, compatibility with practical farm operations, and the potential to stifle autonomy. The enforcement of regulations in the farming context can encounter resistance due to its dispersed and isolated nature (Lower & Temperley, 2018; Pickett et al., 2022; Sorensen et al., 2017). Furthermore, Campbell et al. (2011) found little knowledge of which policy tools are more likely to get results in specific contexts.

These interventions may also be subject to policy revision and passage delays, hindering swift responses to emerging safety concerns (Lower & Temperley, 2018). Additionally, despite their potential effectiveness, regulatory measures may not address the underlying behavioural and attitudinal aspects that contribute to safety lapses. A punitive approach, without an intrinsic understanding of safety's value, may not foster a sustained culture of safety (Wiegmann et al., 2022).

Educational interventions, the most popular approach among farm safety research, primarily focus on knowledge dissemination, training, and awareness-building to equip farmers with the necessary information and skills to navigate potential hazards and adopt safe practices. Educational initiatives aim to empower farmers with a comprehensive understanding of safety protocols, risk assessment, and effective preventive measures (Pickett et al., 2022).

The universal applicability of educational approaches contributes to their potential for widespread impact. These interventions can be designed to cater to the diverse demographic and operational spectrum of farmers, ensuring that safety education reaches far and wide across various agricultural contexts. These interventions excel in providing farmers with a fundamental understanding of safety hazards, risk factors, and protective measures. By instilling this knowledge, they lay a strong foundation for informed decision-making (D. J. Murphy et al., 1996).

The educational interventions also come with several challenges. Notably, the assumption is that the acquisition of knowledge will inevitably translate into changed behaviours. However, studies indicate that this knowledge-to-action transition is not always straightforward. Moreover, sustaining behavioural changes resulting from educational interventions over the long term can be challenging. While these interventions might lead to short-term improvements in safety practices, maintaining such changes necessitates a multifaceted and sustained approach that goes beyond knowledge dissemination (DeRoo & Rautiainen, 2000; Rose et al., 2018).

In essence, the Three E's framework is vital, but the true catalyst for success lies in the behaviour change of farmers. As we navigate the realm of farm safety, it is clear that with the support of evidence-based education, engineering and policy solutions, aligned with an understanding of local context and focus on farmers' behaviour change, paves the way for a safer future in agriculture (DeRoo & Rautiainen, 2000; Giles et al., 2020). The Irish Health and Safety Authority, through the BeSafe Initiative, is aligned with these principles and is aiming for long-term farmer-centric sustainable solutions for safer Irish farms. Hence, the BeSafe initiative is therefore seeking a deep understanding of farmers' behaviour and the underlying factors driving their actions. The overarching goal is to devise interventions that

are optimally poised to enhance adherence to safety protocols, thereby fostering substantial improvements in overall farm safety.

Behaviour Change Towards Safer Farming

The connection between human actions and injuries/illnesses in farm machinery safety is crucial. While it is crucial to acknowledge that human behaviour does not always serve as the sole catalyst for safety incidents, it consistently emerges as a contributing factor. In conjunction with other factors like organisational shortcomings, the prevailing safety culture, and engineering controls, behaviour becomes an influential determinant of safety outcomes (Glasscock et al., 2006; Rasmussen et al., 2003; Rose et al., 2018). In high-risk industries like construction, manufacturing, and agriculture, behaviour's impact on safety outcomes is particularly significant, yet safety behaviours often receive insufficient attention. This gap in focus leads to both fatal and non-fatal injuries, emphasising the need to modify and redirect behaviour to address unsafe actions and reduce injury rates (Bowdler, Steijn, & Van Der Beek, 2023). In the current agricultural context, this requires targeting deeply ingrained safety behaviours through behaviour change interventions that consider the individual's social, physical, and cultural context.

Understanding Behaviour Change

Behaviours, the actions farmers take in response to various internal and external factors, play a pivotal role in ensuring safety within the realm of farm machinery operations. These actions, whether they involve meticulously inspecting a tractor's safety features or unintentionally lapsing in attention during machine operation, are driven by the intricate interplay of various factors such as beliefs, ability and other environmental factors (Colémont & Van den Broucke, 2008; Rose et al., 2018; Sorensen et al., 2017).Behaviours are not uniform and differ greatly among individuals due to the influence of their social, physical, and cultural contexts. These factors give rise to a multitude of behavioural patterns that contribute to a diverse set of responses to safety challenges, creating a complex and intricate web of behaviours (Rose et al., 2018).

In the agricultural sphere, habit holds a substantial role. Farmers typically adhere to established routines and may resist altering their practices (Alwall Svennefelt, 2019; Caffaro et al., 2018). This inclination to maintain the status quo is a well-established psychological phenomenon (Samuelson & Zeckhauser, 1988). Research indicates that individuals frequently opt to maintain their existing beliefs and actions, even when confronted with compelling alternatives. This inclination to resist change becomes particularly noticeable when decisions become intricate, presenting a multitude of options with uncertain consequences. In these situations, the attraction of familiarity becomes overpowering. People are more disposed to welcome change when it is uncomplicated and involves minimal risk, but tend to retreat when the journey is demanding and the potential benefits remain uncertain (Fleming et al., 2010; Kahneman et al., 1991).In the context of farming, this inclination to cling to established practices poses a significant challenge in the pursuit of safety enhancements. Farmers may hesitate to adopt new practices when presented with numerous choices and uncertain benefits. This is where the imperative to transform deeply ingrained safety behaviours, the very routines that define farm practices, comes to the forefront (Pickering et al., 2020).

Effecting changes in these ingrained behaviours necessitates the development of precisely targeted behaviour change interventions. A behaviour change intervention is a complex intervention with a number of interacting components and behaviours (Craig et al., 2008). Behaviour change interventions have also been described as “co-ordinated sets of activities designed to change specified behaviour patterns” (Michie et al., 2014). In the realm of farm safety, they serve as coordinated efforts to drive the adoption of safer practices and the cultivation of safer work-related habits.

These interventions, applicable at individual, community, and population levels, aim to reshape the prevalence or incidence of particular behaviours among specified farm populations. Yet, their effectiveness hinges on more than mere intent; it necessitates a comprehensive understanding of how these interventions can induce behaviour change (Helitzer et al., 2014; Pickering et al., 2020). This forms the crux of the matter—behaviour change interventions should not be viewed in isolation but as part of a holistic process. They must be developed, implemented, and evaluated with precision. Failures in behaviour change interventions often arise from insufficient consideration of the theories and principles, stakeholder participation, intervention reporting and the lack of theory-informed evaluation that underpins effective planning, delivery, and evaluation (Michie et al., 2014).

Use of theory for intervention design

Understanding human behaviour is a complex undertaking. Behaviours are influenced by a myriad of factors, including psychological, environmental, biological, and psychosocial elements. Theories provide us with invaluable frameworks and structured insights into the human psyche, helping us decipher the intricate mechanisms governing behavioural choices (Gifford & Nilsson, 2014; Michie et al., 2014).

The importance of theory in designing behaviour change interventions cannot be overstated. It serves several critical purposes. Theory allows interventions to focus on the causal determinants of behaviour and behaviour change. By identifying and addressing these determinants, interventions become more effective in eliciting meaningful change. For theories to evolve and become more effective, they must be rigorously tested and developed through evaluations of interventions. This underscores the significance of interventions and evaluations being theoretically informed. Theory-based interventions offer invaluable insights into what works, not only shedding light on specific contexts, populations, and behaviours but also catalysing the evolution of more robust theories (Craig et al., 2008; Michie et al., 2008).

However, it is noteworthy that despite the evident benefits of theory-based interventions, research in the field of farm safety indicates a gap. Often, interventions are designed, evaluated, and reported without explicit theoretical underpinnings. Even when theory is incorporated, it is frequently not rigorously applied to the intervention's design and evaluation (Rautiainen et al., 2008; Rose et al., 2018).

Behaviour Change Theories

Behaviour change theories offer invaluable insights into the intricate realm of human behaviour. These theories delve into the 'why,' 'when,' and 'how' of behaviours – elucidating the factors that either trigger or inhibit them (Michie et al., 2008).

One widely recognised theory in intervention research is the 'Theory of Planned Behaviour' (TPB), an extension of the 'Theory of Reasoned Action' in health research. TPB, along with other prominent theories like the 'Trans theoretical Model' and 'Health Belief Model,' constitutes the most commonly used theories in farm research (Ajzen, 1991; Colémont & Van den Broucke, 2008; Franklin et al., 2015a; Green et al., 2020; J. G. McNamara, 2014; Prochaska & Velicer, 1997; Rose et al., 2018; Sorensen et al., 2017).

Theory of Planned Behaviour (TPB): The TPB suggests that people's behaviour is determined by their intention to perform the behaviour, which is influenced by three factors: attitudes towards the behaviour, subjective norms, and perceived behavioural control. Attitudes refer to a person's positive or negative evaluation of the behaviour, subjective norms refer to the social pressure to perform or not perform the behaviour, and perceived behavioural control refers to the perceived ease or difficulty of performing the behaviour (Ajzen, 1991).

Transtheoretical Model (TTM): The TTM, also known as the Stages of Change model, was developed by Prochaska and di Clemente in 1984 to address behaviour change. The TTM has been applied to many health behaviours, including safety. The model assumes that an individual moves through stages of change, and that the processes involved at each stage are independent and different from each other. There are five stages of readiness proposed by TTM: pre-contemplation, contemplation, preparation, action, and maintenance. The model also proposes that a person will weigh up the pros and cons of changing behaviour at each stage of the process (decisional balance) (Prochaska & Velicer, 1997).

Health Belief Model (HBM): The HBM is a psychological theory that explains and predicts health-related behaviour (Rosenstock, 2000). It states that the perception of a personal health behaviour threat is influenced by at least three factors: general health values, interest and concern about health; specific beliefs about vulnerability to a particular health threat; and beliefs about the consequences of the health problem. Once an individual perceives a threat to their health and is simultaneously cued to action, if their perceived benefits outweigh their perceived costs, then the individual is most likely to undertake the recommended preventive health action (Green et al., 2020).

It's important to note that while these theories provide valuable insights, they often focus predominantly on cognitive processes and individual-level factors related to motivation and capability. They may overlook the broader socio-cultural and environmental influences that shape behaviours. Therefore, while theory-based interventions hold promise, they also present challenges. Theoretical frameworks can sometimes oversimplify the intricate process of behaviour change (Armitage & Conner, 2000). They may not fully encapsulate the role of "automatic" processes such as habits and emotions. Additionally, they often emphasise individual-level constructs and may underemphasise factors like capability and opportunity (Michie et al., 2014). Moreover, the mere use of theory does not guarantee intervention effectiveness. The choice of theory should align with the intervention's objectives, and the application of theory should be precise, tailoring it to the specific context. It's not just about selecting a popular theory but one that fits the intervention's unique needs .

Theory-based interventions require a granular understanding of the mechanisms of action, i.e., the active components of an intervention that drive behaviour change (Michie et al., 2014a). However, a mere focus on theory may not always specify how to change these

constructs effectively. Therefore, while theories are valuable guides in behaviour change interventions, helping us navigate the complex landscape of human actions and motivations, their application requires careful consideration and adaptation for successful results (Davis et al., 2015; Michie et al., 2014).

Choosing the most appropriate theory for a specific context can be difficult due to the sheer number of theories and their overlapping constructs (Davis et al., 2015). However, there are various systematic frameworks that have been created to combine different theoretical viewpoints and provide direction for their application (Barker et al., 2016a). Michie et al. (2014) conducted a systematic review of behaviour change frameworks spanning multiple diverse disciplines and sectors, evaluating each for their coherence, comprehensiveness, and association with an overarching behavioural model. No identified framework met all three criteria, and multiple frameworks had many overlapping components. These frameworks were then synthesized to develop a comprehensive, integrated framework, the Behaviour Change Wheel (BCW), to support evidence-based intervention development and implementation (Michie et al., 2014).

BCW is a well-established behaviour change framework that integrates and synthesizes 19 other existing frameworks of behaviour change into one unified model for developing interventions. BCW not only provides a comprehensive framework to understand the key constructs driving behaviours but also contextualizes them within the intricate fabric of social and environmental influences. This holistic approach makes BCW an invaluable tool for researchers, intervention designers, and policymakers alike, enabling them to navigate the complexities of behaviour change more effectively (Michie et al., 2014). Hence, the BCW, with its holistic approach, emerges as a powerful tool for developing interventions aligning seamlessly with the underlying philosophy of this research. This alignment, coupled with the pragmatic consideration of available resources, renders the BCW the framework of choice for our study.

Theoretical underpinning of BeSafe Study: Behaviour change framework

The Behaviour Change Wheel (BCW) framework, a comprehensive tool for behaviour change intervention design, is rooted in the COM-B model (Capability, Opportunity, Motivation, and Behaviour). It comprises three layers: the Capability-Opportunity-Motivation-Behaviour (COM-B) model, intervention functions, and policy categories. The COM-B model divides into Capability (both psychological and physical), Opportunity (social and environmental), and Motivation (reflective and automatic) and postulates that these factors are fundamental drivers of human behaviour (Figure 5). This model serves as a foundation for understanding why certain behaviours are not engaged in and identifies which components need modification to induce behaviour change. Notably, all three components mutually influence behaviour, with motivation acting as the central mediator. To achieve behaviour change, one or more of these COM-B components must change, whether related to the behaviour itself or behaviours that support or compete with it.

Figure 5: The COM-B System (Michie et al., 2014)

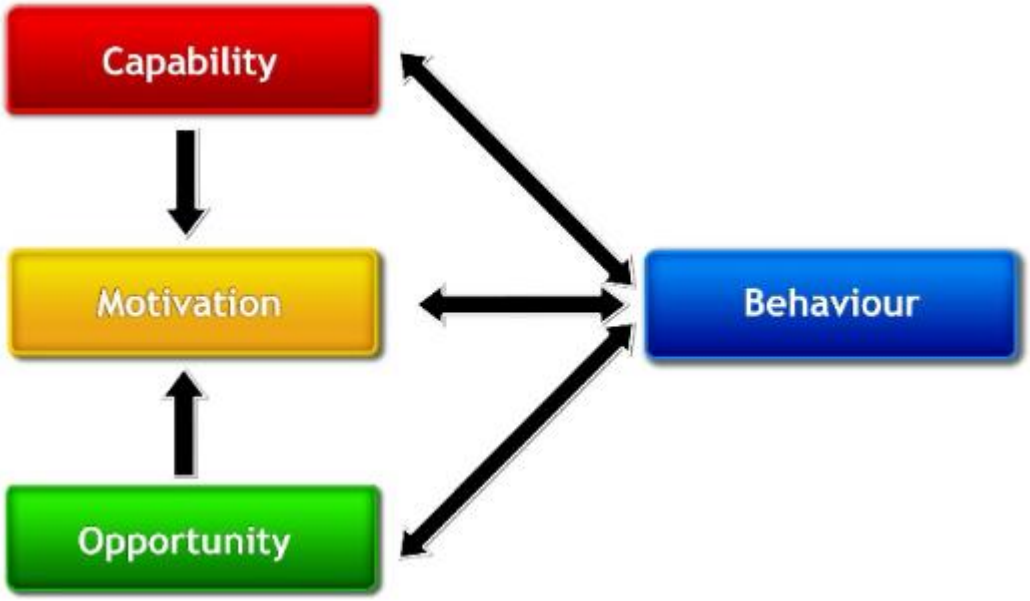


Figure 6: Behaviour change wheel (Michie et al., 2014)

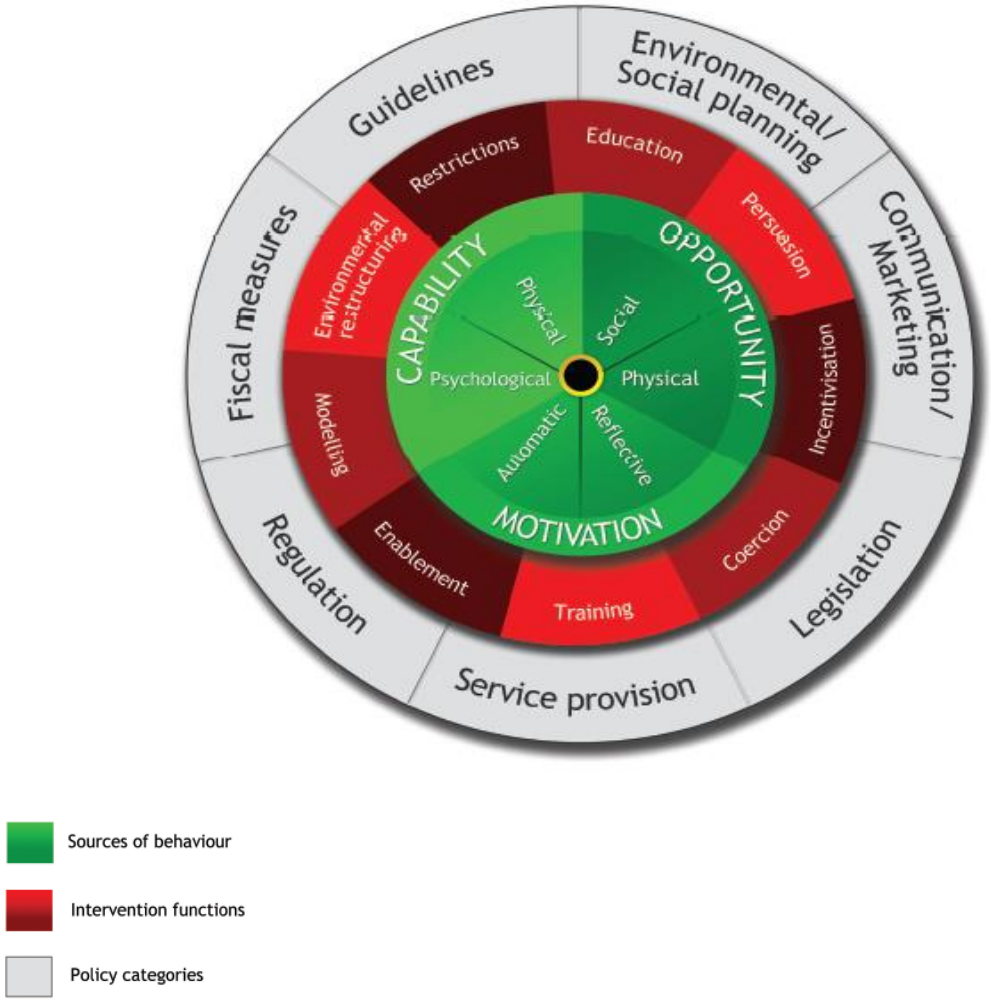
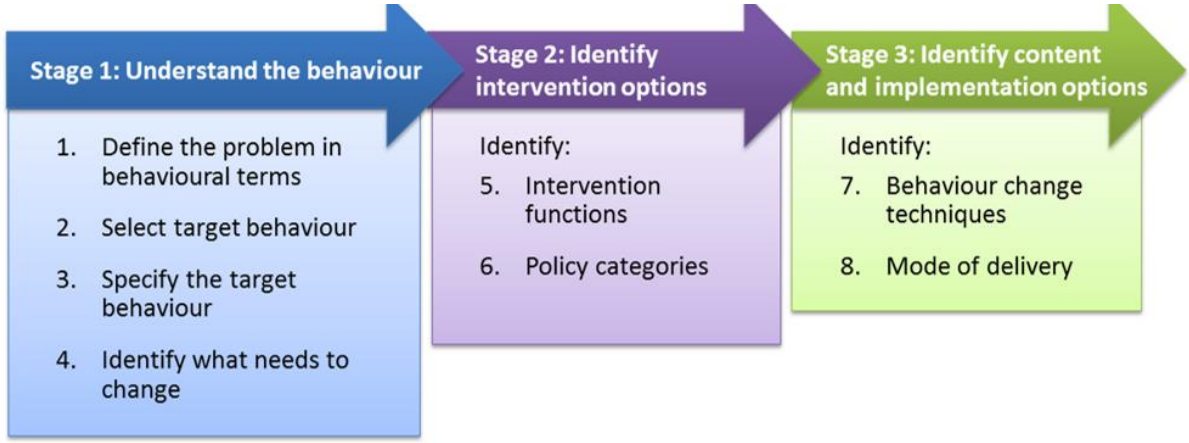


Figure 7: Behaviour change intervention design process (Michie et al., 2014)



Within the BCW, nine intervention functions and seven policy categories are outlined (Figure 6). These intervention functions, like education, persuasion, and environmental restructuring, offer a toolbox of strategies for behaviour change. The policy categories, including communication/marketing and regulation, provide guidance on how to deliver interventions effectively. This comprehensive set of options allows researchers and practitioners to tailor their approaches to the specific context and target population.

A critical aspect of the BCW is the specification of Behaviour Change Techniques (BCTs) and their link to Mechanisms of Action (MOAs). BCTs represent the proposed mechanisms for achieving behaviour change, while MOAs are theoretical constructs explaining how BCTs affect behaviour. This linkage is immensely valuable as it helps in understanding the "why" and "how" of behaviour change. For example, if the BCT is "instruction on how to perform a behaviour," the MOA might be an increase in the individual's skills in that behaviour. Furthermore, in order to address the challenge of describing and reporting the content of behaviour change interventions, Michie and her team have developed a taxonomy of behaviour change techniques (BCTs). This taxonomy, known as BCTv1, identifies 93 distinct BCTs and provides clear definitions and examples. It serves as a standardized method for classifying intervention content, ensuring clarity and consistency. This taxonomy plays a crucial role in specifying the 'active ingredients' of interventions, supporting their replication, and accumulating evidence for their effectiveness (Michie et al., 2013).

The BCW follows a three-stage process for intervention design (Michie et al., 2014) (Figure 7):

1. Understand the behaviour

2. Identify intervention option

3. Identify components and implementation options.

The first stage, "Understanding the Behaviour," is deeply rooted in the COM-B model. This stage emphasizes the need to define the behaviour in specific terms. It involves identifying who needs to perform the behaviour, what actions they must take to achieve the desired change, when and where these actions should occur, how frequently, and with whom. The COM-B model is instrumental in exploring what aspects need to change, either within the

individual (capability and motivation) or their environment (opportunity), to facilitate the desired behaviour modification. This comprehensive analysis ensures a clear and holistic comprehension of the behaviour and its determinants (Michie et al., 2008, 2014).

The next stage, "Identifying Intervention Options," involves identifying intervention functions and policies. In this stage, researchers consider a wide range of strategies and techniques to influence the behaviour. The BCW provides a structured menu of nine Intervention Functions and seven Policy Categories, serving as a toolkit for selecting appropriate intervention strategies. These functions and categories align with the determinants of the behaviour identified in the previous stage (Michie et al., 2014).

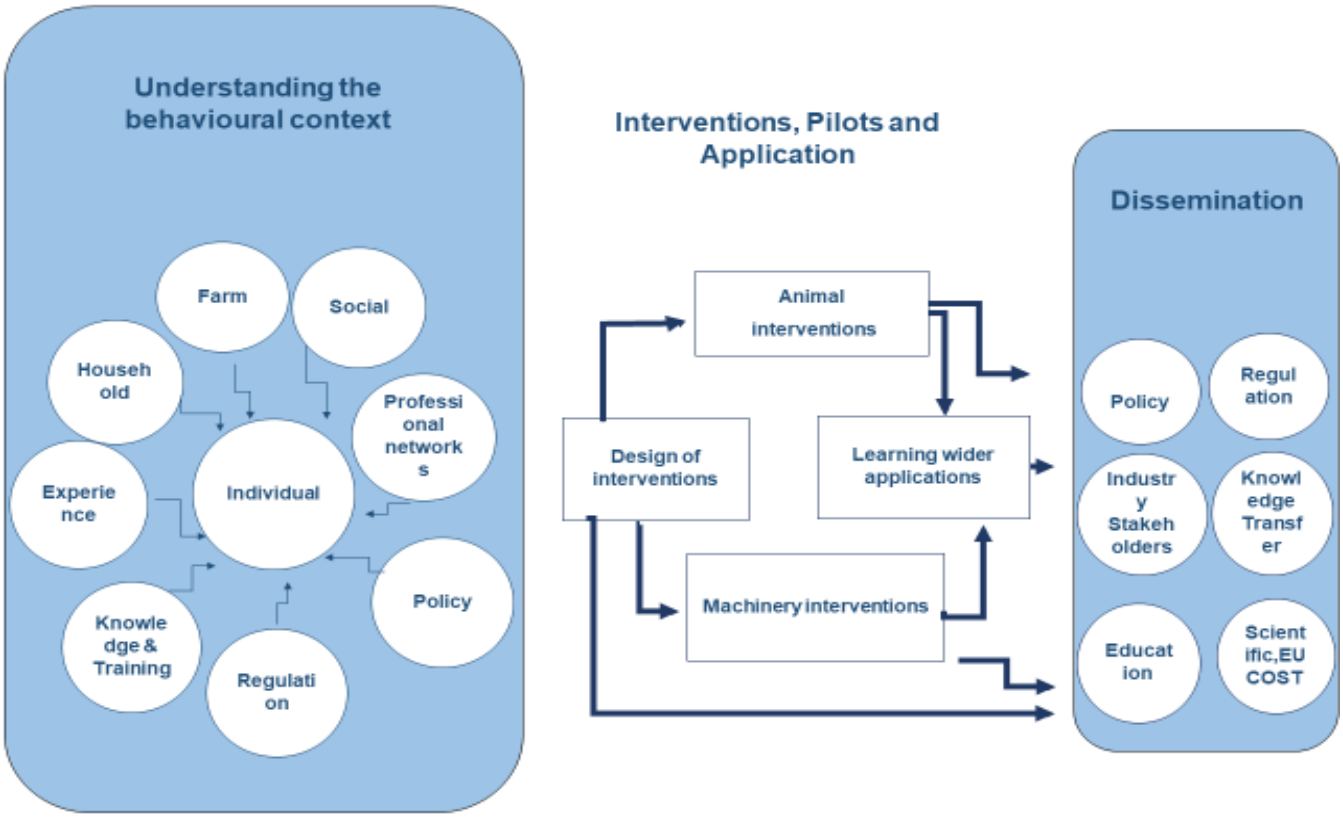
In the final stage "Identify Content and Implementation Options", researchers delve into the specifics of the intervention. The content of the intervention refers to the behaviour change techniques employed. These techniques are the actionable methods that are designed to bring about the desired behaviour change. Additionally, implementation options are detailed, outlining how each behaviour change technique within the intervention should be delivered effectively (Michie et al., 2013, 2014).

In essence, the BCW provides a systematic approach to intervention design, ensuring that interventions are both theoretically grounded and practically implementable. This three-stage process helps researchers and practitioners address the intricacies of behaviour change by providing a structured framework for developing interventions tailored to the specific behaviour and context under consideration.

BeSafe Project

BeSafe is a multidisciplinary research project with the primary goal of comprehensively understanding and addressing the factors influencing farm safety in Ireland (Figure 8). This endeavor is a collaboration involving a diverse team of experts from various disciplines, including agricultural engineers, agricultural scientists, animal behaviour specialists, geographers, psychologists, sociologists, and veterinarians. By bringing together this wide range of expertise, the project strives to enrich the research landscape in Ireland and bolster the nation's research capabilities. This includes fostering the development of Post-Doctoral candidates and Graduate students, thus further enhancing the country's research capacity (*BeSafe Project - Teagasc | Agriculture and Food Development Authority*, 2017.).

Figure 8: BeSafe project framework



Besafe focuses on identifying behaviours that need to be changed, testing behaviour modification strategies, and sharing findings with relevant stakeholders. The goals of the initiative include understanding the knowledge, attitudes, behaviours, and priorities of farmers and trainees regarding safety and risk management. Furthermore, the BeSafe Initiative evaluates the outcomes of previous undertakings, designs and enacts pilot interventions to enhance risk perception concerning machinery-related safety, and crafts safer work systems for farm machinery operation. The project also aspires to devise practical tools for behavioural interventions that can elevate safety at the farm level as well as develop a template for developing evidence-based, stakeholder-informed intervention. Dissemination of project findings to policy and research stakeholders, the agricultural community, and the shaping of policy and regulatory initiatives in farm safety constitutes a vital part of the initiative's objectives (*BeSafe Project - Teagasc | Agriculture and Food Development Authority*, 2017.).

Relevance to this Thesis

Within the expansive scope of the BeSafe Project, this thesis takes a focused lens to examine machinery-related farm safety, recognizing its pivotal role in overall farm safety. It aims to build upon and extend the insights garnered from previous research endeavors (Furey et al., 2016; Mohammadrezaei et al., 2022a; M. Murphy & O'Connell, 2017; O'Connor et al., 2022; Ramos et al., 2021). By delving into the behavioural dimensions associated with machinery-related farm safety within the Irish farming context, this research aligns itself with the overarching goals of the BeSafe Project. Farmers' autonomy and decision-making freedom provide an opportunity to examine how behavioural drivers such as knowledge, attitudes, and beliefs impact task planning and performance. Understanding these factors sheds light on the drivers of unsafe behaviours and, consequently, informs the design of interventions tailored to the specific requirements of Irish farmers.

Development of complex intervention

Farming is an inherently complex endeavour, and ensuring safety within this multifaceted context demands interventions of equal complexity. The farming community comprises individuals with considerable autonomy and decision-making authority, and their safety behaviours are influenced by social and environmental elements, as well as demographic and psychosocial factors (Colémont & Van den Broucke, 2008; Franklin et al., 2015a; Mohammadrezaei et al., 2022a). As discussed in the previous sections, considerable efforts have been made to improve farm safety, yet farm remains one of the most dangerous workplaces (Rautiainen et al., 2008; Stoskopf & Venn, 1985). Many interventions have yielded limited and varied effects. This may be due to the lack of explicit rationale for intervention development and the inappropriate use of methods in their design. Additionally, there has been insufficient focus on identifying and evaluating the active ingredients of these interventions (Craig et al., 2008).

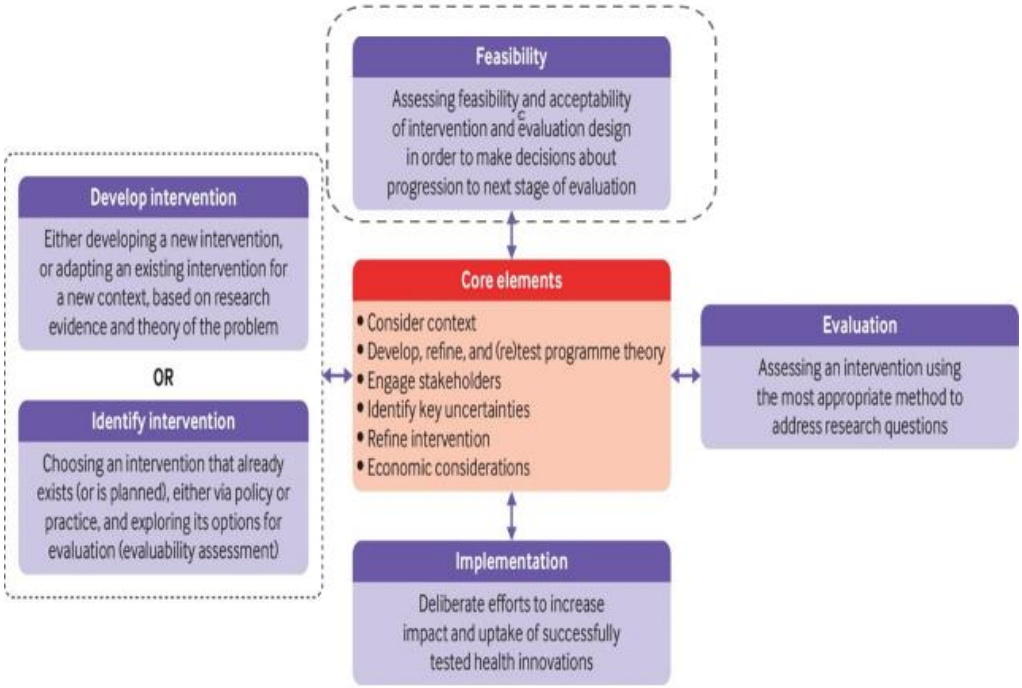
To enhance farm safety effectively, this research recommends integrating principles from Implementation Science and the guidance provided by the Medical Research Council (MRC) framework for complex interventions (Brownson et al., 2022; Craig et al., 2008). Implementation Science operates as a pragmatic bridge, connecting research findings to real-world applications. Its guiding principles establish that interventions must be finely tuned to the specific needs, nuances, and complexities of the target population, such as the farming community(Brownson et al., 2022). It recognizes the autonomy of individual farmers, the influence of social and environmental factors, and the complex interplay of demographic and psychosocial factors on safety behaviours. This approach ensures that interventions suit the unique characteristics of farmers, aligning with their decision-making authority and considering various influencing factors.

The design of effective interventions demands a systematic approach guided by strong theoretical underpinnings and explicit reporting of the development process (Craig et al., 2008). The MRC framework lays out four key phases integral to the development and evaluation of health behaviour change interventions. This framework offers a non-linear, four-phase approach to guide the process, as depicted in Figure 9 (Skivington et al., 2021). The current thesis focuses on the first two phases: 1. Develop intervention

2. Feasibility

These phases are essential for understanding the complexity of farm safety interventions before proceeding to large-scale effectiveness evaluation.

Figure 9: MRC Framework for complex interventions.



The initial phase of the MRC framework, which revolves around developing interventions systematically, is an essential starting point in the journey toward developing effective intervention strategies. However, it is important to note that the MRC framework doesn't provide explicit guidance on theory selection or integration. Instead, it encourages researchers to adopt a systematic approach and draw upon the best available evidence and appropriate theories (Barker et al., 2016b; Craig et al., 2008; Skivington et al., 2021).

As noted previously in the section 2.5.2, multiple theories and frameworks related to behaviour change exist. However, only a few of these theories have been tested in farm safety settings, leaving a gap in understanding which theories are most precise in predicting behaviour change in this context (Rose et al., 2018). In this project, the BCW was adopted as a theoretical framework for intervention development, as it offers a systematic and evidence-based approach to understanding and changing behaviour. It provides a structured process that allows for the identification of key behaviour change components and the development of interventions that are theoretically grounded and empirically informed (described in more detail in section 2.5) (Michie et al., 2014).

As shown in Figure 6, the BCW involves three key stages of intervention design, which can be undertaken sequentially or in parallel (Michie et al., 2014). These stages are:

1. Understanding the Behaviour: This stage entails a comprehensive definition of the target behaviour, including who needs to perform it, what needs to change, when, where, how often, and with whom. It also delves into exploring the necessary modifications within the individual or their environment to facilitate behaviour change.

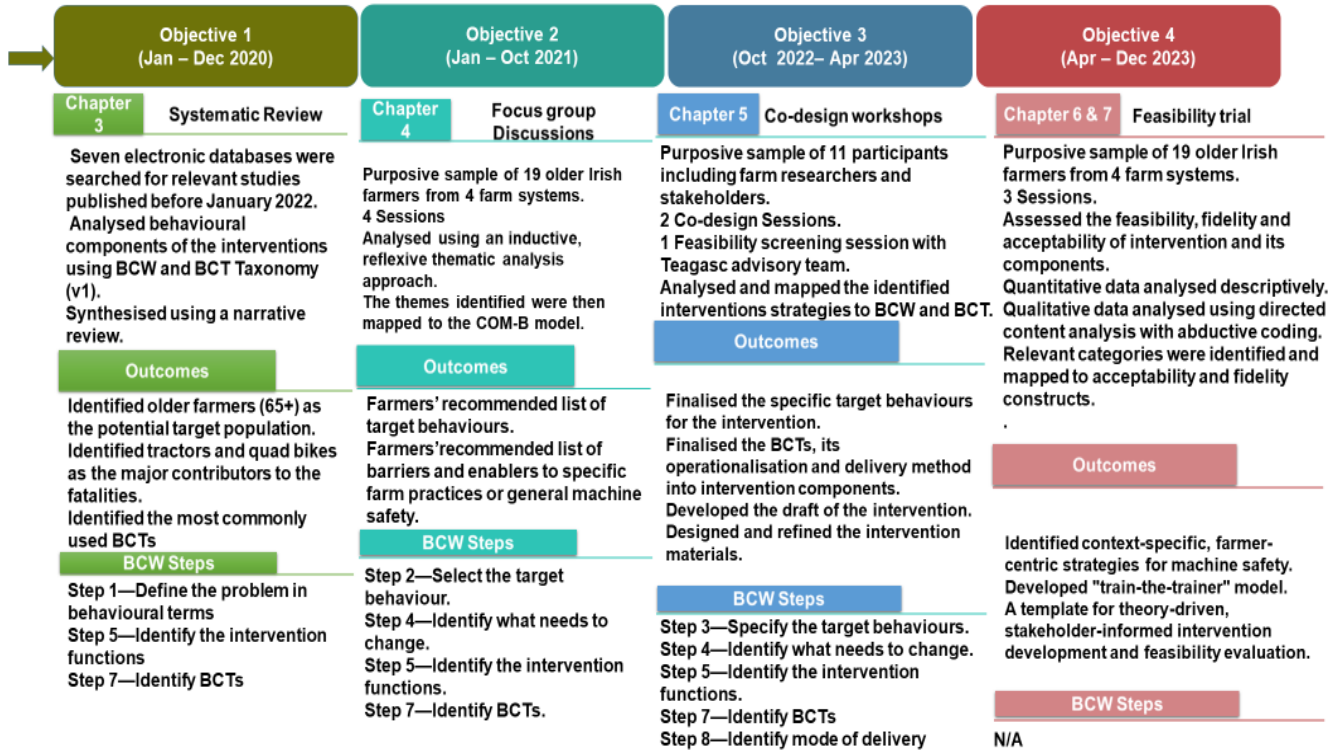
2. Identifying Intervention Options: This stage focuses on the identification of intervention functions and policies that align with the behaviour change components identified in the previous stage.

3. Identifying Content and Implementation Options: The content of the intervention comprises behaviour change techniques, while implementation options describe how each technique within the intervention should be delivered.

By adopting BCW and adhering to these stages, current work ensures that intervention development is systematic, evidence-based, and tailored to the complexities of farm conditions.

Figure 10 serves as an overview, mapping the entire PhD study to the Behavior Change Wheel (BCW) steps, offering a comprehensive visual representation of the study's structure and alignment with behavior change wheel design process.

Figure 10: PhD study overview mapped to Behaviour Change Wheel steps



Feasibility trials, as recommended by MRC framework, serve as essential precursors to large-scale intervention rollouts (Skivington et al., 2021). To ensure that the BeSafe intervention align with the guidelines for non-randomised feasibility trials (Lancaster & Thabane, 2019a), this project adopted a comprehensive evaluation strategy, including assessments of feasibility, fidelity, and acceptability of the intervention and its components (Lancaster &

Thabane, 2019b; Tickle-Degnen, 2013). Within this feasibility trial, key objectives include assessing participant recruitment and retention to ensure smooth trial progression. Additionally, the feasibility of recruiting a diverse range of participants from various demographic backgrounds in the farming community is evaluated.

A key aspect of this feasibility phase is the evaluation of fidelity, which is the degree to which the intervention aligns with its intended design, delivery, receipt, and enactment. In line with this, the evaluation employs the National Institutes of Health's Behaviour Change Consortium (NIH BCC) Treatment Fidelity Framework (Bellg et al., 2004a), offering a structured approach to evaluating fidelity across four dimensions (see Appendix E1 for definition of the fidelity constructs). Fidelity evaluation ensures that the intervention is not only designed systematically but also consistently delivered, well comprehended by participants, and effectively implemented in practice (Bellg et al., 2004a; Palsola et al., 2020).

In addition to feasibility and fidelity assessments, acceptability is a central focus of the study. Acceptability, within the context of feasibility trials, refers to understanding how the intervention is received and embraced by the participants. The Theoretical Framework for Acceptability (TFA) (Sekhon et al., 2017) is employed to gain a nuanced understanding of how participants perceive and engage with the BeSafe intervention. This framework outlines seven specific domains considered essential for evaluating overall acceptability (see Appendix E1 for definition of the TFA constructs). TFA's structured approach allows the exploration of the cognitive and emotional responses of participants across various dimensions of acceptability (Palsola et al., 2020; Sekhon et al., 2017).

In essence, the feasibility phase represents the critical bridge between theory-driven intervention development and the practical implementation of farm safety strategies. By rigorously assessing the feasibility, fidelity, and acceptability of the BeSafe intervention, the study not only ensures its readiness for larger trials but also contributes valuable insights into the complexities of farm safety interventions. Together, these elements form a comprehensive foundation for advancing farm safety practices, emphasizing the importance of contextually relevant, evidence-based, and systematically developed interventions for enhancing machine-related safety on farms.

Summary of the literature and the perceived gap in research

This chapter provided a comprehensive overview of the multitude of factors that intricately shape the decision-making processes of farmers and their subsequent adherence to safer practices within the agricultural sector (Mohammadrezaei et al., 2022b). It points out the lack of research attention given to areas that are crucial for improving safety in Irish farming, particularly in high-risk areas such as tractor safety. The chapter also noted that older farmers, who face unique challenges due to their age, have been largely overlooked in existing research on farm safety (Nilsson, 2016).

Furthermore, although existing evidence shows that demographic and psychosocial factors play a crucial role in shaping farmers' behaviour, there is a noticeable lack of interventions that systematically address these complex factors. Despite recognizing their importance, very few interventions explore the nuances of these variables, which limits our understanding of how they affect safety practices in the farming community (Bowdler, Steijn, & van der Beek, 2023; Glasscock et al., 2006; M. Murphy & O'Connell, 2018a; Rose et al., 2018).

Furthermore, the theoretical exploration of farmers' behaviour and the practical application of behaviour change theories in intervention development are also limited (Morgan et al., 2002; PhD & PhD, 2012). This significant research gap highlights the urgent need for theory-informed tailored interventions to actively address these vital determinants of farmers' safety behaviour.

Furthermore, the farm literature often suffers from inadequate reporting, particularly in relation to the specifics of interventions and their impact on farmers' behaviours. This lack of comprehensive documentation creates a significant obstacle to replicating studies and identifying effective components of interventions, which in turn limits the ability of researchers and policymakers to create and implement effective safety interventions (DeRoo & Rautiainen, 2000; Rautiainen et al., 2008).

In light of these complex research gaps, the current thesis is appropriately situated to address these significant concerns. Thesis utilizes the Behaviour Change Wheel (BCW) as a comprehensive conceptual framework to establish a strong basis for comprehending the intricate array of obstacles and enablers influencing the adoption of safer practices. This investigation particularly focuses on the realm of tractor operations, known for its high risk of injury, and extends its scope to encompass the often-overlooked demographic of older farmers. By understanding these factors, this thesis aimed to develop and test behaviour-change-based interventions to enhance awareness of safer farming practices and reduce the prevalence of tractor-related risk-taking behaviours among farmers and their families. Through this initiative, the study aims to bridge the existing gap between theoretical concepts and their practical implementation. Ultimately, the overarching objective is not only to reduce fatalities but also to enhance the overall safety and well-being of Irish farmers navigating the evolving and ageing agricultural landscape.

References (for chapters 1 and 2)

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alwall Svennefelt, C. (2019). Occupational injuries and communications in Swedish agriculture safety interventions. Acta Universitatis Agriculturae Sueciae, 2019: 50.

Armitage, C. J., & Conner, M. (2000). Social cognition models and health behaviour: A structured review. Psychology and Health, 15(2), 173–189.

Balaine, L. (2019). Gender and the preservation of family farming in Ireland. EuroChoices, 18(3), 33–37.

Barker, F., Atkins, L., & de Lusignan, S. (2016a). Applying the COM-B behaviour model and behaviour change wheel to develop an intervention to improve hearing-aid use in adult auditory rehabilitation. International Journal of Audiology, 55(sup3), S90–S98.

Barker, F., Atkins, L., & de Lusignan, S. (2016b). Applying the COM-B behaviour model and behaviour change wheel to develop an intervention to improve hearing-aid use in adult auditory rehabilitation. International Journal of Audiology, 55(sup3), S90–S98.

Bellg, A. J., Borrelli, B., Resnick, B., Hecht, J., Minicucci, D. S., Ory, M., Ogedegbe, G., Orwig, D., Ernst, D., & Czajkowski, S. (2004). Enhancing treatment fidelity in health behavior change studies: Best practices and recommendations from the NIH Behavior Change Consortium. Health Psychology, 23(5), 443. https://doi.org/10.1037/0278-6133.23.5.443

Bertolozzi-Caredio, D., Bardají, I., Garrido, A., Berry, R., Bijttebier, J., Gavrilescu, C., Harizanova, H., Jendrzejewski, B., Meuwissen, M. M., & Ollendorf, F. (2021). Stakeholder perspectives to improve risk management in European farming systems. Journal of Rural Studies, 84, 147–161.

BeSafe Project—Teagasc | Agriculture and Food Development Authority. (2017). Retrieved 27 June 2023, from https://www.teagasc.ie/rural-economy/rural-economy/besafe-project/

Bowdler, M., Steijn, W. M. P., & Van Der Beek, D. (2023). Effective Components of Behavioural Interventions Aiming to Reduce Injury within the Workplace: A Systematic Review. Safety, 9(3), 46. https://doi.org/10.3390/safety9030046

Brownson, R. C., Shelton, R. C., Geng, E. H., & Glasgow, R. E. (2022). Revisiting concepts of evidence in implementation science. Implementation Science, 17(1), 1–25.

Caffaro, F., Lundqvist, P., Micheletti Cremasco, M., Nilsson, K., Pinzke, S., & Cavallo, E. (2018). Machinery-related perceived risks and safety attitudes in senior Swedish farmers. Journal of Agromedicine, 23(1), 78–91.

Campbell, J. T., Koontz, T. M., & Bonnell, J. E. (2011). Does collaboration promote grass-roots behavior change? Farmer adoption of best management practices in two watersheds. Society & Natural Resources, 24(11), 1127–1141.

Cherryholmes, C. H. (1992). Notes on pragmatism and scientific realism. Educational Researcher, 21(6), 13–17.

Colémont, A., & Van den Broucke, S. (2008). Measuring determinants of occupational health related behavior in Flemish farmers: An application of the theory of planned behavior. Journal of Safety Research, 39(1), 55–64.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: The new Medical Research Council guidance. BMJ, 337.

Creswell, J. W., & Clark, V. L. P. (2017). Designing and conducting mixed methods research. Sage publications.

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: A scoping review. Health Psychology Review, 9(3), 323–344.

Demographic Profile of Farm Holders—CSO - Central Statistics Office. (2021). Retrieved 7 September 2023, from https://www.cso.ie/en/releasesandpublications/ep/p-coa/censusofagriculture2020-preliminaryresults/demographicprofileoffarmholders/

Denzin, N. K., & Lincoln, Y. S. (2011). The Sage handbook of qualitative research. Sage.

DeRoo, L. A., & Rautiainen, R. H. (2000). A systematic review of farm safety interventions. American Journal of Preventive Medicine, 18(4), 51–62.

Europäische Kommission (Ed.). (2004). The magnitude spectrum of farm injuries in the European Union countries. European Communities.

Farmers over 65 Years—Health and Safety Authority. (2021). Retrieved 7 September 2023, from https://www.hsa.ie/eng/your_industry/agriculture_forestry/young_elderly_on_farms/farmers_over_65_years/

Fleming, S. M., Thomas, C. L., & Dolan, R. J. (2010). Overcoming status quo bias in the human brain. Proceedings of the National Academy of Sciences, 107(13), 6005–6009.

Franklin, R. C., McBain-Rigg, K. E., King, J. C., & Lower, T. (2015). Exploring the barriers and facilitators to adoption of improved work practices for safety in the primary industries. Barton ACT: Australian Government, RIRDC.

Furey, E. M., O'Hora, D., McNamara, J., Kinsella, S., & Noone, C. (2016). The Roles of Financial Threat, Social Support, Work Stress, and Mental Distress in Dairy Farmers' Expectations of Injury. Frontiers in Public Health, 4. https://doi.org/10.3389/fpubh.2016.00126

Gifford, R., & Nilsson, A. (2014). Personal and social factors that influence pro-environmental concern and behaviour: A review. International Journal of Psychology, 49(3), 141–157.

Giles, A., Bauer, M. E., & Jull, J. (2020). Equity as the fourth 'E'in the '3 E's' approach to injury prevention. Injury Prevention, 26(1), 82–84.

Glasscock, D. J., Rasmussen, K., Carstensen, O., & Hansen, O. N. (2006). Psychosocial factors and safety behaviour as predictors of accidental work injuries in farming. Work & Stress, 20(2), 173–189.

Goles, T., & Hirschheim, R. (2000). The paradigm is dead, the paradigm is dead… long live the paradigm: The legacy of Burrell and Morgan. Omega, 28(3), 249–268.

Green, E. C., Murphy, E. M., & Gryboski, K. (2020). The health belief model. The Wiley Encyclopedia of Health Psychology, 211–214.

Helitzer, D. L., Hathorn, G., Benally, J., & Ortega, C. (2014). Culturally relevant model program to prevent and reduce agricultural injuries. Journal of Agricultural Safety and Health, 20(3), 175–198.

Jakob, M., Santa, D., Holte, K., Sikkeland, I., Hilt, B., & Lundqvist, P. (2021). Occupational health and safety in agriculture – a brief report on organization, legislation and support in selected European countries. Annals of Agricultural and Environmental Medicine, 28(3), 452–457. https://doi.org/10.26444/aaem/140197

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. Educational Researcher, 33(7), 14–26.

Kahneman, D., Knetsch, J. L., & Thaler, R. H. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias. Journal of Economic Perspectives, 5(1), 193–206.

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for social work research. Social Sciences, 8(9), 255.

Lancaster, G. A., & Thabane, L. (2019). Guidelines for reporting non-randomised pilot and feasibility studies. Pilot and Feasibility Studies, 5(1), 1–6. https://doi.org/10.1186/s40814-019-0499-1

Lower, T., & Temperley, J. (2018). Farm safety—Time to act. Health Promotion Journal of Australia, 29(2), 167–172.

McCallum, D. M., Reed, D. B., Claunch, D. T., Davis, C. M., & Conaway, M. B. (2022). Farm Dinner Theater: Testing an innovative health and safety intervention among older farmers and their families. The Journal of Rural Health, 38(2), 433–441.

McNamara, J. G. (2014). A study of the effectiveness of risk assessment and extension supports for Irish farmers to improve farm safety and health management.

Michie, S., Atkins, L., & West, R. (2014). The behaviour change wheel: A guide to designing interventions. Silverback Publishing. http://www.behaviourchangewheel.com/

Michie, S., Johnston, M., Francis, J., Hardeman, W., & Eccles, M. (2008). From theory to intervention: Mapping theoretically derived behavioural determinants to behaviour change techniques. Applied Psychology, 57(4), 660–680.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M. P., Cane, J., & Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. Annals of Behavioral Medicine, 46(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6

Mohammadrezaei, M., Meredith, D., & McNamara, J. (2022). Beyond Age and Cause: A Multidimensional Characterization of Fatal Farm Injuries in Ireland. Journal of Agromedicine. https://www.tandfonline.com/doi/abs/10.1080/1059924X.2022.2116138

Murphy, D. J., Kiernan, N. E., & Chapman, L. J. (1996). An occupational health and safety intervention research agenda for production agriculture: Does safety education work? American Journal of Industrial Medicine, 29(4), 392–396.

Murphy, M., & O'Connell, K. (2017). Farm deaths and injuries: Changing Irish farmer attitudes and behaviour on farm safety.

Murphy, M., & O'Connell, K. (2018). The Use of Mentoring To Effect Cultural Change: Irish Farm Deaths And Injuries. https://sword.cit.ie/dptmecp/3

Nilsson, K. (2016). Interventions to reduce injuries among older workers in agriculture: A review of evaluated intervention projects. Work, 55(2), 471–480. https://doi.org/10.3233/WOR-162407

O'Connor, T., Kinsella, J., O'Hora, D., McNamara, J., & Meredith, D. (2022). Safer tomorrow: Irish dairy farmers' self-perception of their farm safety practices. Journal of Safety Research, 82, 450–458. https://doi.org/10.1016/j.jsr.2022.07.012

Palsola, M., Renko, E., Kostamo, K., Lorencatto, F., & Hankonen, N. (2020). Thematic analysis of acceptability and fidelity of engagement for behaviour change interventions: The Let's Move It intervention interview study. British Journal of Health Psychology, 25(3), 772–789. https://doi.org/10.1111/bjhp.12433

Pickering, J., Jenner, A., Haantera, K., Moore, S., Iseppi, C., Markey-Towler, B., & Ruzsicska, N. (2020). Why behavioural science matters in extension. Rural Extension and Innovation Systems Journal, 16(1), 24–30.

Pickett, W., Belton, K. L., Lear, A., Anderson, R., & Voaklander, D. C. (2022). International commentary: Child injuries on the farm: A brief commentary from Canada. Frontiers in Public Health, 10, 1050621.

Prochaska, J. O., & Velicer, W. F. (1997). The transtheoretical model of health behavior change. American Journal of Health Promotion, 12(1), 38–48.

Ramos, A. K., Girdžiūtė, L., Starič, J., & Rautianinen, R. H. (2021). Identifying "Vulnerable Agricultural Populations" at Risk for Occupational Injuries and Illnesses: A European Perspective. Journal of Agromedicine, 26(3), 340–345. https://doi.org/10.1080/1059924X.2020.1771498

Rasmussen, K., Carstensen, O., Lauritsen, J. M., Glasscock, D. J., Hansen, O. N., & Jensen, U. F. (2003). Prevention of farm injuries in Denmark. Scandinavian Journal of Work, Environment & Health, 288–296.

Rautiainen, R., Lehtola, M. M., Day, L. M., Schonstein, E., Suutarinen, J., Salminen, S., & Verbeek, J. H. (2008). Interventions for preventing injuries in the agricultural industry. Cochrane Database of Systematic Reviews. https://doi.org/10.1002/14651858.CD006398.pub2

Rose, D. C., Keating, C., & Morris, C. (2018). Understanding how to influence farmers' decision-making behaviour: A social science literature review.

Samuelson, W., & Zeckhauser, R. (1988). Status quo bias in decision making. Journal of Risk and Uncertainty, 1, 7–59.

Sekhon, M., Cartwright, M., & Francis, J. J. (2017). Acceptability of healthcare interventions: An overview of reviews and development of a theoretical framework. BMC Health Services Research, 17(1), 1–13. https://doi.org/10.1186/s12913-017-2031-8

Shannon, G. (2005). The Safety, Health and Welfare at Work Act 2005 Update. Q. Rev. Tort L., 1, 23.

Skivington, K., Matthews, L., Simpson, S. A., Craig, P., Baird, J., Blazeby, J. M., Boyd, K. A., Craig, N., French, D. P., McIntosh, E., Petticrew, M., Rycroft-Malone, J., White, M., & Moore, L. (2021). A new framework for developing and evaluating complex interventions: Update of Medical Research Council guidance. BMJ, 374. https://doi.org/10.1136/bmj.n2061

Sorensen, J. A., Tinc, P. J., Weil, R., & Droullard, D. (2017). Symbolic Interactionism: A Framework for Understanding Risk-Taking Behaviors in Farm Communities. Journal of Agromedicine, 22(1), 26–35. https://doi.org/10.1080/1059924X.2016.1248306

Stoneman, Z., Jinnah, H. A., & Rains, G. C. (2014). Changing a Dangerous Rural Cultural Tradition: A Randomized Control Study of Youth as Extra Riders on Tractors. Journal of Rural Health, 30(4), 388–396. https://doi.org/10.1111/jrh.12073

Stoskopf, C. H., & Venn, J. (1985). Farm accidents and injuries: A review and ideas for prevention. Journal of Environmental Health, 250–252.

Sutherland, L.-A., & Marchand, F. (2021). On-farm demonstration: Enabling peer-to-peer learning. The Journal of Agricultural Education and Extension, 27(5), 573–590. https://doi.org/10.1080/1389224X.2021.1959716

Tickle-Degnen, L. (2013). Nuts and bolts of conducting feasibility studies. The American Journal of Occupational Therapy, 67(2), 171–176. https://doi.org/10.5014/ajot.2013.006270

US EPA, O. (2016, February 12). National Enforcement and Compliance Initiative: Reducing Risks of Accidental Releases at Industrial and Chemical Facilities [Overviews and Factsheets]. https://www.epa.gov/enforcement/national-enforcement-and-compliance-initiative-reducing-risks-accidental-releases

Wiegmann, D. A., Wood, L. J., Cohen, T. N., & Shappell, S. A. (2022). Understanding the “Swiss Cheese Model” and Its Application to Patient Safety. Journal of Patient Safety, 18(2), 119–123. https://doi.org/10.1097/PTS.0000000000000810

Yardley, L., & Bishop, F. L. (2015). Using mixed methods in health research: Benefits and challenges. In British journal of health psychology (Vol. 20, Issue 1, pp. 1–4). Wiley Online Library.

Chapter 3 Deconstructing complex machine-related farm safety interventions to identify common behaviour change techniques - Systematic review[1]

Authors: Ms. Aswathi Surendran[1], Dr JenniferMcSharry[1], Ms Rossella Di Domenico[1], Dr David Meredith[2], Dr Oonagh Meade[1], Dr Denis O'Hora[1]

[1]School of Psychology, University of Galway, Ireland
[2]Rural Economy & Development Programme, Teagasc

Abstract

Introduction

Agricultural workplaces have a high incidence of fatal accidents, with tractor-related incidents being the most common. This systematic review aims to identify interventions to reduce machine-related accidents on farms and describe the behavioural components included in these interventions.

Methods

The systematic review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Seven electronic databases were searched for relevant studies published before January 2022, and the quality of included studies was assessed using Cochrane risk of bias assessment tools. Analysis of behavioural components of the interventions was guided by the Behaviour change wheel framework (BCW) and behaviour change techniques (BCTs) Taxonomy (v1). The findings were synthesised using a narrative review.

Results

Nine studies were included. The reported outcomes included decreased injury rate (n=1), increased PPE usage (n=2), installation and usage of safety devices (n=5), implementation of safety measures and guidelines (n=4) and positive changes in safety norms and perception (n=2). A total of 21 BCTs were identified. The most frequently coded BCTs were 4.1 Instruction on how to perform the behaviour, 10.8 Incentive (outcome) and 16.3 Vicarious consequences (each n=6). Reporting quality was variable, and heterogeneous evaluation methods were employed. As a consequence, evidence synthesis was limited due to difficulties identifying, dissociating and assessing the effects of individual active ingredients of the interventions on effectiveness measures.

Discussion

The use of BCT taxonomy provided a common language for describing intervention components and enabled the standardisation of intervention content analysis. Clear patterns were identified in the components included across interventions, suggesting that intervention developers have similar expectations of the content of successful intervention approaches.

[1] Surendran, A., Mc Sharry, J., Di Domenico, R., Meredith, D., & O'Hora, D. (2023). Enhancing machine-related safety on farms: A systematic review. https://doi.org/10.31219/osf.io/rp9cj (pre-print) (Under review)

Providing (i) greater precision in reporting active intervention components and (ii) clearer connections between components and specific outcomes will enable enhanced comparisons of future studies, which will facilitate a greater understanding of how to support safe machine-related behaviours on farms.

What's Important About This Paper?

This is the first systematic review that attempts to identify and describe the behavioural components included in interventions aimed at reducing machine-related accidents on farms. The review aims to promote a systematic examination of farm safety interventions aided by behavioural science frameworks that would facilitate standardised reporting and easier access to supplemental intervention details. Doing so would enable promising intervention strategies to be evaluated and shared across farming contexts. Therefore, this paper contributes to the growing body of literature on the application of behaviour change theories and frameworks in occupational health and safety interventions.

Keywords: farm safety; behavioural change interventions; BCT; farm injuries; occupational safety interventions; tractor safety; tractor rollover; farm injuries

Introduction

Farm machines are a leading cause of fatalities in the agricultural sector worldwide (Stoskopf and Venn, 1985; Lundqvist and Gustafsson, 1992). Stoskopf et al. (1985) reported that with the wide adoption of farm machines in the 1950s, the agricultural industry had become one of the most hazardous industries in the United States, along with mining and construction. Of greater concern is the fact that while fatality rates in other industries have reduced with the introduction of safety innovations and regulations (e.g. Directive 89/391/EEC – OSH in EU), fatality rates in agriculture have remained high (Stoskopf and Venn, 1985). Reports from the International Labour Office (ILO) estimated that at least 170,000 fatalities and 250 million accidents are reported yearly on farms globally (Forastieri, 2000). In addition to the tragic human cost, the economic cost of agricultural injuries has been estimated at 8.3 billion dollars annually, including medical costs and reduced productivity. Although the causes of fatal incidents vary, farm machinery and vehicles such as tractors and all-terrain vehicles have been identified as major contributors to the majority of agricultural fatalities (Murphy and O'Connell, 2017; Sorensen *et al.*, 2017). Despite the global effort to reduce farm injuries and fatalities, studies have not identified an effective and widespread solution (Sorensen *et al.*, 2016, 2017).

Agricultural safety research has primarily relied on the "Three Es" approach, adopted from the industry safety model, to prevent hazard exposure - Education, Engineering, and Enforcement (Murphy, 1992; Sorensen *et al.*, 2016). In the Three Es model, engineering interventions involve preventive measures focusing on structural changes or modifications to minimise or eliminate risks. Enforcement interventions introduce safety rules and aim to ensure compliance among farmers through legal enforcement. The education component of the Three Es approach encompasses various measures, including training programs, knowledge dissemination, and skill translation, intending to enable workers to understand safety knowledge and develop safe attitudes. However, certain features of the agricultural context increase the complexity of implementing solutions derived from the Three E approach and highlight the role of behaviour. First, farm workers often work alone, increasing the training requirements for engineering solutions and increasing the cost and difficulty of enforcement of safety regulations. Second, farms often operate under a diverse range of work conditions using a wide variety of equipment, making it difficult to apply standardised engineering solutions across different farming operations. Third, small farms (which constitute a majority of farms worldwide) run on very thin margins, meaning the costs (both financial and time) of implementing engineering solutions are significant and sometimes prohibitive. Additionally, the enforcement of safety regulations on farms can be more challenging due to the decentralised and independent nature of agricultural work, which often involves a large number of small or sole operators who may not have the resources or capacity to comply with regulations or be subject to enforcement measures. In addition, in lone working situations, oversight and monitoring of safety practices may not be possible, further complicating efforts to ensure compliance with regulations (Murphy, 1992; Gallagher, 2012; McNamara *et al.*, 2017).

Regarding educational interventions, the focus on education is based on the belief that knowledge leads to better practices. However, because of the unique nature of the farming environment, the success of any of these interventions primarily depends on behaviour modification, which can be challenging to achieve (Narasimhan *et al.*, 2010; Gallagher, 2012). There is limited research on strategies for changing farmers' machine safety

behaviours, and it is challenging to identify specific content that supports behaviour change and isolate its effects from other influences (Irwin and Poots, 2015). Therefore, though identifying the content that supports behaviour change in these interventions is difficult, understanding their impact is crucial.

To address the need for effective interventions in farm safety, there has been a growing recognition among researchers of the need to evaluate not only the overall intervention program effectiveness but also to understand the influence of individual components of multicomponent interventions (DeRoo and Rautiainen, 2000; Coman *et al.*, 2020). This approach facilitates the identification of effective ingredients and their impact on behaviour, knowledge, and attitudes (Petrea, 2001; Gallagher, 2012). By understanding which components are effective and their impact on behaviour, knowledge, and attitudes, interventions can be modified without compromising their efficacy while clarifying dependencies between components for future implementation (Skivington *et al.*, 2021).

In health behaviour research, there has been a move towards using a comprehensive intervention development framework. The Behaviour Change Wheel (BCW) encourages researchers to systematically determine behavioural determinants, map behavioural determinants to relevant intervention functions/strategies and develop behaviour change techniques to effect behaviour change (Appendix A1) (Michie *et al.*, 2015). Behaviour change techniques (BCTs) are observable and replicable components of interventions (Michie, Van Stralen and West, 2011). These BCTs are defined and categorised in the BCT Taxonomy (v1), a comprehensive list of 93 techniques that provides a standardised language for describing intervention components and enables consistent analysis of intervention content (Michie *et al.*, 2013).

Although the BCT Taxonomy has been utilised in systematic reviews (French *et al.*, 2014) to identify behaviour change techniques across various interventions, its application to improving farm machine safety is currently limited. This gap in the literature highlights the need to explore and understand the specific behaviour change techniques employed in interventions targeting machine safety. By employing the BCW framework and utilizing the BCT Taxonomy, this review aims to identify and analyse the behaviour change techniques utilized in machine-related farm safety interventions. Through this analysis, valuable insights can be gained regarding the ingredients of these interventions, ultimately informing the development of policies, regulations, and future interventions to improve machine-related farm safety. It is important to note that deconstructing interventions, a key aspect of this review, involves breaking them down into their constituent components and analysing the specific techniques and strategies used. This approach allows for a more comprehensive understanding of the active ingredients and mechanisms of change within interventions. With this deconstruction, we can provide a more nuanced analysis of the interventions employed to improve machine-related farm safety and their impact on various outcomes. Additionally, understanding the context in which these BCTs are implemented and how they are delivered will also be useful for future studies.
The review questions are:

1. What interventions and intervention components have been employed to improve machine-related farm safety?

2. What BCTs are present in these interventions?

3. What are the outcomes of machine-related farm safety interventions?

Methods

The current systematic review is designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement guidelines (Moher *et al.*, 2009) and is pre-registered with PROSPERO, the International Prospective Register of Systematic Reviews (registration # CRD42020173834).

Search strategy

The multidisciplinary nature of the farm research warranted a search across multiple disciplines and different databases. Cochrane Central Register of Controlled Trials, Cochrane Injuries Group's specialised register, PubMed, Ovid EMBASE, Ovid PsycINFO, SCOPUS, Ovid EBSCOHOST, and SafetyLit electronic databases were searched in October 2020, and a search update was completed in January 2022 with no time restrictions on the publication date. Reference lists of articles included in the review, relevant reviews and additional topic-related databases and websites were also searched for relevant studies. These included the Irish Health and Safety Authority (HSA) website, agriculture-specific databases and articles in grey literature.

The search strategy was developed based on the Cochrane review of farm safety interventions by Rautiainen et al. (2008). The search terms were modified based on the search format of individual databases. The search strategy for PubMed is provided in the supplementary file (see Appendix A1). For the search strategies of the other databases, please refer to the BeSafe OSF repository (Aswathi et al., 2022).

Inclusion and exclusion criteria

Inclusion Criteria:

The inclusion criteria are as follows:

1. Studies that included randomised controlled trials (RCT), Cluster randomised controlled trials (CRCT), prospective cohort studies with a concurrent control group and non-randomised studies such as quasi-experiments, pre-post-intervention designs, longitudinal studies and interrupted time-series studies. The review included a wide range of study designs due to the heterogeneous nature of the farm research. A control comparator was not necessary for inclusion in this review.
2. Studies that described interventions in which at least one component was explicitly designed to increase vehicle or machine-related safety among farm workers.
3. Studies that analysed the impact of the intervention on machine safety specifically.
4. Machine-related safety was measured in terms of injury rate, adoption of safety devices/ Personal Protective Equipment (PPE), behaviour changes and risk awareness among farmers and farm families (including children).
5. Studies published in English.

Exclusion Criteria:

The exclusion criteria are as follows:

1. Studies that did not address machine safety on farms
2. Studies that measured the impact of the intervention on the general population, like school students, did not report specific effects on the farming population (e.g. farm children).

3. Interventions for loggers, fishery workers and hunters (Perez-Lopez, 2021).

Study selection

After the deduplication of articles, AS conducted title and abstract screening of all articles while the second reviewer (RDD) independently screened 20% of these articles. Discrepancies and disagreements were resolved through discussions between the reviewers to reach a consensus on the inclusion of studies. These discussions primarily focused on clarifying the interpretation of the predefined inclusion criteria and ensuring a shared understanding of what studies should be included.
Notably, during this stage, there were discussions regarding including studies targeting school children, as their impact on farm children was initially uncertain. It was decided that these studies would be retained at the screening stage for further examination during the full-text screening phase to verify whether the study explicitly evaluated the impact of the intervention on farm children. DOH & JMS appraised the findings when there was a disagreement and provided their expertise to reach a final decision. Furthermore, discussions were held to determine whether studies targeting general machine safety adequately evaluated the impact of the intervention on machine safety in the farming context. These discussions aimed to clarify the criteria and ensure that the inclusion and exclusion criteria were consistently applied throughout the screening process. The collaborative approach among the reviewers helped address uncertainties, clarify the interpretation of criteria, and maintain the rigour of the study selection process.

Quality Assessment

Two Cochrane tools for risk of bias assessment tools were used to assess the bias that affects the reporting of interventions. The Cochrane risk-of-bias tool for randomised trials (RoB2) assesses the five biases that can affect the reporting of interventions in RCT studies. The Cochrane risk-of-bias tool for non-randomised trials (ROBINS-NRCI) covers seven domains of bias of non-RCT studies, such as cohort studies, quasi-randomised trials, concurrently controlled studies and pre-post studies with no control groups. Both tools assign "low risk of bias," "some concerns," or "high risk of bias" for each domain. The overall risk of bias is decided based on domain-specific outcomes (Jüni *et al.*, 2016; Higgins *et al.*, 2019).

Studies were not excluded from the review if they had poor risk of bias scores. The risk of bias score was used primarily to provide context on the quality of the included studies.

Data extraction and coding strategy

The data extraction form was developed following the recommendations of the Cochrane Handbook for Systemic Reviews of Interventions (Higgins *et al.*, 2019), and the following data were extracted from the included studies by AS: Reference, Author, Year, Population, Duration, Relevant issues addressed, Intervention Details, Study Design, Relevant outcome and Country.

Operational definitions of the intervention components, including the categories, sub-categories and behaviour change components, are provided in Appendix A6-9.

Intervention strategies and coding of interventions

In order to assess the range of interventions employed to improve farm safety and their relative frequency (Research Question-1) and to facilitate the comparison with previous reviews (Lehtola *et al.*, 2008; Nilsson, 2016) of farm safety, interventions were first categorised on the basis of their surface features into the following categories/approaches:

engineering/technology, education/behaviour change (including incentives), and legislation/enforcement.

The first author (AS) identified and coded the intervention functions and BCTs present in the included studies using the BCW and BCT Taxonomy v1 (Michie *et al.*, 2013), respectively, using MAXQDA 2022 software (Verbi, 2019). The second reviewer (RDD) coded 20% of the studies independently; discrepancies were discussed among the research team (AS, RDD, JMS & DOH), and a consensus was reached.

Unintended Behaviour Change Techniques

As observed in safety literature (Pekkarinen, Anttonen and Pramila, 1994; Stoneman, Jinnah and Rains, 2014), outcome measuring instruments like questionnaires and surveys and incentives for the participation and completion of the intervention may act as an intervention as they provide ideas and prompt the participants to think about safety and to re-evaluate their behaviours. Since these were included to improve the retention rate or for data collection and not to modify the target behaviours, they were noted as unintended BCTs and included in the analysis.

Data Synthesis

Outcomes were measured in terms of improved farm safety, for which a number of indicators were employed across studies, as summarised in Table 1. If an intervention program incorporated more than one component, the efficacy of each component and its impact were estimated independently to the extent that the information provided in the article allowed. There was considerable heterogeneity across the studies included in this review regarding the study population, study design, intervention comparison and outcome measures. Thus, a meta-analysis was not appropriate, and a narrative review, as described by Popay et al. (2006), was used to synthesise the findings.

Results

Following the search, 3,928 articles were identified, and 3,128 studies went through title and abstract screening after removing the duplicates (Figure 1). A full-text screening was conducted on 46 studies, and nine studies that met the inclusion criteria were included in the review. This included five randomised control trials (RCT) (Pekkarinen, Anttonen and Pramila, 1994; Rasmussen *et al.*, 2003; Gadomski *et al.*, 2006; Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014), two pre-post intervention studies (Morgan *et al.*, 2002; Day, Rechnitzer and Lough, 2004), one randomised comparative study (Hallman, 2005) and one quasi-RCT (Sorensen *et al.*, 2011) (Table 1).

Figure 1: PRISMA 20009 Flow diagram of review process (Moher et al., 2009)

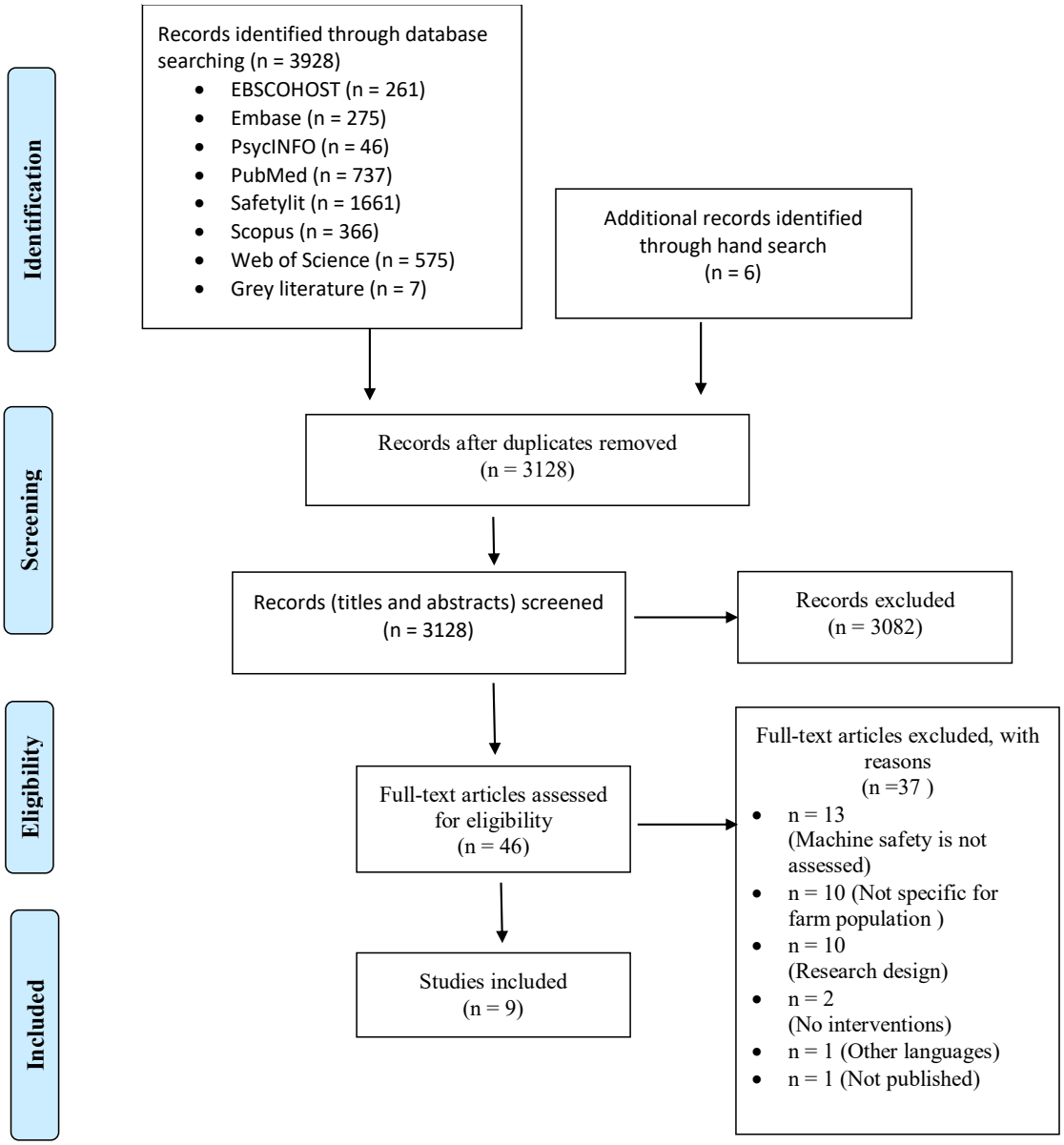


Table 1: Study Characteristics

Reference	Study Design	Participants	Intervention(s)	Results*
Pekkarinen et al., 1994	Community-randomized controlled trial	Reindeer herders in 53 herding districts in Finland	Intervention Group 1 : Information dissemination by theme letters via selected leaders employed by the project Intervention Group 2 : Information dissemination during medical examinations conducted by health personnel Control group: No intervention, had access to information about the study from the press	Herders reported implementing an average of 5.8 safety measures per herder. The number of helmet users doubled to 5%, and eye/face protector usage increased to 10%. Accident rate decreased from 20 to 15 accidents per 1000 working days over two years.
Morgan et al., 2002	Pre-Post study	Farmers in the state of Kentucky, USA	Phase-1: Incentives for retrofitting Phase-2: Incentive and ROPS Community based safety campaign	The number of retrofitted tractors with ROPS increased from 4 to 61 after the implementation of the ROPS promotion campaign.
Rasmussen et al., 2003	Randomized controlled trial	Farms in the county of Ringkoebing, Denmark	Intervention Group : Injury registration, safety checks on farms, 1-day farm safety course and custom safety plans Control group : No intervention	Farmers reported improvement in machinery repairs post-intervention.
Day et al., 2004	Pre-Post study	Full and part-time farmers from the state of Victoria, Australia	Regulatory amendments requiring ROPS installation, a rebate program and media-based safety campaign	The number of tractors without ROPS decreased from approximately 24% to 7% in the state.

Hallman, 2005	Randomized comparative study	350 farms in the state of New York, USA	Offer packages with varying levels of funding for retrofitting ROPS on tractors and free engineering consultation	30 farms accepted the subsidy and retrofitted the ROPS.
Gadomski et al., 2006	Randomized controlled trial	Farm children between 7-16 years old employed at New York State farms	Farm visits, telephone injury surveillance, tailored age-related NAGCAT guidelines, and reminders	No difference in the increase in the number of retrofitted tractors. Intervention farms reported less violation in recommended minimum age guidelines on using ATVs and tractors.
Sorensen et al., 2011	Quasi-Randomized controlled trial	Small-scale crop and livestock farms in the state of New York, USA	Intervention Group 1 : Rebates and Toll-free hotline assistance Intervention Group 2 : Rebates, Toll-free hotline assistance, Social marketing messages and promotion Intervention Group 3 : Toll-free hotline assistance, Social marketing messages and promotion Control group: No intervention	5.1% of the participants retrofitted ROPS The social marketing region reported the greatest increases in readiness to retrofit and intentions to retrofit. Farmers in this region also had higher message recall. Movement from precontemplation to contemplation in farm safety habits was observed in the rebate-only and social marketing regions. In the social marketing region, the mean behavioral intention score increased roughly 4 times the baseline value. Comparisons of changes in subjective norms scores found the most notable increase in the social marketing region, followed by the rebate-only region, the messages and promotion region, and the control region.
Jinnah et al., 2014	Randomized controlled trial	Crop farming families with children aged 10-19 employed on farms of Georgia state, USA	Intervention Group 1 : AgTeen lessons taught by fathers to the children. Intervention Group 2 : AgTeen lessons taught by a peer farmer employed by the project to the	70% of farmers of parent-led group began using seatbelts on ROPS-equipped tractors, compared to 40% in other groups. 77% of fathers of parent-led group required their youth to wear seatbelts on ROPS-eqipped tractors, compared to 47% in other groups. Fathers of parent-led group showed positive change

			children. Control group: No intervention.	in perception of injury susceptibility for youth. Youth of parent-led group less likely to operate ROPS tractor without seatbelt compared to control group.
Stoneman et al., 2014	Randomized controlled trial	Crop farming families with children aged 10-19 employed on farms of Georgia state, USA	Intervention Group 1 : AgTeen lessons taught by fathers to the children. Intervention Group 2 : AgTeen lessons taught by a peer farmer employed by the project to the children. Control group: No intervention.	Fathers from both parent-led and staff-led group were less likely to give youth tractor rides compared to control group. The intervention positively affected the attitudes and injury risk perceptions of both mothers and fathers. Both intervention groups showed a decline in youth giving tractor rides to others post-intervention. After the intervention, parents in the intervention groups demonstrated reduced positive cultural attitudes about extra riding, but many still endorsed its value.

*reported machine safety related outcome

Risk of Bias assessment

Tables S2-3 summarise the risk of bias assessment for the studies. In the randomised studies, all except one(Hallman, 2005) were judged to have a low risk of bias. However, among the non-randomised studies, except for the one quasi-RCT study (Sorensen *et al.*, 2011), the other studies were judged to have a high risk of bias. This can be attributed to the fact that the primary objective of these studies was not to evaluate the effectiveness of intervention but rather to conduct a cost-benefit analysis of a rebate-based intervention (Day, Rechnitzer and Lough, 2004) and evaluate the impact of different message types in a campaign-based intervention (Morgan *et al.*, 2002). Therefore, they provided insufficient information relevant to the review.

Study Characteristics

A detailed overview of the studies is provided in Appendix A5.

Population

The target population for six studies were adult farmers (Pekkarinen, Anttonen and Pramila, 1994; Morgan *et al.*, 2002; Rasmussen *et al.*, 2003; Day, Rechnitzer and Lough, 2004; Hallman, 2005; Sorensen *et al.*, 2011) and the remaining three studies (Gadomski et al., 2006; Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014) targeted children from the farming families. Five of the nine studies addressed specific farm types, while others were not specific in terms of focus, addressing farming in general. One (Rasmussen *et al.*, 2003) of those five studies reported that their study included an equal number of participants from all the farm types to eliminate the effect of farm types on the outcome. Of the four remaining studies, Sorensen et al.(2011) targeted livestock and crop farmers, two studies (Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014) targeted crop farmers alone, and Pekkarinen et al.(1994) targeted reindeer herders. Interventions were carried out between 1985 and 2014. Except for two studies (Morgan *et al.*, 2002; Hallman, 2005), all other studies provided exact details on the duration of the study, which varied from one to five years.

Theoretical Background

Seven studies (Pekkarinen, Anttonen and Pramila, 1994; Morgan *et al.*, 2002; Day, Rechnitzer and Lough, 2004; Hallman, 2005; Sorensen *et al.*, 2011; Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014) were explicitly designed to address farm machine-related accidents, whereas the remaining two studies (Rasmussen *et al.*, 2003; Gadomski *et al.*, 2006) addressed machine safety as one of the contributing factors to general farm safety. Four of the studies were underpinned by one or more theories, including the theory of cognitive dissonance and extended parallel process model (Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014), the theory of planned behaviour(Sorensen *et al.*, 2011), dual coding theory & narrative theory (Morgan *et al.*, 2002). Only two of the studies included input from farmers in the development phase (Morgan *et al.*, 2002; Rasmussen *et al.*, 2003). Four studies were tailored to suit the farm practices (Rasmussen *et al.*, 2003; Gadomski *et al.*, 2006; Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014).

Outcomes

Across the nine studies included in our review, a diverse range of outcomes was identified, reflecting the heterogeneity in study objectives, designs, population and measurement strategy (Appendix A5). While certain outcomes, such as safety perception, PPE usage, and

ROPS adoption, were assessed across studies (2, 2 and 5 studies, respectively), each study also focused on specific outcomes aligned with their research objectives. It is important to note that even when studies examined the same outcomes, variations in measurement approaches were observed. For instance, the assessment of retrofit adoption differed across studies regarding the time frame, ranging from monthly to annually. Moreover, data collection methods varied, with some studies utilising surveys or questionnaires, while others relied on observational data, self-reported data or rebate reports.

The interventions in the reviewed studies resulted in a range of positive changes related to farm machine safety (Table 1). Notably, there was increased adoption of safety devices such as, Roll Over Protection Systems (ROPS) across five studies (Morgan *et al.*, 2002; Day, Rechnitzer and Lough, 2004; Hallman, 2005; Sorensen *et al.*, 2011), along with greater usage of Personal Protective Equipment (PPE) like helmets and eye/face protectors (Pekkarinen, Anttonen and Pramila, 1994; Rasmussen *et al.*, 2003). Improved safety habits and awareness were also observed (Gadomski *et al.*, 2006; Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014). Promotion campaigns and incentives for retrofitting ROPS on tractors increased the number of retrofitted tractors (Morgan *et al.*, 2002; Day, Rechnitzer and Lough, 2004). Additionally, interventions such as safety courses, injury registration, and custom safety plans contributed to improved machinery repairs and the adoption of safer behaviours on farms (Pekkarinen, Anttonen and Pramila, 1994; Gadomski *et al.*, 2006). Farm safety lessons taught by fathers or peers led to increased seat belt usage and positive changes in youth's perception of injury susceptibility (Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014). However, the studies that focused on the initial adoption of the safety devices gave limited attention to their long-term use and maintenance.

Positive effects of machinery-related farm safety interventions were relatively consistently observed, but direct comparisons and synthesis of evidence of intervention effectiveness were hindered by the lack of standardized outcome measure identification of active key components and their impact and differences in the details provided of intervention implementation. Therefore, in the next section of this review, we will examine the different categories of interventions and analyse the behaviour change techniques (BCTs) employed within them. Additionally, we will explore the reported impacts of these individual intervention components or their combinations on enhancing machine-related farm safety.

Intervention categories

Education was the most common intervention approach. In fact, eight of the nine studies included only education, and the remaining study included both education and enforcement. Following the classification provided by the latest Cochrane review on farm safety (Rautiainen *et al.*, 2008), financial assistance, such as rebates, is analysed under the educational approach.

The educational approach consisted of varied strategies (Appendix A6); Financial assistance (n=4), Safety campaign (n=3), Safety demonstration (n=2), Farm Audit (n=2), and Social marketing campaign (n=1).

Behavioural content description

A summary of the breakdown of the intervention components and behaviour change components present in the intervention sub-categories is provided in Table 2.

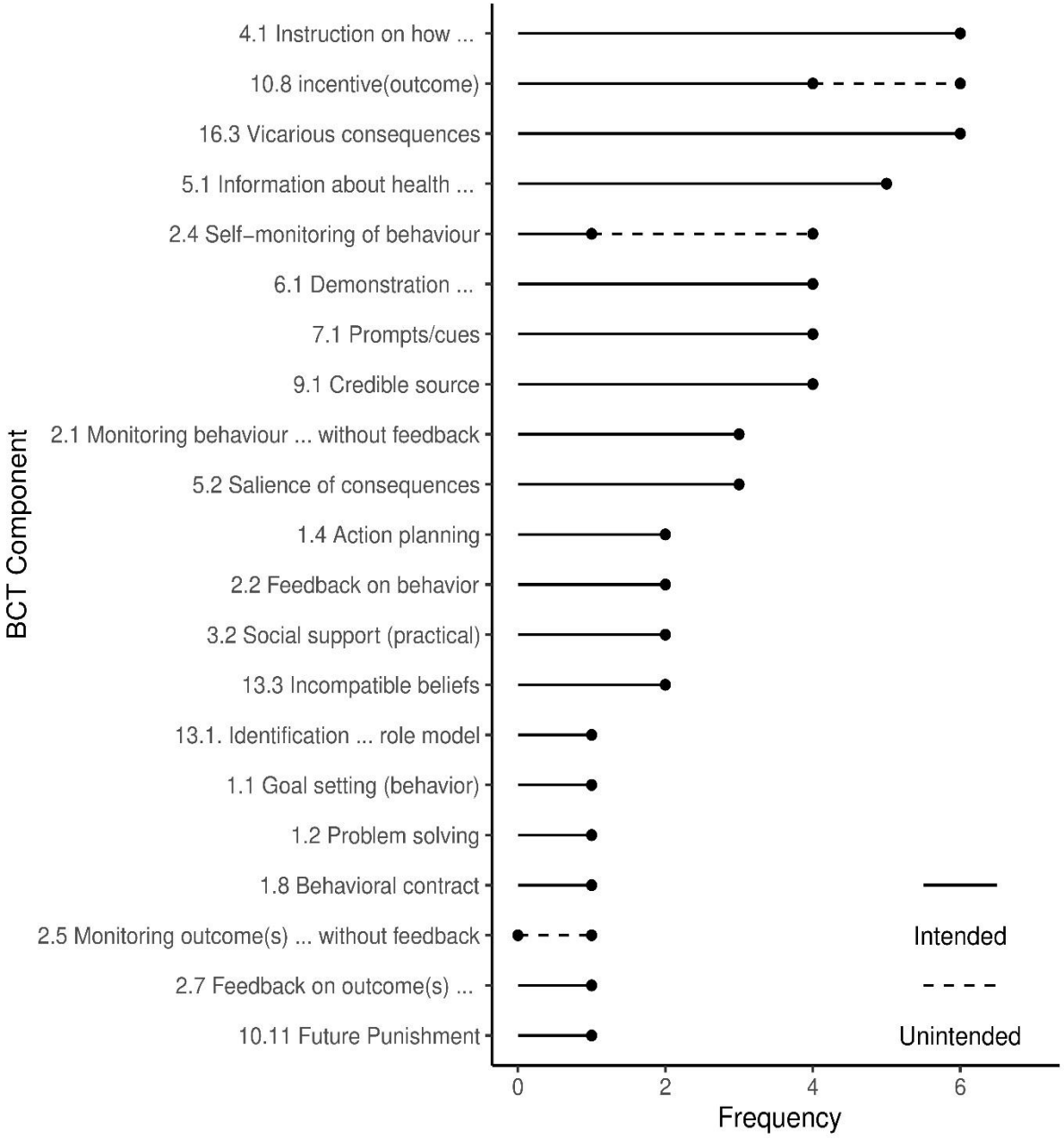
Table 2: Break down of the intervention categories, sub-categories and behaviour change components present in the included studies

Study	Intervention categories	Intervention sub-categories	BCW Intervention Functions identified	BCTs identified
Pekkarinen et al., 1994	Safety education	Safety campaign	Education	2.4 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour 9.1 Credible source
Morgan et al., 2002	Safety education	Financial assistance	Incentivisation	10.8 Incentive(outcome)
		Safety Campaign	Education Persuasion Training	4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 6.1 Demonstration of the behaviour 7.1 Prompts/cues 9.1 Credible source 16.3 Vicarious consequences
Rasmussen et al., 2003	Safety education	Farm audit	Education Persuasion Training Environmental restructuring	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.8 Behavioural contract 2.2 Feedback on behaviour 2.4 Self-monitoring of behaviour 2.7 Feedback on outcome(s) of behaviour 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 5.2 Salience of consequences 6.1 Demonstration of the behaviour 9.1 Credible source 16.3 Vicarious consequences
Day et al., 2004	Safety education	Financial assistance	Incentivisation	10.8 Incentive(outcome)
		Safety campaign	Education Persuasion Training	4.1 Instruction on how to perform the behaviour 7.1 Prompts/cues 16.3 Vicarious consequences
	Enforcement	Regulation	Restriction	10.11 Future Punishment
Hallman, 2005	Safety education	Safety education	Enablement	3.2 Social support (practical)
		Financial assistance	Incentivisation	10.8 Incentive(outcome)
Gadomski et al., 2006	Safety education	Safety education	Education Persuasion Training	1.4 Action planning 4.1 Instruction on how to perform the behaviour 7.1 Prompts/cues
		Farm safety audit	None Identified	2.1 Monitoring of behaviour by others without feedback 2.5 Monitoring outcome(s) of behaviour by others without feedback 2.2 Feedback on behaviour
Sorensen et al., 2011	Safety education	Safety education	Enablement	3.2 Social support (practical)
		Financial assistance	Incentivisation	10.8 Incentive(outcome)

		Promotion	Education Persuasion	5.1 Information about health consequences 5.2 Salience of consequences 7.1 Prompts/cues 9.1 Credible source 16.3 Vicarious consequences
Jinnah et al., 2014	Safety education	Safety demonstration	Education Modelling Persuasion Training	2.1 Monitoring of behaviour by others without feedback 2.4 Self-monitoring of behaviour 4.1 Instruction on how to perform the behaviour 5.1 Information about health consequences 6.1 Demonstration of the behaviour 13.3 Incompatible beliefs 16.3 Vicarious consequences
		Financial assistance	Incentivisation	10.8 Incentive(outcome)
Stonemann et al., 2014	Safety education	Safety demonstration	Education Persuasion Training Modelling	2.1 Monitoring of behaviour by others without feedback 2.4 Self-monitoring of behaviour 5.1 Information about health consequences 5.2 Salience of consequences 6.1 Demonstration of the behaviour 13.1. Identification of self as role model 13.3 Incompatible beliefs 16.3 Vicarious consequences
		Financial assistance	Incentivisation	10.8 Incentive(outcome)

Overall, 21 (of 93) unique BCTs were coded in the reported intervention descriptions, with an average of 6 BCTs (range 2–13) per study (Figure 2). The most commonly applied techniques were 4.1 Instruction on how to perform the behaviour, 10.8 Incentive (outcome) and 16.3 Vicarious consequences (n=6). The authors analysed the participation incentives, surveys, questionnaires and accident reports used by the studies for the BCTs and presented them along with the rest of them as unintended BCTs in Figure 2. BCTs; 2.4 Self-monitoring of behaviour and 2.5 monitoring of outcomes of behaviour without feedback were present in three studies as this was used to collect accident data. 10.8 Incentives(outcome) were mapped to the studies offering incentives for participation.

Figure 2: Illustration of the frequency of the BCTs of the interventions in included studies (included studies = 9)



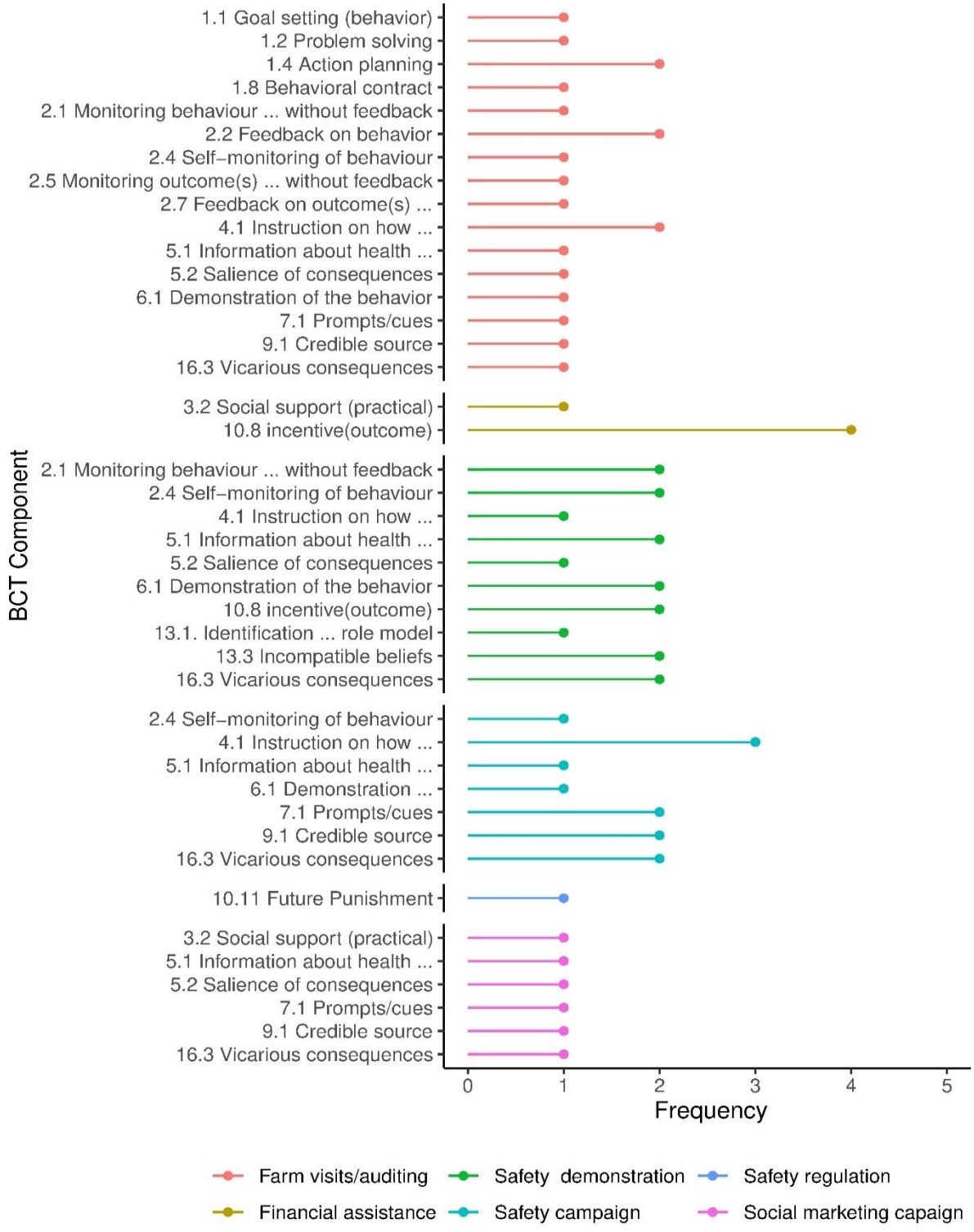
In four studies (Pekkarinen, Anttonen and Pramila, 1994; Morgan *et al.*, 2002; Day, Rechnitzer and Lough, 2004; Gadomski *et al.*, 2006), all probable BCTs could not be identified due to missing information. For example, the safety campaign reported in the Victora rebate program (Day, Rechnitzer and Lough, 2004), may have included 6.1 Demonstration of the behaviour, 16.3 Vicarious consequences and 5.1 Information about health consequences, like other campaign programs, but the details of the safety campaign content were not sufficient to confidently assign the BCTs. In addition, certain intervention components were difficult to assign to a specific BCT, even when sufficient information was provided. For example, rebates were designated as 10.8 Incentives(outcome). Rebates are typically construed as incentives (Dietz *et al.*, 2009; Rand, Norman and Goyder, 2020; Bunker *et al.*, 2021), but it is worth noting that rebates might function, instead, as enabling responses that were prevented by lack of funds (removal of a cost-related barrier to

behaviour). If so, then rebates do not motivate behaviour but, rather, provide resources necessary for a behaviour (that is already motivated) to occur.

Narrative synthesis of interventions

This section provides a comprehensive analysis of the interventions included in this review. The focus is on understanding the various intervention approaches employed, reported outcomes, and the BCTs utilized to achieve them.

Figure 3: Illustration of the frequency of each BCTs against intervention sub-categories



Enforcement-based interventions

The enforcement-based study (Day, Rechnitzer and Lough, 2004) examined the regulatory amendment that required all operational tractors to be fitted with ROPS. They reported a decrease in the proportion of unprotected tractors, from approximately 24% to 7% in the state, indicating an increase in tractor safety compliance. The study observed that since the amendments had not come into effect during the intervention, the fear of future amendments

and anticipated punishments drove the participants' decisions. As demonstrated in Figure 3, the enforcement category had the least number of BCTs (10.11 Future punishment). Furthermore, a rebate and safety campaign was introduced to raise awareness and financially assist ROPS adoption.

Education-based interventions

Education-based interventions primarily focused on raising awareness about risks and various schemes, skill development, and adoption of safety devices. The review identified five sub-categories within these interventions; financial assistance programs, safety campaigns, social marketing campaigns, safety demonstrations, and farm visits/auditing. Further analysis revealed that the same or similar BCTs are employed across these sub-categories (Figure 3). Financial assistance programmes had the least number of BCTs as they primarily focused on financially supporting the purchase and retrofitting of ROPS. Farm auditing, which constitutes farm visits, training sessions, monitoring and feedback sessions, employed the most number of BCTS.

Four studies (Morgan *et al.*, 2002; Day, Rechnitzer and Lough, 2004; Hallman, 2005; Sorensen *et al.*, 2011) had financial assistance, such as subsidies or rebates, as an active component of the intervention (barring incentives for participation) and focused on financially supporting the purchase and retrofitting of ROPS. Among these studies, three studies packaged it with other educational components, while one study (Hallman, 2005) solely focused on examining the influence of various rebate rates (0-100%) in adopting ROPS and determined the optimal rebate rate for their local community (70%). Surprisingly, despite clear evidence of the effectiveness of ROPS in preventing fatal rollover injuries, a significant number of participants refused to retrofit ROPS, even with a 100% rebate. By contrast, few participants were ready to retrofit for no financial incentives. A similar pattern was reported in other rebate programs targeting ROPS adoption as well. Day et al.(2004) reported that the current program involving regulatory amendments, publicity, and a widespread ROPS rebate program had a significantly higher participation rate than the past three rebate-only programs combined.

In two financial assistance-based studies (Hallman, 2005; Sorensen *et al.*, 2011), BCT 3.2 Social support (practical) was operationalised as a hotline/technical support centre. Participants who volunteered to retrofit with zero rebates reported that the education and assistance provided through these hotlines in sourcing the appropriate model influenced their decisions. Findings from these studies suggested that participants' purchasing decisions were not only influenced by cost but also by multiple factors, such as the perception of risk, locus of control, availability of suitable ROPS models, support in finding the right parts, and the time taken to retrofit the device. These studies primarily focused on the financial rebate (10.8 Incentives (outcome)) for ROPS adoption and did not examine financial assistance's effectiveness in adopting other safety devices, such as retrofitting seat belts and reverse cameras.

Two studies showed that combining a financial assistance program with an awareness/education campaign positively impacted ROPS purchases. Sorenson et al. (2011) reported that while rebates increased participants' readiness and intention to retrofit, the combination of social marketing and rebates was the most effective. Meanwhile, Morgan et al. (2002) reported that the ROPS purchase rate that remained low after introducing the subsidy increased following the launch of the safety campaign.

Seeing the impact of the safety campaign, Morgan et al.(2002) further analysed the persuasiveness of narrative-versus statistics-based messages present in the campaigns. Though there were no significant differences in the reported effectiveness of the messages, the statistics-based messages were persuasive among the participants who already favour the messages, while narrative–based messages were more effective among the resistant audience. Therefore, the study summarised that to increase the emotional appeal and interest in the long term and improve effectiveness, the messages should convey the threat, severity, probability, and doable actions to avoid the threat. 16.3 Vicarious consequences was one of the most commonly used BCTs, indicating the popularity of fear appeals among farm researchers. It was often packaged along with BCTs 5.1 Information about health consequences and 5.2 Salience of consequences and delivered as a testimony of accident survivors, footage of accidents, videos on the effect of traumatic brain injury and so on. 4.1 Instruction on how to perform the behaviour and 6.1 Demonstration of the behaviour was frequently used to convey the target behaviours and instructions for the doable actions. Regarding the evaluation strategies for campaign-based interventions, Rasmussen et al. (2003) observed that campaigns often focus on general safety information, and it is difficult to find suitable control groups or differentiate the effect of information from other sources like media or farm websites.

Three studies evaluated the influence of the message's source on the participants. Two of them (Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014) compared the effect of the instructors in a home-based peer-learning program by comparing the effect of parent-led and staff-led safety demonstrations on children. Meanwhile, a campaign among reindeer farmers (Pekkarinen, Anttonen and Pramila, 1994) compared the effect of the information source by comparing the effects of disseminating information through health professionals, farm personnel and media among adult farmers. These studies reported no statistical difference in overall effectiveness between the groups and observed that blinding the participants is a challenge in farm evaluations, and often farmers travel between intervention regions and share information, increasing the possibility of information leaks. Evidence indicated that newspapers and digital media are increasingly used in campaigns to disseminate information and persuade participants through emotional messages and accident reports (Pekkarinen, Anttonen and Pramila, 1994; Rasmussen *et al.*, 2003; Sorensen *et al.*, 2011).

Two studies (Rasmussen *et al.*, 2003; Gadomski *et al.*, 2006) examined the effectiveness of the farm safety audit approach. They reported that the visits provided an opportunity to adapt the prevention strategies according to the farm's needs. While auditing, a safety officer assessed the whole farm, and farmers were provided with feedback to improve the safety of the farm. Farm audits were reported to be effective in implementing farm machine-related guidelines targeted at farm children (Gadomski *et al.*, 2006) and improving the handling of the farm machines (Rasmussen *et al.*, 2003). While the audits did employ the common BCTs that were utilised for the dissemination in other studies, these visits also involved BCTs related to customisable and personalised actions such as 1.1 Goal setting (behaviour), 1.4 Action planning, 1.8 Behavioural contracts and 2.2 Feedback on behaviour. Neither of these two studies reported an increase in retrofitting tractors with ROPS. However, Gadomski et al. (2006) found promising results in reducing violations of NAGCAT-recommended minimum age guidelines for certain farm vehicles.

While the audit focused on the farm visit involving the overall health of the farm, home-based farm demonstrations focused on specific safety topics, such as teaching farm children safer tractor operation. The researchers anticipated that fathers who demonstrated the safe practice might experience cognitive dissonance while demonstrating practices they themselves do not follow, such as using seat belts while operating tractors. Hence, these studies expected the fathers to adopt these safer behaviours to reduce this dissonance, though the primary target population of these studies were farm children. Both studies demonstrated the effectiveness of the interventions in promoting safer tractor behaviours among farmers and youth. In the parent-led group, an increase in farmers using seatbelts on tractors was reported, and fathers showed improved perceptions of injury susceptibility for youth. Youth in this group were also less likely to operate ROPS tractors without seatbelts. Similarly, in the other study, fathers from both intervention groups were less likely to give youth tractor rides, and the interventions positively influenced parents' attitudes and injury risk perceptions. These studies demonstrated the potential of modelling-based learning involving target peers and family units and intergenerational transmission of farm risk behaviours (Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014).

In addition to the BCTs that were discussed so far, the review identified 7.1 Prompts/cues in four studies as a tool to disseminate information or as a reminder in multiple educational sub-categories (Morgan *et al.*, 2002; Day, Rechnitzer and Lough, 2004; Gadomski *et al.*, 2006; Sorensen *et al.*, 2011). However, a few discrepancies were reported at the initial stage of using code 7.1 Prompts/cues. Intervention details often focused on how it was delivered and failed to describe the content of the materials used or how the participants used it. If more information were available, BCTs 5.1 Information about health consequences, 12.1 Restructuring the physical environment, 12.5 Adding objects to the environment may have likely been present in some of these interventions and may have been coded along with the 7.1 Prompts/cue.

Some studies (Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014) with no financial assistance as an intervention component had financial incentives to encourage the recruitment and retention of participants. The impact of incentives on participation and retention rate was not independently analysed in any of the studies, therefore, its effectiveness is unknown.

Overall, our review investigated strategies to enhance machine-related farm safety and behaviour change techniques employed to achieve them. Our analysis of the interventions revealed promising findings regarding the effectiveness of multiple behaviour change techniques and their implementation.

Discussion

This systematic review aimed to address three key questions pertaining to machine-related farm safety interventions. Firstly, it explored the interventions and components utilised to enhance farm safety. Secondly, it identified the behaviour change techniques (BCTs) employed within these interventions. Lastly, it examined the outcomes of machine-related farm safety interventions in the context of the BCTs used. There were limits to what can be strongly concluded in terms of the effectiveness of different intervention strategies and behaviour change techniques due to (i) the range of intervention components employed concurrently, (ii) the complex interactions among those components affecting safety behaviour, and (iii) difficulties recording safety behaviours and safety failures and (iv) lack of

details of the reported interventions. Often, the success of the intervention program varies on a multitude of heterogeneous components concurrently introduced as a part of the program along with confounding variables, and many studies failed to examine the effect of these factors. With these caveats applied to the findings, certain patterns were observed among the reviewed studies. These insights contribute to the broader understanding of enhancing machine safety and provide a foundation for future research and intervention development.

The current review notes that safety education remains as the popular approach in machine safety interventions despite engineering and enforcement measures being reported as more effective in safety literature (Fragar and Houlahan, 2002). Education-based interventions focused on raising awareness and skill development, often combining financial assistance programs with campaigns. While the effectiveness of legislation was evident in improving the retrofit of ROPS, installation of safety cabins and use of helmets among farmers, it is essential to package it with promotional campaigns and financial assistance to increase the knowledge and means to implement it and improve the long-term adaptation (Pekkarinen, Anttonen and Pramila, 1994; Day, Rechnitzer and Lough, 2004). The provision of practical social support through hotlines and technical support centres was found to influence participants' decisions to retrofit ROPS. In conjunction with other educational components, financial assistance programs also increased participants' readiness and intention to retrofit ROPS. Combining social marketing campaigns with financial incentives yielded the most effective results regarding ROPS purchase rates. The employment of farm audits and home-based farm demonstrations provided opportunities for personalised and customisable actions, and their effectiveness was observed in improving farm safety practices, machine handling and the physical condition of farms. The findings suggest that no single intervention component alone can comprehensively address the multitude of safety threats in agricultural settings. This echoes the observations from the previous systematic review on farm safety, where multi-faceted interventions encompassing enforcement, engineering and education are recommended to achieve fundamental changes in the farmer's attitudes and behaviour to stay safe (Rautiainen *et al.*, 2004; Lehtola *et al.*, 2008; Lee *et al.*, 2017).

The analysis of the reviewed studies revealed the presence of various behaviour change techniques (BCTs) in the interventions targeting machine-related farm safety. Most commonly employed BCTs, such as vicarious consequences and information about health consequences, were related to changing farmers' attitudes, knowledge, and behaviours towards safety practices by providing detailed instructions on safety procedures and machine operation and the consequences of poor compliance (Figure 2). Interventions often included detailed explanations of the potential risks and injuries associated with machine-related farm accidents and fatal or near-fatal incidents of fellow farmers. By highlighting the adverse health outcomes and emphasising the importance of safety measures, these interventions aimed to motivate farmers to adopt safer practices. Examining the effectiveness of narratives and statistics-based messages that explained the consequences demonstrated that statistics-based messages were more persuasive among participants who already favoured the messages, and narratives were more effective among resistant audiences. Another commonly employed BCT was the use of demonstration of the behaviour (Morgan *et al.*, 2002; Rasmussen *et al.*, 2003; Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014). This technique aimed to enhance farmers' understanding and encourage them to replicate the demonstrated behaviours by providing visual examples of safe practices.

Given the popularity of incentives, we recommend further analysis of the optimal rate of financial incentives and their effectiveness in increasing recruitment and retention (Horsburgh and Langley, 2011). Although the potential to maintain long-term adherence is demonstrated in various safety intervention programs, we identified a gap in utilising non-monetary-based BCTs, such as 10.4. Social reward, 10.5. Social incentive, 10.7. Self-incentive,10.9. Self-reward and 16.2. Imaginary reward in machine safety literature (Martinsson *et al.*, 2016; Dyreborg *et al.*, 2022).

The systematic review revealed a wide range of outcomes across the included studies, reflecting the diversity in study designs and participant populations. While some interventions focused on general farm safety (Rasmussen *et al.*, 2003; Gadomski *et al.*, 2006), neglecting high-risk areas such as farm vehicles and machine handling, others specifically targeted machine-related accidents. Positive outcomes were observed in areas such as increased compliance with personal protective equipment (PPE) usage, adoption of safety measures like rollover protective structures (ROPS) and seat belts, and reduced accident rates. However, the lack of standardised outcome measures and inconsistent reporting limited direct comparisons and conclusive assessments of intervention effectiveness. Future research should incorporate standardised measures and evaluate the impact of different intervention components. Furthermore, a comprehensive assessment of outcomes is essential in farm safety interventions. This entails considering behavioural changes, knowledge improvement, safety enhancements, and compliance with regulations. Interventions should adopt a holistic approach to capture the broader impact on the well-being and safety of farmers and the farming community. Despite the outcome variability, these findings underscore the importance of tailored strategies to address specific safety concerns in agriculture and further exploration of the effectiveness of specific intervention components in improving farm safety outcomes.

Demographic factors such as gender, age, location, and farm type play a significant role in farm fatality. However, these factors are often overlooked in research. While it is known that children and older adults are particularly vulnerable to fatal incidents, there is limited attention given to age-specific concerns (Nilsson, 2016; Murphy and O'Connell, 2017). Similar to the previous review (Nilsson, 2016), this review found no studies that addressed the safety of older farmers. Additionally, in the context of age-related factors, children are frequently affected by machine hazards. But, only one study (Gadomski *et al.*, 2006) addressed the concern related to the minimum age to handle the tractor. Two studies on child safety reported the influence of prevailing norms (Jinnah, Stoneman and Rains, 2014; Stoneman, Jinnah and Rains, 2014). Though both studies addressed specific target behaviours concerning children using a similar demonstration approach, due to prevailing cultural attitudes, the demonstration was more effective in increasing the use of safety belts than decreasing the extra riding of youth on tractors. Given the increased likelihood of injuries among children and older farmers, prioritizing evidence-based interventions for these target groups is essential. In summary, given that the success of a program relies on addressing relevant barriers and facilitators present in the local context, the review recommends evidence-based interventions that include specific BCTs to address the existing demographic factors, norms and values.

Strengths and limitations

The review was limited by a small number of studies focused on farm machine safety. Including general safety interventions allowed for a more comprehensive sample but led to challenges in making direct comparisons due to diverse interventions and outcome measures. Furthermore, the lack of robust studies led to the inclusion of studies regardless of quality, bias, or sample size, requiring caution in interpreting the findings.

Though more than 50% of the global farm population resides in low-income countries (Stoskopf and Venn, 1985; Forastieri, 2000), no studies from these nations were included, possibly due to excluding non-English literature and unpublished articles, leading to potential selection bias.

Previous reviews were often limited to identifying the interventions and measuring their effectiveness, whereas this review attempted to identify the underlying behavioural components, the intervention functions and BCTs that are commonly employed in farm safety interventions. However, the omission of intervention details in some studies and lack of clarity concerning the intended active ingredients of interventions in others may have resulted in the omission of BCTs. Additionally, due to a lack of understanding of active ingredients and their impact on the measured outcomes, there were limits to what could be strongly concluded regarding behaviour change techniques and their effectiveness. In order to tackle the heterogeneity observed among the included studies, future systematic reviews could explore potential sources of heterogeneity and consider stratified analyses based on factors such as study design, participant characteristics, and intervention types (Van Sluijs, McMinn and Griffin, 2007). Additionally, conducting subgroup analyses or sensitivity analyses based on key factors can provide valuable insights into the effectiveness of behaviour change techniques in specific populations or settings (Popay *et al.*, 2006).

The review reaffirms the findings of the previous reviews on the lack of high-quality studies on farm safety interventions, especially the problems with or lack of evaluation in study designs and active ingredients. Including supplementary details such as intervention manuals or the TIDieR (Hoffmann et al., 2014) checklist may help communicate the intervention context accurately and improve the transparency, replicability, and generalizability of the study.

For future studies, addressing the reporting quality and clearly linking intervention components to specific outcomes will enhance our understanding of the active ingredients driving intervention success and contribute to the development of more targeted and impactful tractor safety interventions.

Conclusions

Previous reviews on farm machine safety interventions have shown that voluntary education programs have been the most popular intervention strategy, but short-term educational interventions focusing only on increasing safety knowledge have minimal effect on actual behaviours. The current review found that a combination of educational approaches was frequently used, but few studies evaluated their independent impact. Future studies need to examine the impact of the active ingredients independently to provide evidence-based recommendations on the most effective strategies for different contexts. The lack of scientifically rigorous studies in farm safety interventions has been highlighted for more than a decade, and stakeholders, funding agencies and researchers should prioritise designing

interventions with a theoretical underpinning targeting specific demographic groups and targeted safety behaviours concerning them. Furthermore, detailed descriptions of intervention components and scientifically robust evaluation of their effectiveness would facilitate meta-analysis of interventions, thereby allowing for definite conclusions on their effectiveness.

Data Availability Statement[2]

The dataset supporting the conclusions of this article is included within the article. Additional data supporting the project is available in the OSF repository (Aswathi, O'Hora and Mc Sharry, 2022).

Author contribution statement

Conceptualisation and formal analysis: A.S., J.M. (Jennifer McSharry) and D.O.; Methodology: A.S., D.O., J.M. (Jennifer McSharry).; writing—original draft preparation: A.S.; writing—review and editing: A.S., J.M. (Jennifer McSharry), O.M., D.O.; Validation: D.O., J.M. (Jennifer McSharry), D.M., J.M. (John McNamara) and F.B.; Project Administration—D.O., D.M..; Funding acquisition: D.O.; Supervision: D.O., J.M. (Jennifer McSharry), D.M. and O.M.

References

Aswathi, M., Surendran, O'Hora, D. and Mc Sharry, J. (2022) 'BeSafe Tractor: Developing behavioural based interventions to reduce machine related accidents on farms'. OSF. Available at: osf.io/ayxvs.

Bunker, A. *et al.* (2021) 'Housing structure and occupant behaviour to increase the environmental and health co-benefits of housing: Insights from expert interviews in New Zealand', *Indoor and Built Environment*, 30(4), pp. 535–553.

Coman, M.A. *et al.* (2020) 'Educational interventions to improve safety and health literacy among agricultural workers: a systematic review', *International journal of environmental research and public health*, 17(3), p. 1114.

'crd.york.ac.uk/prospero/display_record.php?RecordID=173834' (no date). Available at: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=173834 (Accessed: 6 February 2023).

Day, L., Rechnitzer, G. and Lough, J. (2004) 'An Australian experience with tractor rollover protective structure rebate programs: process, impact and outcome evaluation', *Accident Analysis & Prevention*, 36(5), pp. 861–867. Available at: https://doi.org/10.1016/j.aap.2003.09.001.

DeRoo, L.A. and Rautiainen, R.H. (2000) 'A systematic review of farm safety interventions', *American journal of preventive medicine*, 18(4), pp. 51–62. Available at: https://doi.org/10.1016/S0749-3797(00)00141-0.

[2] In the appendix, we have included most of the supplementary files published along with the journal. However, a few supplementary files that are not included here can be accessed on our Open Science Framework (OSF) profile or on the respective publisher websites.

Dietz, T. *et al.* (2009) 'Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions', *Proceedings of the national academy of sciences*, 106(44), pp. 18452–18456.

Dyreborg, J. *et al.* (2022) 'Safety interventions for the prevention of accidents at work: A systematic review', *Campbell Systematic Reviews*, 18(2), p. e1234. Available at: https://doi.org/10.1002/cl2.1234.

Forastieri, V. (2000) 'The ILO Programme on Safety and Health in Agriculture: The challenge for the new century–providing occupational safety and health services to workers in agriculture1', *Top on the agenda: Health and safety in agriculture*, 1, p. 1.

Fragar, L. and Houlahan, J. (2002) 'Australian approaches to the prevention of farm injury', *New South Wales public health bulletin*, 13(5), pp. 103–107.

French, D.P. *et al.* (2014) 'Which Behaviour Change Techniques Are Most Effective at Increasing Older Adults' Self-Efficacy and Physical Activity Behaviour? A Systematic Review', *Annals of Behavioral Medicine*, 48(2), pp. 225–234. Available at: https://doi.org/10.1007/s12160-014-9593-z.

Gadomski, A. *et al.* (2006) 'Efficacy of the North American guidelines for children's agricultural tasks in reducing childhood agricultural injuries', *American Journal of Public Health*, 96(4), pp. 722–727.

Gallagher, S.S. (2012) 'Characteristics of evaluated childhood agricultural safety interventions', *Journal of agromedicine*, 17(2), pp. 109–126.

Hallman, E.M. (2005) 'ROPS retrofitting: Measuring effectiveness of incentives and uncovering inherent barriers to success', *Journal of agricultural safety and health*, 11(1), pp. 75–84.

Higgins, J.P. *et al.* (2019) *Cochrane handbook for systematic reviews of interventions*. John Wiley & Sons.

Hoffmann, T.C. *et al.* (2014) 'Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide', *Bmj*, 348. Available at: https://doi.org/10.1136/bmj.g1687.

Horsburgh, S. and Langley, J.D. (2011) 'Recruitment and retention of farm owners and workers for a six-month prospective injury study in New Zealand: a feasibility study', *Journal of Occupational Medicine and Toxicology*, 6(1), p. 16. Available at: https://doi.org/10.1186/1745-6673-6-16.

Irwin, A. and Poots, J. (2015) 'The human factor in agriculture: An interview study to identify farmers' non-technical skills', *Safety science*, 74, pp. 114–121.

Jinnah, H.A., Stoneman, Z. and Rains, G. (2014) 'Involving fathers in teaching youth about farm tractor seatbelt safety—a randomized control study', *Journal of Adolescent Health*, 54(3), pp. 255–261.

Jüni, P. *et al.* (2016) 'Risk of bias in non-randomized studies of interventions (ROBINS-I): detailed guidance', *Br Med J* [Preprint].

Lee, B.C. *et al.* (2017) 'Using the socio-ecological model to frame agricultural safety and health interventions', *Journal of agromedicine*, 22(4), pp. 298–303.

Lehtola, M.M. *et al.* (2008) 'Effectiveness of interventions in preventing injuries in agriculture—a systematic review and meta-analysis', *Scandinavian journal of work, environment & health*, pp. 327–336. Available at: https://doi.org/10.5271/sjweh.1279.

Lundqvist, P. and Gustafsson, B. (1992) 'Accidents and accident prevention in agriculture a review of selected studies', *International Journal of Industrial Ergonomics*, 10(4), pp. 311–319.

Martinsson, C. *et al.* (2016) 'What incentives influence employers to engage in workplace health interventions?', *BMC Public Health*, 16(1), pp. 1–12. Available at: https://doi.org/10.1186/s12889-016-3534-7.

McNamara, J. *et al.* (2017) 'Health and safety adoption from use of a risk assessment document on Irish farms', *Journal of agromedicine*, 22(4), pp. 384–394.

Michie, S. *et al.* (2013) 'The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions', *Annals of behavioral medicine*, 46(1), pp. 81–95. Available at: https://doi.org/10.1007/s12160-013-9486-6.

Michie, S. *et al.* (2015) 'Behaviour change techniques: the development and evaluation of a taxonomic method for reporting and describing behaviour change interventions (a suite of five studies involving consensus methods, randomised controlled trials and analysis of qualitative data)', *Health technology assessment*, 19(99). Available at: https://doi.org/10.3310/hta19990.

Michie, S., Van Stralen, MM and West, R. (2011) 'The behaviour change wheel: a new method for characterising and designing behaviour change interventions', *Implementation science*, 6(1), pp. 1–12. Available at: https://doi.org/10.1186/1748-5908-6-42.

Moher, D. *et al.* (2009) 'Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement', *Annals of internal medicine*, 151(4), pp. 264–269.

Morgan, S.E. *et al.* (2002) 'Stories or statistics? Farmers' attitudes toward messages in an agricultural safety campaign', *Journal of agricultural safety and health*, 8(2), p. 225.

Murphy, D.J. (1992) *Safety and health for production agriculture.* American Society of Agricultural Engineers.

Murphy, M. and O'Connell, K. (2017) 'Farm Deaths and Injuries: Changing Irish Farmer Attitudes and Behaviour on Farm Safety'.

Narasimhan, G.R. *et al.* (2010)' Operational safety practices as determinants of machinery-related injury on Saskatchewan farms', *Accident Analysis & Prevention*, 42(4), pp. 1226–1231. Available at: https://doi.org/10.1016/j.aap.2010.01.016.

Nilsson, K. (2016) 'Interventions to reduce injuries among older workers in agriculture: A review of evaluated intervention projects', *Work*, 55(2), pp. 471–480. Available at: https://doi.org/10.3233/wor-162407.

Pekkarinen, A., Anttonen, H. and Pramila, S. (1994) 'Accident prevention in reindeer herding work', *Arctic*, pp. 124–127.

Perez-Lopez, J.F. (2021)' Appendix C. United Nations International Standard Industrial Classification of All Economic Activities', in *Measuring Cuban Economic Performance*. University of Texas Press, pp. 165–172.

Petrea, R.E. (2001) 'The theory of planned behavior: use and application in targeting agricultural safety and health interventions', *Journal of agricultural safety and health*, 7(1), p. 7.

Popay, J. *et al.* (2006) 'Guidance on the conduct of narrative synthesis in systematic reviews', *A product from the ESRC methods programme Version*, 1(1), p. b92.

Rand, M., Norman, P. and Goyder, E. (2020) 'A systematic review of interventions to increase attendance at health and fitness venues: identifying key behaviour change techniques', *BMC Public Health*, 20(1), pp. 1–13.

Rasmussen, K. *et al.* (2003) 'Prevention of farm injuries in Denmark', *Scandinavian journal of work, environment & health*, pp. 288–296.

Rautiainen, R.H. *et al.* (2008) 'Interventions for preventing injuries in the agricultural industry', *Cochrane database of systematic reviews* [Preprint], (1).

Rautiainen, R.H. *et al.* (2004) 'Injuries in the Iowa certified safe farm study', *Journal of Agricultural Safety and Health*, 10(1), p. 51.

Skivington, K. *et al.* (2021) 'A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance', *BMJ*, 374. Available at: https://doi.org/10.1136/bmj.n2061.

Sorensen, J.A. *et al.* (2011) 'The social marketing of safety behaviors: a quasi–randomized controlled trial of tractor retrofitting incentives', *American Journal of Public Health*, 101(4), pp. 678–684.

Sorensen, J.A. *et al.* (2016) 'Symbolic interactionism: A framework for understanding risk-taking behaviors in farm communities', *Journal of agromedicine*, 22(1), pp. 26–35.

Sorensen, J.A. *et al.* (2017) 'A comparison of interventional approaches for increasing power take-off shielding on new york farms', *Journal of agromedicine*, 22(3), pp. 251–258.

Stoneman, Z., Jinnah, H.A. and Rains, G.C. (2014) 'Changing a dangerous rural cultural tradition: a randomized control study of youth as extra riders on tractors', *The journal of rural health*, 30(4), pp. 388–396.

Stoskopf, C.H. and Venn, J. (1985) 'Farm accidents and injuries: a review and ideas for prevention', *Journal of Environmental Health*, pp. 250–252.

Van Sluijs, E.M.F., McMinn, A.M. and Griffin, S.J. (2007) 'Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials', *BMJ*, 335(7622), p. 703. Available at: https://doi.org/10.1136/bmj.39320.843947.BE.

Verbi, S. (2019) 'MAXQDA'. Berlin: VERBI Software. Available at: https://www.maxqda.com/new-maxqda-2020.

Chapter 4 Barriers and facilitators to adopting safe farm-machine related behaviours: A focus group study exploring older farmers' perspectives[3]

Authors: Aswathi Surendran[1], Jenny McSharry[1], Oonagh Meade[1], David Meredith[2], John McNamara[2], Francis Bligh[2] and Denis O'Hora[1]

[1]School of Psychology, University of Galway, H91 TK33 Galway, Ireland
[2]Irish Agriculture and Food Development Authority, R93 XE12 Carlow, Ireland

*Correspondence: Author: Aswathi Surendran; Email: s.aswathi@nuigalway.ie

Abstract

Background

Tractors and quad bikes pose a significant risk of fatal injuries among farmers, particularly affecting older farmers. This study aimed to explore the barriers and facilitators to the adoption of machine related safety behaviours among older farmers in Irish farm settings.

Method

Four focus groups were conducted via Zoom in February 2021. Nineteen Irish farmers from four farm types participated. The discussions were audio-recorded, transcribed verbatim, and analysed using an inductive, reflexive thematic analysis approach. The themes identified were then mapped to the COM-B (Capability-Opportunity-Motivation) model, providing a systematic theoretical basis for designing a future intervention to reduce machine-related accidents.

Results

The analysis identified five inductive themes that encompassed both barriers and facilitators in farm safety practices: 1) Capability to manage competing responsibilities; 2) Characteristics of the farm and its work environment; 3) Availability and affordability of resources; 4) Prevailing sociocultural opportunities; and 5) Perceived likelihood and cost-benefit analysis in safety decision-making. These themes captured the complex interplay of capability, opportunity, and motivation in farmers' decision-making processes. The study also revealed limitations in existing interventions, such as voluntary guidelines and educational methods, in effectively addressing these barriers.

Conclusions

Farmers' abilities (capability), prevailing sociocultural factors, resource availability (opportunity), and their perceived consequences and benefits (motivation) affect how safely they work with machines. The study emphasises the need for comprehensive, theory-driven approaches that consider the interplay of capability, opportunity, and motivational factors that may support or impede machine safety. Understanding the challenges faced by Irish farmers highlights potential strategies for safety intervention, and these strategies should be co-designed with farmers and attentive to the local context.

[3] Surendran, A., McSharry, J., Meade, O., Meredith, D., McNamara, J., Bligh, F., & O'Hora, D. (2024). Barriers and facilitators to adopting safe farm-machine related behaviours: A focus group study exploring older farmers' perspectives. Journal of Safety Research, in press.

Practical applications

The study provides a template for understanding farmers' perspectives using the COM-B model. The findings can inform the development of theoretically informed intervention strategies based on the Behaviour Change Wheel framework in the future.

Keywords: farm safety; tractor; qualitative study; focus group; Ireland

Introduction

Globally, the International Labour Office (ILO) has identified farming as one of the most dangerous sectors.[1] Despite the implementation of health and safety initiatives and regulations, the farming sector continues to face challenges in reducing injury rates and improving safety practices.[2] The use of machinery is a crucial aspect of agricultural work worldwide, as it significantly contributes to increasing productivity and efficiency. However, the use of machinery in farming operations also introduces inherent risks, making machine safety a paramount concern.[3] Vehicles, particularly tractors and quad bikes, have been identified as the leading causes of fatal injuries on farms.[1,4]

Farmers often work alone, assuming the role of both worker and boss, which can make enforcing safety regulations and engineering solutions challenging. This situation exacerbates the impact of workplace injuries when they occur, as the consequences can be more severe not only for the farmer's health, given the potential delay in receiving help, but also for their livelihood and overall farming operation.[5,6] Additionally, psychosocial factors like age, gender, social norms, attitudes, isolation, and stress significantly influence farmers' safety behaviours. Surprisingly, despite their impact on risk perception and safety outcomes, these factors are frequently overlooked in machine safety interventions.[7–9] While some successful interventions, such as the West Jutland study in Denmark, have demonstrated effectiveness in reducing farm injuries, safety interventions that considered psychosocial factors remain limited.[2,10]

Many interventions have focused on raising awareness about occupational hazards among farmers and promoting safer practices.[9] However, their success has often been limited. This limited success can be attributed to the fact that many interventions primarily emphasise risk analysis and raising awareness. Research in preventive health behaviour change has shown that knowledge and awareness of potential risks alone are often insufficient to drive behavioural change.[11] To enhance the effectiveness of prevention programs, it is crucial to address other key determinants of behaviour, including attitudes, perceived social norms, self-efficacy, and environmental factors that influence or reinforce farmers' safety behaviour.[2,11,12]

Recognising the significant influence of psychosocial factors on farmers' attitudes and behaviours, some studies have utilised behaviour change theories, such as the Theory of Planned Behaviour, the Health Belief Model, and the Capability-Opportunity-Motivation-Behaviour (COM-B) model, to explore the factors shaping farmers' attitudes and behaviours.[13–15] However, despite employing behaviour models to investigate the factors affecting farm safety, behaviour-change-based interventions specifically targeting the psychosocial factors identified in these studies remain limited.[2,10,16] The COM-B model,[17] in particular, offers a comprehensive framework for understanding the determinants of target behaviours, encompassing experiences, opportunities, and prevailing norms. The model suggests that for any behaviour to occur, a person should have the capability, opportunity or motivation to engage in that behaviour. Capability refers to the ability of a person to perform a specific task. Capability can be physical factors like skills, physical strength etc. or psychological such as knowledge, mental state etc. Opportunity encompasses the external circumstances that enable or facilitate the enactment of a particular behaviour. These circumstances might involve physical factors like available time or social aspects such as societal norms. Motivation refers to cognitive and emotional processes that influence a person's decision-making and preferences. It can be either reflective, which involves evaluation, planning etc. or automatic, such as emotions, habits etc.[17] Although the COM-B model has been widely applied in various contexts, such as smoking cessation[18], worker

sitting habits[18], and adoption of helmets among ATV users on farms,[15] its application to adopting safe farm-machine-related behaviours remains limited. Building upon this model, the Behaviour Change Wheel (BCW) framework provides a practical guide for the development of targeted and effective interventions. The BCW framework emphasises the need to identify key behaviour change techniques and intervention functions based on an understanding of the psychological, social, and physical environment.[17,19] By integrating the COM-B model within the BCW framework, interventions can be designed to address the specific psychosocial factors influencing farmers' attitudes and behaviours, leading to more successful behaviour change outcomes.

Ireland's agricultural landscape is characterised by its small-scale, family-run farms. According to a recent farm survey[20], the Irish farming system consists of 135,037 farms in 2020. As per the survey, the largest farms by area were in the Specialist Dairying category (65.1 hectares), while Specialist Beef Production farms were, on average, 26.9 hectares. Specialist Dairying farms were 9.8 hectares larger on average than in 2010. In 33% of farms, the holder was 65 or older, while 7% were under 35. Approximately one in every eight (13.4%) farmholders were female. The farming system is divided into four main types: Specialist Beef Production, Specialist Sheep, Specialist Dairying, and Specialist Tillage. Specialist Beef Production was the most common type of farming in Ireland, with 74,159 farms engaged in this activity.[20]

The agricultural industry in Ireland plays a vital role in the country's economic growth and is a key indigenous sector.[21,22] However, farming is also recognised as one of the most dangerous job sectors in Ireland, with approximately 50% of all occupational fatalities occurring on farms.[23] Despite implementing various health and safety initiatives and legislations, the fatality rates from the farming sector remain among the highest among all occupational sectors.[4,12] While there has been a decrease in reported fatal injuries since 2021, the National Farm Survey (NFS) reported that approximately 4,523 incidents occur on Irish farms annually. Over 88% of these farm accidents involved the farm operator and an additional 11% involved family members. Vehicle-related incidents, particularly involving tractors and quad bikes, were responsible for almost half of all farm fatalities.[4] A salient demographic feature of Irish farmers is that they are an ageing population, with approximately 33% of farmers being 65 years old or older. While recent farm reports indicate that fatal injuries are reduced among younger farmers, older farmers face increased vulnerability to fatal injuries compared to other age groups, with 47% of farm-related fatalities occurring among individuals aged 65 years or older.[20,24–26] Despite this disproportionate impact on older farmers, studies rarely explore their perspectives or address their specific safety needs.[27,28]

A review by Nilsson et al.[27] highlighted a shortage of farm safety interventions targeting older farmers and noted that older farmers are less likely to participate and more likely to drop out of safety initiatives compared to their younger counterparts. Intervention development must be informed by the psychological, social, and physical context in which those interventions will be implemented. In the Irish farming context, there is a need to develop tailored interventions that directly address the safety needs of older farmers, particularly in high-injury-prone areas such as tractor and quad bike safety. Exploratory research, such as focus group studies, can provide valuable insights into the local context and psychosocial factors, enabling the identification of tools, skills, and supports required to design and implement evidence-based behavioural change interventions on farms. Furthermore, such research can shed light on the suboptimal performance of previous safety

initiatives. Aligned with these objectives, the current study aims to investigate the attitudes and behaviours of older farmers towards machine safety. By focusing on this specific age cohort and utilising the COM-B framework, this study seeks to inform the development of evidence-based, farmer-centric interventions that are directly relevant to the Irish farm setting. This research will bridge the gap in understanding older farmers' perspectives and address their unique safety needs, contributing to improved farm safety outcomes.

Method

Design

The study followed a qualitative research design and employed focus group discussions as the primary data collection method. The Irish Agriculture and Food Development Authority (Teagasc) is the semi-state authority in the Republic of Ireland responsible for research and development, training and advisory services in the agro-food sector. Teagasc personnel assisted the research team with designing and facilitating the focus group discussions and recruiting participants. This study followed the COnsolidated criteria for REporting Qualitative research (COREQ) guidelines.[29]

Ethics

The study received ethical approval from the Research Ethics Committee at the University of Galway on December 12 2020 (#2020.10.022). No major risks to the participants or the researchers were anticipated, and none eventuated. Consent was obtained from all participants before or at the beginning of each session, either through written means such as email or verbally over the Skype session.[31] Participants were also informed that they could withdraw from the study at any point without giving a reason.

Procedure

Based on the Irish COVID-19 regulations, the research team decided to conduct an online-based data collection instead of an in-person approach. An audio-based focus-group discussion with open-ended questions allowed participants to express their insights and recommendations with relative anonymity and build on others' observations. The topic guide (Appendix B2) was developed by the research team based on a review of the literature on machine safety [30] and the COM-B model. At least one question was developed for each COM-B subdomain, and questions were followed up with additional prompts if further clarification was required. A Teagasc staff member (FB) provided feedback on a draft version of the topic guide (Appendix B1). The topic guide was used flexibly to explore themes and ideas that were not explicitly covered in the guide.

Teagasc farm advisors contacted eligible farmers via telephone and provided study details. The information sheet and consent form were then sent by the advisor via email or post to farmers who expressed an interest in participating in the study. Semi-structured focus group discussions were conducted online via Skype,[31] facilitated by AS, a PhD student who had no previous knowledge of the participants.

Participants

The recruitment was carried out with the assistance of Teagasc farm advisors using purposive sampling.[32] This approach aimed to achieve heterogeneity in recruiting farmers from different farm types. Eligible participants were male or female farmers aged 60 years or older, representing one of four farm types: dairy, beef, sheep, or tillage. The decision to set the lower age limit at 60 was based on Teagasc's recommendation. This consideration was made in light of the practicality of conducting online-based interviews, especially with older

farmers who may have limited experience with digital devices and online interviews. This age limit ensured that insights were gathered from the most at-risk age group while maintaining the feasibility of recruitment.

Nineteen Irish farmers aged above 60 participated in the study, forming four focus groups with a range of 3-6 participants per group. The duration of each focus group discussion varied from 55 to 105 minutes. To express our gratitude for their valuable contribution, participants received a €15 one-4-all voucher as a token of appreciation for their time and insights. Data collection occurred between January 2021 and February 2021.

Data analysis

The data analysis was guided by a subtle-realist approach[33], chosen for its suitability in exploring the nuanced perspectives of farmers and understanding the complexities of their lived experiences related to farm safety. This approach acknowledges the existence of an objective social reality while recognising that its understanding is shaped by the subjective interpretations of both participants and researchers. It allows for the consideration of subjective perceptions and observations, drawing meaningful insights despite the absence of absolute certainty.[33,34] This subtle-realist perspective was particularly well-suited for the study's exploratory nature, enabling an inductive, reflexive thematic analysis approach.[35]

The data analysis team comprised four authors with backgrounds in health psychology: AS, OM, JMS, and DOH. AS is a Psychology PhD student. OM and JMS are experienced health psychologists and qualitative researchers, while DOH is an expert in health and safety research and an experienced quantitative researcher. All interviews were audio-recorded online, transcribed verbatim, and checked for accuracy by AS. The thematic analysis was conducted in two phases. The first phase involved inductively analysing the data in accordance with Braun & Clarke.[36] The steps of inductive analysis were (1) familiarisation with the data, (2) coding, (3) generating initial sub-themes and themes, (4) developing and reviewing themes, and (5) refining, defining and naming the themes. In the subsequent deductive phase, the identified themes were mapped to the COM-B model.

During the inductive phase, AS engaged in data immersion by repeatedly reading the transcripts and coding all data line-by-line in MAXQDA[37]. Initial coding focused on inductively identifying the factors that participants perceived to positively or negatively influence the adoption of farm machine-related safety behaviours. They were then clustered together, based on semantic or conceptual similarity, to develop sub-themes and themes. These were subsequently deductively mapped onto the six sub-domains of COM-B.[17] JMS, OM, and AS discussed and refined the codes and themes over multiple meetings and then shared the data with DOH for additional refinement. This two-phase, inductive-deductive approach is gaining traction among qualitative studies focusing on behaviour change-based intervention development.[38–40] During the inductive phase, researchers explored farmers' perspectives without initially linking codes to the COM-B model. The data-driven inductive phase allowed the retaining of potential codes and themes that may not have a clear relation to the COM-B domains. The subsequent theory-driven analysis facilitated the interpretation of our data in the context of behaviour change theory.

The lead author (AS) maintained a reflexive journal to critically evaluate the researchers' influence on the study. This approach allowed us to navigate the complexities of the data and maintain a rigorous and transparent analysis. Participants were not involved in the analysis or in providing feedback on the accuracy of the transcription or findings.

Results

Characteristics of the participants, including demographics and farm types, are presented in Table 1.

Table 1: Characteristics of the participants in the four focus groups

Characteristics	Total
Age range	60-79
Gender:	
Female	1
Male	18
Farm Types:	
Beef	8
Diary	4
Sheep	5
Tillage	6
Mixed farms	4
Number of participants who owned at least one tractor	19
Number of participants who owned at least one quad bike	8
Number of participants who reported personal experience with farm-machine-related injuries	13

Five main themes were identified which related to barriers and enablers to the safe use of farm machinery: Perceived likelihood and cost-benefit analysis in safety decision-making; Characteristics of the farm and its environment; Availability and affordability of safety resources; Prevailing sociocultural opportunities; and Capability to manage competing responsibilities (Table 2). The following sections present an analysis of each theme, accompanied by illustrative quotes from the participants, categorised within the respective dimensions of the COM-B model (see Appendix C3 for the summary table of codes, sub-themes, and themes identified through reflexive thematic analysis).

Table 2: Themes, sub-themes and mapping to the COM-B subdomains

Themes	Sub-Themes	Motivation		Opportunity		Capability	
		Reflective	Automatic	Physical	Social	Physical	Psychological
1.Perceived likelihood and cost-benefit analysis in safety decision-making	1.1 Perceived cost and benefits	Y	Y				
	1.2 Perceived control and likelihood of risk in safety decision-making	Y					
	1.3 Non-compulsory nature of guidance	Y	Y				
2. Characteristics of the farm environment	2.1Characteristics of the farm environment			Y			
3.Availability and affordability of resources	3.1 Accessibility of services, resources and technology			Y			
	3.2 Financial limitations and opportunities			Y			
	3.3 Nature of the safety legislation and policies			Y			
4.Prevailing sociocultural opportunities	4.1 Role of familial support and partnerships				Y		
	4.2 Peer support and other social factors				Y		
5.Capability to manage competing responsibilities	5.1 Knowledge about safety procedures and support						Y
	5.2 Situational awareness and competing priorities					Y	Y

Motivation

One theme was identified that corresponds to the Motivation COM-B domain. This theme is 'perceived likelihood and cost-benefit analysis in safety decision-making,' which encompasses both reflective and automatic motivational factors. It examines how farmers' safety perceptions influence various aspects of motivation and how it evolves over time, impacting their safety decision-making processes. It encompasses both conscious and automatic thought processes, shedding light on the dynamic nature of farmers' safety attitudes and behaviours.

Theme 1 Perceived likelihood and cost-benefit analysis in safety decision-making

Findings suggest that farmers' motivation towards disengaging from risky behaviours and adopting safer practices is influenced by their perceptions of the risks. This theme describes how farmers make decisions about safety based on their perceived ability to perform a task and the expectations they have about the outcome. Additionally, confidence in their ability to handle tasks and prevent accidents plays a role in their safety decision-making. Farmers may engage in risky behaviours if they perceive that the potential benefits outweigh the risk outcomes.

1.1 Perceived control and the likelihood of risk in safety decision-making

Participants expressed a varying degree of confidence in their command over tasks and the prevention of accidents on their farms. Some reported that injuries are caused by carelessness and are thus preventable. A few others believed that accidents and injuries are inevitable on farms, therefore, nothing was to be done other than pushing forward and getting things done. Though participants had different views on their control over safety, the consensus was that if you are careful, you are likely to come out safe.

"I'm not as sharp as I used to be either. Yes, there's lots of challenges to older fellows not able to do [farm tasks]. I'm 74 myself but what can you do about that?"(P6_FFG2)

While a few participants expressed that they continue to engage in risky tasks due to the external factors as detailed in section 2.1, e.g. rugged terrain and weather conditions, others expressed that their decisions about whether or not to do a task by themselves or take recommended safety precautions often come down to the perceived risk inherently involved in that task and confidence in their ability to handle them. For example, many participants discontinued or never used quad bikes because they were perceived to be dangerous and difficult to control.

"No quad bikes. Because they are dangerous."(P8_FFG2)

While participants observed that tasks like slurry agitation and quad bikes are dangerous regardless of age, they agree that heavy machinery and vehicles with rapidly rotating Power Take Off (PTO) shafts and exposed moving parts, as well as heavy machinery in general, pose vulnerabilities that increase with age and declining cognitive abilities. They reported that in such cases of tasks that demand high skills, they either ensured that the machines were well-maintained or delegated the tasks to contractors[4] or young farmers. One participant shared that he is moving away from dairy farming to farming forestry as he gets older due to concerns about his safety in relation to operating machinery.

[4] Contractors refer to external workers or service providers hired by farmers for specific tasks or services, such as slurry operation, construction, or maintenance, in agricultural settings

"Especially, working machinery that's going with PTO, going very fast and lively. Maybe my reflexes aren't good enough or sharp enough for working that type of machinery now. It was okay 10 years ago, but I'm just coming to this stage of life I'm not just capable of doing that type of work. Nowadays, I get the contractor to do 90% of my work.."(P9_FFG2)

1.2 Perceived cost and benefits

Participants recognised that prioritising their physical and mental well-being was essential for reducing risks and ensuring safety on the farm. They acknowledged that taking shortcuts or engaging in risky behaviours for short-term benefits could lead to long-term costs, such as potential injuries, prolonged rehabilitation periods, and decreased productivity. Farmers emphasised that planning and organising tasks while prioritising their well-being played a crucial role in their safety decision-making.

Participants reported engaging in risky behaviours when they believed that the potential benefits outweighed the risk outcomes, especially when they faced time pressure or a rush. This cost-benefit analysis involved weighing potential benefits against the perceived risks. For instance, farmers mentioned taking shortcuts or making makeshift repairs on machinery without seeking professional assistance due to concerns about inconvenience or potential financial losses if they were to stop and ask for help.

"...getting somebody to repair a machine at the time you want is not very handy either. You learn as you go along working with these machines to rightly become a sort of a mechanic as well.." (SG_FFG4)

Of the interviewees, 68% reported farm accidents, with 23% additionally mentioning near misses. These experiences raised awareness of potential consequences, prompting changes in work habits. Adjustments included task delegation, heightened attention to work, and improved adherence to safety guidelines and personal protective equipment (PPE) usage.

"I got out [of the tractor] too fast, and I slipped on one of the steps. So I am much more careful now." (P3_FFG1)

The cost-benefit analysis also extended to deliberations about adhering to Irish safety legislation. During the discussions about adhering to codes of practice related to farm childhood and young person safety[41] that prohibit the carriage of children under seven years of age inside the cab of a tractor, some farmers believed that the benefits of early exposure of children to the farm environment, such as safety knowledge, outweighed the potential risks associated with having children inside the tractor's cabin.

"Children and tractors is a very good idea because I have grandchildren there and it is perfectly safe to have them there." (P19_FFG4)

Conversely, although time-consuming, some participants viewed safety risk assessment documents as valuable because of the perceived value gained from implementing them. These documents provided a systematic approach to identifying and mitigating risks, leading to potential cost savings in the long run by preventing accidents and damages that could have financial implications.

"*I am very familiar with the [safety risk assessment] statement. It's actually one of the most important things to have on a farm. If somebody comes in and a new person starts to work, you show them the safety statements. The observations I have made and my family have made*

to make them aware of any difficulties or dangers on the farm.. So, if you have somebody new working for you or working with you, always go to the book because the book gives you a good idea of what to expect rather than word of mouth..” (P12_FFG3)

Those who emphasised planning and organising tasks as critical safety strategies shared a common concern about the potential long-term consequences of accidents, motivating them to prioritise safety over short-term productivity gains. They acknowledged that injuries could lead to slow or ineffective rehabilitation and loss of working days, affecting their own well-being and the well-being of their family and employees.

“*…. it is getting scarcer all the time, and when you’re a Jack of all trades around the farm working on your own and nobody else within miles of you need to be more than careful because a simple slip can have awful consequences.” (P20_FFG4)*

1.3 Non-compulsory nature of guidance

Participants noted that as the farm owners, the onus of safety responsibilities and productivity lies with farmers. "Being your own boss" means no one else enforces the safety rules. With no oversight and no one else to delegate the tasks, they are often burdened with administrative work, prompting them to overlook safety standards to meet the targets.

"In the[non-farm] workplace, the boss is probably in the office and he has all of the instructions outside and if the worker doesn't adhere to them, he's probably sacked. On the farm, the farmer is the boss. He's a bit too lackadaisical."(P6_FFG2)

Participants observed that the advisory nature of the farm inspections and the fact that there are no penalties for non-compliance give little to no encouragement to farmers in implementing them.

"As well as that, he (farm inspector) didn't want to become authoritarian. He tried to talk through his job rather than laying down the rules. I looked really hard and I thought to myself, I don't have to worry about that guy too much."(P20_FFG4)

Participants suggested introducing strict regulations instead of general guidelines for safe practices, their adoption and adherence, and punitive outcomes for non-compliance. They emphasised that fear of penalty is the only way to persuade the farmers, whether it is the adoption of safety apparatuses or the regular maintenance of their tractors.

"It scares the living daylights out of any farmer when [they hear the] word inspections, be an inspection of livestock, an inspection of crops or whatever it may be. We don't want to see another inspector coming around the corner, but thinking about it, when lives and health is involved, that is coming .....People are going to wake up and they're going to realise that, yes, they would have to spend money to get machines into the proper fit way of working." (P20_FFG4)

Overall, although some suggested that safety is just a matter of common sense and expressed a sense of the inevitability of injury on farms, the majority recognised the importance of planning and prioritising well-being. They acknowledged that if they lack confidence in their ability to handle certain tasks and recover in old age, they seek help or avoid taking unnecessary risks. Participants suggested strict regulations and punitive outcomes for non-compliance to encourage adoption and adherence to safe practices.

In summary, this theme reflects the psychological underpinnings of farmers' decision-making processes regarding safety behaviours, highlighting how their beliefs and expectations about the outcomes of their actions influence their motivation to prioritise safety.

Opportunity

In exploring the opportunity domain (Table 2), it became evident that certain themes predominantly align with physical opportunities, while others highlight social opportunities. The first two themes identified are primarily associated with physical aspects of farm safety. These themes delve into tangible factors such as geographical conditions as well as the availability and affordability of resources. On the other hand, the third theme, "Nature of safety legislation and policies," revolves around social opportunities, emphasising the significance of safety regulations, institutional initiatives, and the need for effective communication and farmer-friendly policies.

Theme 2 Characteristics of the farm environment

Farmers observed that the characteristics of the farm and uncontrollable external factors like weather act as barriers to farm safety behaviours. Farmers extensively discussed the constant pressure they experience in managing their farm tasks, especially when they have a variety of responsibilities such as calving, harvesting and slurry management. They emphasised the challenges posed by time constraints and the need to coordinate tasks according to the needs of livestock (which may require tending early in the morning and late at night), resource availability, and weather conditions. The participants expressed the urgency to complete tasks within limited dry days, leading to a sense of rush and panic to get things done. This immense pressure to meet the demands of the farm and maintain productivity and how it often made it difficult for them to plan and organise their tasks, despite being motivated to do so, was repeatedly highlighted during the discussions.

"You usually only have two dry days in that week. Every farmer's looking for the contractor to come in, the rush is on, and the panic's on, and that's part of the problem, is the rush, the panic. We can't wait until the next day, it has to be done on the day."(P15_FFG4)

Owing to diverse agricultural practices, tasks vary according to the farm types and seasonal demands. While a few farmers referred to themselves as a jack of all trades, one of them likened farming to school days since every day is a learning day. Many tasks are seasonal; thus, they are infrequently practised, further reducing the scope to gain expertise.

"*As well as that too, if you were to count all the different jobs in farming at different times of the year. And the seasons go by, you change jobs on the farm and you forget from the previous year all the weak points."(P6_FFG1)*

While discussing how farm characteristics influence their safety decision, livestock farmers acknowledged the dependency on quad bikes despite acknowledging their perceived dangers, as they are needed to navigate rugged terrains and effectively manage livestock. Similarly, tillage farmers noted the necessity to spend long hours driving tractors due to the nature of their farming activity, which often resulted in fatigue and raised safety concerns.

"We're totally tillage farmers that we've been on a tractor for five or six hours. We get tired. That's when problems pop up"(P12_FFG3)

Overall, farmers' strong intentions to prioritise workplace safety can be overshadowed by external factors such as the demands of produce or livestock and unfavourable weather

conditions. As a result of rushing and fatigue, safety measures are overlooked, leading to risk-taking behaviours such as taking unwarranted shortcuts, performing makeshift repairs on machinery, and hurrying without adequate attention to their surroundings or well-being.

Theme 3 Availability and affordability of safety resources

Farmers described availability and affordability as the key determinants of the uptake of safety resources and services. Participants also detailed various aspects of safety initiatives that determine farmers' long-term adoption.

3.1 Accessibility of services, resources and technology

Farmers identified that help is crucial to reducing the risk of injury and maintaining a safe work environment, as additional support can reduce the dependency on the farm owner, share the responsibility and delegate riskier tasks. This help could be in the form of hired labour, family members, partners, or contractors. Farmers noted that contractors often have better machinery and skills. However, a shortage of skilled labour in the farming sector was reported as a significant cause of rush and barrier to decreasing workload and pressure on farmers, especially during the peak season.

"I suppose labor is scarce. And, like, at certain times of the year…there's a lot more work. You have to try and get around a lot of things, most definitely [this is] the reason that you have to rush at all"(P2_FFG1)

Despite agreeing that tractors help to reduce manual labour, a few participants observed that recent tractor models have become bigger in size, with higher horsepower, making it challenging to manoeuvre for older farmers. They also highlighted how the poor design of machines like tractors, trailers and loaders creates blind spots and increases accident susceptibility.

"One of the most frightening things is definitely one is loading with loader. Either loading grain or whatever, or putting up silage. Okay, and somebody suddenly walks behind you and you don't see them.? Oh, yeah. you can't see them."(P16_FFG4)

Participants also voiced their concerns about the quality of some of the safety devices. While discussing Personal Protective Equipment (PPE), they pointed out the severe drawbacks of available PPEs and safety devices and how risk gets exacerbated by poor design. They noted that safety goggles do not fit with their everyday eyeglasses and how quickly they fog up.

"Now, shafts, power take-off, the covers are very easily damaged. It's very difficult as well to keep them in order all the time."(P18_FFG4)

Likewise, quad helmets currently available in markets restrict their vision and are very heavy, thus leaving them in a very vulnerable position. Most participants were also apprehensive about the lack of safety measures, such as safety frames, on quad bikes.

"A proper helmet for a motorbike or a quad bike, you can see straight ahead…but if something happens to you off to your right or left, you are unaware of that until you are involved in it. That's really one of the things."(P17_FFG4)

Overall, the farmers observed that the farm machines and safety equipment need to be more farmer-friendly and of higher quality to reduce the risks and maintenance and increase adoption.

3.2 Financial limitations and opportunities

Most farmers expressed concern about the poor financial return and admitted that their financial conditions often influence the decision to purchase safer models of farm vehicles and invest in safety. Participants reported the substantial difference in income based on the farm types and the steadily rising cost of farm equipment and services as a major concern. They described how often the repair and machine parts cost deter them from seeking expert service. They end up with a makeshift solution which often makes these machines more hazardous:

"If we were getting paid for our produce properly, I think there'd be less farm accidents. More help and I guess the biggest root of the problem is we can't make money on our own land, just it is got that bad now"(P15_FFG4)

On a similar note, regardless of the knowledge about the benefits of skilled assistance like hired labour and contractors, cost made it difficult to hire them.

""If there was more money in the farm, I suppose, fellows would employ a fellow or something to help them. I know a lot of fellas who'll be working late into the night there."(P6_FFG2)

Participants identified that access to financial grants was a key determinant in upgrading to safer models and on-time maintenance.

"if a young fella takes over the farm, his grants there to buy different machines. Luckily, we use it ourselves."(P6_FFG2)

Sub-themes1.1 focused on farmers' subjective perceptions of cost and benefit related to risky tasks and safety measures, in which cost might not necessarily be financial in nature. In contrast, here, the discussion is focused on tangible financial constraints and opportunities that impact farm safety practices. Overall, farmers indicated that affordability is a major criterion in their decision-making process, and unaffordability poses a significant barrier to farmers' abilities to change their practices or environment.

3.3 Nature of the safety legislations and policies

Farmers responded positively to the potential of safety guidelines and policies targeted to increase safety awareness and the adoption of farm machine-related safety behaviours. Mandatory regulation was one of the most recommended accident prevention strategies. Though participants had confidence in the potential of institutional initiatives, such as national safety campaigns and financial schemes, they questioned the efficacy of existing initiatives.

While the current guidelines were described as 'very good', they questioned how guidelines were communicated. Often, these guidelines are distributed via booklets or documents, and participants observed that farmers are not generally keen on reading documents.

"you just drop it (leaflets). It's just kept in the drawers and forgotten about. It's not even read."(P12_FFG3)

A few participants emphasised the necessity of mandatory training to be incorporated into equipment purchases. Currently, participants describe how they often had to navigate the complexities and risks of the equipment through trial and error since farm equipment dealers

do not provide the necessary information[5]. Another suggestion from participants was to realign regulations, focusing on encouraging positive behaviour rather than solely penalising non-compliance.

"So, if you have someone that's doing an excellent job, you could use them as an example for other people, they could do their job better."(P11_FFG3)

Most participants expressed concerns about the administrative burden created by tasks such as tax filing, insurance guidelines, farm safety initiatives and regulations. They identified the paperwork involved as a significant source of stress and distraction. A few participants were sceptical about the additional paperwork accompanying these safety programs. Though farm advisors are available to assist them, being the sole worker and farm owner, the majority of the work needs to be done by the farmer himself.

"One thing that gets me is not working out on the farm and paperwork that's added to everything in the bureaucracy and with the amount of paperwork you have to do. You spend that much time that that now is nearly spent on the farm"(P5_FFG1)

Overall, the participants' experience indicated that even if they are in favour of safer practices, the opportunity to change is often hindered by the poor design of the equipment and financial constraints. This highlights the practical challenges they face in adhering to safety measures. Though they were in favour of organisational-level initiatives to increase the adoption of safety behaviours, farmers advocated for farmer-friendly initiatives with heavy penalties for non-adherence, revealing their preference for a balanced approach that addresses both positive reinforcement and consequences. The participants' suggestions regarding mandatory training and realigned safety legislation emphasise their perspectives on enhancing safety practices within the agricultural context.

Theme 4 Prevailing sociocultural opportunities

4.1 Role of familial support and partnerships

The study participants observed that long working hours and low income are barriers to attracting young people and family members to work on farms, leading to increased labour shortages and lone-worker farms, which in turn can impact machine safety due to limited oversight and assistance. They noted that while the isolated nature of farming protected the farmers from COVID-19 infection, the pandemic had exacerbated social isolation and inaccessibility.

"It's total isolation and I can tell you it is rough times now for farmers they're on their own now and you have to be more than aware now because something happens in the farm now there's no one there to help you."(P15_FFG4)

There was a consensus among participants on the positive influence of having family members and young farmers on the farm. They noted that knowing how often young farmers look up to older farmers and get influenced by their safety habits, they are much more cautious and take fewer chances when a young farmer is present. Moreover, the presence of

[5] Legal requirements outlined in the Safety, Health and Welfare at Work Act 2005[42] mandate manufacturers, importers, and suppliers of equipment to provide information on safe usage. This Act underscores the duty to ensure safety and health in the use of materials at work, encompassing proper installation, use, maintenance, and disposal.

family members helps farmers to share the workload, delegate risky jobs, and take breaks or vacations. Participants explained that they are much more cautious and take fewer chances in the presence of younger farmers to set the right example. In turn, their children help to ensure safety guidelines are followed and provide an opportunity to learn different outlooks and possibilities.

".. farm safety would always be our priority here on the farm and I always practice and the lads said to me that you can't brush it off.... I suppose, especially if we've young people round the place I think it is good to give them a good example anyway and it'd kind of-- I suppose from an early age, it kind of rubs off on them…"(P2_FFG1)

They also indicated that their familial succession plans directly influence safety investments. One participant admitted that he is reluctant to invest in safety or farm maintenance since he finds no value in investing in a farm that will close down in the next five years. A few participants noted that since they had no children to take over the farm, they decided to hand it over to other young farmers. They agreed that having a successor to take over the farm encouraged them to invest in safety.

"I handed it over to the young fellow, and I do a lot less work now on the farm. That was my answer to it. He has turned the farm around, believe it or not, and done a lot of jobs I'd never think to do because I was getting too old to do anything else."(P6_FFG2)

Participants identified making succession plans or having a partnership with young farmers as an effective strategy to reduce the responsibility of riskier tasks and work pressure.

4.2 Peer support and other social factors

Participants strongly agreed on the pivotal role of social interactions, such as discussions with peers, contractors, and safety advisors, in shaping farm safety awareness and practices. They endorsed discussion groups and interactions in casual settings as vital avenues for raising safety awareness and disseminating knowledge about potential hazards and safety measures through word of mouth. Furthermore, participants expressed enthusiasm for participating in these discussions, as they provided a platform for sharing personal experiences, insights, and strategies related to safety. Participants noted that learning from others' experiences with accidents and safety measures helped them enhance their understanding and adopt safer practices.

"At least encouraging discussion group meetings to maybe spend a little bit more time talking on safety. Share their ideas on how to do jobs maybe slightly different than we're in the habit of doing them. Maybe do them easier and more safely"(P11_FFG3)

They also observed that, beyond personal experience, learning from the accidents and fatalities experienced by other farmers played a major role in identifying potential safety hazards on their own farms. Peer interaction was perceived as a source of valuable insights, and anecdotes shared by neighbours and friends often informed participants about equipment lifespans and maintenance requirements.

"I have a good friend and he lost his hand, and a lot of tendons got his leg damaged..But he was a very strong man. And he was able to pull through it..the pain he went through. So those are things..I'd be very concerned about. PTO is a serious bit of equipment. And if you haven't covered it, and you lean in and you're a loser"(P9_FFG2)

Participants also noted how often they learned about the potential risks and safety measures from their interaction with contractors, and one even commented that he had spoken to his contractors about farm safety before attending the session. Some also mentioned that farm publications and media reports had an impact on their decision-making.

"A good friend of mine was working with slurry, thought he knew everything and he was rushing. This particular day he didn't apply the brake properly and it came back. Luckily, he escaped just about to get caught. It's so important to make sure you lock the handbrake up fully."(P2_FFG1)

Participants expressed high regard for their interactions with safety advisors, describing them as helpful in initiating safety discussions and a reliable source on various grants and safety programmes. They also emphasised how the inspection by a third party can help to identify the overlooked potential risks. Some cited specific incidents where they learned about the danger of equipment only after the advisor shared details of fatal incidents.

"The shear grab was left open which I didn't know until the last few years, you should close the shear grab down, …I realise since that it is only from TEAGASC coming here ... It's so important to close the shear grab every time... Don't ever the shear grab or its forks open, keep them close all the time, that man died over it"(P7_FFG2)

While participants repeatedly endorsed the farm visits, a few shared their experience with inexperienced advisors and how little insight they had gained from these visits. Some pointed out that though these initiatives address general farm safety, they often overlook machine safety.

"I had a health and safety inspector landed on the farm (after an accident)….The fellow goes into the pen and looked around him, and he says, you could do nothing..when this happened it was actually a freak accident. The young fella didn't tell us what you could do, so we just went (back) to the yard."(P15_FFG4)

In summary, as noted in theme 1, farmers' perception of the potential risk and consequence often dictate their decision to choose between shortcuts and safe options. The sub-themes associated with social opportunity provided insight into how their beliefs and perceptions evolved through interaction with various sources. However, it was also observed that the implementation of safety measures heavily depends on the farm environment and resources regardless of their awareness and intentions.

Capability

This section examines the physical and psychological factors that influence their capabilities to perform the tasks safely. We explore how managing competing responsibilities influences their safety approach, the importance of knowledge and support in safety procedures, and the impact of situational awareness and competing priorities on their decision-making. Additionally, we investigate how age-related changes affect their ability to perform tasks safely.

Theme 5 Capability to manage competing responsibilities

Farmers highlighted the importance of access to information and increased awareness in making informed decisions about their work and farm practices.

5.1 Knowledge about safety procedures and support

Although participants acknowledge the effectiveness of current guidelines, there is a notable concern regarding the limited understanding of certain aspects of maintenance and tool handling. These concerns encompass the risks associated with machinery, the proper management of weight on trailers, tool maintenance practices, and the safe operation of quad bikes. In these instances where comprehensive guidelines are lacking, participants raised concerns about prevailing erroneous practices that could lead to fatal consequences.

"I actually used to think years ago that to leaves them [shear grab] open..I mean when you have it open, the ram is buried in and it is stuck out in the open it doesn't get rot. It's only from TEAGASC advisor coming here..[I learned]..It's so important to close the shear grab every time"(P12_FFG2)

Many participants reported a gap in their skills when it comes to tasks they are responsible for on the farm and cited it as a major reason for farm fatalities. Participants described that with resource scarcity and financial constraints, it is normal for farmers to take up many jobs on the farm without proper training, thereby resorting to learning by practising and experimenting in the field. As noted in section 2.1, the heterogeneous and seasonal nature of the tasks also exacerbated the situation by reducing the scope of learning by practice and gaining expertise.

"All I do know is if you want to be a full-time farmer, you have to be a mechanic, you have to be a welder, you have to be a builder, you have to do everything. Do that yourself and know everything."(P20_FFG4)

5.2 Situational awareness and competing priorities

Participants observed inattentiveness to the immediate environment as a major cause of accidents. A few participants reflected that though they wish to remain alert to the environmental cues, excessive workload often keeps them in constant worry. They shared that their minds are often overloaded with concerns like paperwork, plans for the next days and family matters. This constant stress and anxiety often resulted in ignoring the tiredness and continuing their tasks, sometimes even resorting to makeshift solutions.

"I think that with most farmers, the physical work is only a part of it. Mental work is more so because when we are in the tractor operating machinery, always thinking on what has to be done tomorrow" ." (P12_FFG3)

Participants agreed that paying attention to the immediate environment and focusing on the task at hand helps them take better stock of their present situation and keep track of the machines and their co-workers. Hence, farmers repeatedly emphasised the need to pay attention to their physical and psychological status and their immediate environment.

""It doesn't matter a good routine, no matter what good equipment you have, if you're not .. you're not awake, and fully alert, the machine can't do the job for you. It's your responsibility or the driver's responsibility to make the right decision" ." (P11_FFG3)

Participants highlighted how age-related physical and cognitive health impairments impacted their ability to carry out tasks safely. They observed that regularly exercising and maintaining good health would make them less vulnerable and have a better chance of recovery in case of injuries.

"When I'm working the tractor now, I'm not as sharp as what I used to be for working the tractor. Especially, working machinery that's going with PTO, going very fast and lively….I'm just coming to this stage of life I'm not just capable of doing that type of work.."(P9_FFG2)

Overall, the farmers reported that managing a large volume of heterogeneous tasks and responsibilities under tight time constraints often encouraged them to rush and work long hours, leading to them spending long periods in an anxious, worried state. They observed that paying attention to their environment and prioritising their health helped counter the tendency to rush.

Discussion

The present study aimed to explore the capabilities, opportunities, and motivations required for older farmers to adopt safer work practices related to farm machine operation in Irish farm settings. The study utilised the COM-B framework[17], which provided a comprehensive model that acknowledges the multifaceted nature of farmers' decision-making processes. Five inductive themes that described both barriers and facilitators were identified and mapped onto COM-B constructs: Capability to manage competing responsibilities (Capability); Characteristics of the farm and its environment, Availability and affordability of resources, Prevailing sociocultural opportunities (Opportunity); Perceived likelihood and cost-benefit analysis in safety decision-making (Motivation). Thus, farmers' abilities (Capability), external factors and resources available to them (Opportunity), and their internal drives and incentives (Motivation) all play significant roles in shaping their behaviours related to machine safety. In addition, the interplay of capability, opportunity, and motivation gives rise to more complex patterns that support or impede machine safety. Considering these factors and their interaction enables a more holistic understanding of the challenges faced by Irish farmers and highlights potential strategies for safety intervention based on farmers' ideas for improvement.

Our findings align with and expand upon previous research in several ways. Traditional farm safety interventions have predominantly focused on the "Three Es" - Education, Engineering, and Enforcement - to prevent hazard exposure.[10] However, the current study reveals the limitations of these approaches in the context of Irish farming. One dominant theme across the focus groups was the lone-working nature of Irish farms, contrasting with the large-scale farming seen in countries like the United States and the organisational settings of other high-risk occupational sectors such as construction and mining.[10,44,45] These distinctive aspects create specific challenges and opportunities for self-employed farmers to adopt safer practices. In terms of capability, lone Irish farmers may have reduced physical and psychological abilities due to the absence of teamwork and the limited support available to undertake high risk procedures involving machines and manage demanding workloads. As a result, individual farmers are expected to take on a greater variability and heterogeneity of tasks due to task diversity, skill set, resource limitations, and decision-making autonomy.[46] Regarding opportunity, social opportunities for Irish farmers are heavily reliant on their families, peers, farm advisors and organisations, which can vary significantly depending on the availability and engagement of these systems. Moreover, the physical opportunities afforded by time and other resources are often limited for lone farmers.

Within the context of the COM-B domains, the current study reveals a complex interplay of capability, opportunity, and motivation in influencing farmers' decision-making processes regarding safety practices. Farmers who expressed motivation towards engaging in safer

machine safety behaviours also identified barriers in capability and opportunity that hindered their ability to act on that motivation. Many farmers exhibited positive reflective motivation, demonstrating risk perception and awareness of the long-term benefits of adopting safer machine safety practices. Physical opportunities and capabilities, however, posed significant challenges. As independent farm owners, farmers shoulder the responsibility of implementing safety measures, often leading to trade-offs between task completion and safety. Economic pressures and time constraints, as evident in the literature [12,47,48], result in rushed and makeshift solutions that compromise farmers' safety for minimal financial returns. Financial constraints, lack of trained workers, and weather conditions also emerged as barriers that hinder farmers' ability to choose safer routes, regardless of their motivation. Furthermore, due to these opportunity-related barriers, farmers are often forced to take up tasks that require expert knowledge, such as repair work, for which they may have limited or no capability. This interplay between motivation, opportunity, and capability is particularly notable among older farmers, who face limitations in physical and psychological ability. They feel compelled to continue farming regardless of their limitations due to financial factors. Their motivations stand in contrast to their Swedish counterparts, who choose to continue working beyond retirement age to avoid idleness.[49] Building upon previous research, our study provides further insight into how these interconnected factors shape farmers' decisions and contribute to the challenges they encounter when adopting safer practices.

The current study underscores the limitations of existing interventions in effectively addressing the factors influencing farmers' decision-making processes regarding safety practices. Participants raised concerns regarding the voluntary nature of safety guidelines and the lack of robust oversight and consequences for non-compliance, which significantly impact their automatic and reflective motivation to adopt and adhere to safety measures. Interestingly, some farmers proposed that stricter regulations, enhanced enforcement, and punitive measures could effectively reduce unsafe behaviour. Reflective motivation, involving the introduction of reliable aversive outcomes for unsafe behaviour, could potentially enhance the likelihood of safer practices.[50] However, this hinges on farmers having sufficient capability and opportunity to engage in these safer behaviours. Significant barriers, such as insufficient financial or social support, could render motivational interventions ineffective[51], potentially leading farmers to either disregard penalties or devise means to avoid them. Moreover, implementing effective oversight mechanisms would come at considerable expense and remains unlikely to gain widespread support.

Notably, the necessary legislation required for enforcement already exists in the Irish context. For instance, Irish legislation, such as the Safety, Health and Welfare at Work Act 2005[42], mandates manufacturers, importers, and equipment suppliers to provide information on safe usage. This Act emphasises the duty to ensure safety and health in the use of materials at work, encompassing proper installation, use, maintenance, and disposal. However, the insights provided by participants suggest a potential gap in compliance by sellers and farmers' lack of awareness about their rights. This underscores that the legal framework is in place, but the challenge lies in its effective implementation and enforcement.

Additionally, as shown in the literature,[5,22] farmers often exhibit an aversion to administrative work due to the additional paperwork it imposes on their demanding workload. This aversion further complicates the implementation of safety policies, schemes, and regulations, as it involves various paperwork and administrative tasks. Farmers face challenges in handling administrative tasks due to time constraints and the distraction caused by paperwork, which compromises their ability to focus on essential farm tasks.

Farmers may call for strict compliance because they recognise the importance of ensuring that their farms are operating responsibly and safely. An alternative interpretation is their desire to lessen their responsibility for unsafe behaviour on their farms. Irish farmers already bear significant responsibilities for developing and supporting safer practices, and this desire to evade responsibility conflicts with their desire for independence as self-employed individuals. Additionally, participants in our sessions may have a heightened awareness of safety, possibly not entirely representing the broader agricultural community. Further research is required to investigate farmers' preferences for stricter regulations, their acceptance within the farming community, and strategies to ensure effective implementation.

While considering engineering solutions, participants' preference for farmer-centric design underscores the need for solutions that fulfil functional requirements and align with the practical realities of farming operations. This echoes the importance of usability testing and involving end-users in the design and evaluation phases of safety interventions. Ensuring that safety equipment and machinery are effective and easily integrated into existing farm operations could potentially enhance their adoption rates.

The current study explored the perceptions of farmers regarding traditional educational methods, such as user manuals and safety newsletters, and found that participants reported these methods to be suboptimal in conveying crucial machine safety information. This indicates a potential mismatch between information delivery and farmers' capabilities in comprehending and utilising safety information, as well as limited physical opportunities regarding accessibility and usability of educational materials. This aligns with previous literature that highlighted the limited usage of manuals due to excessive information content and poor document layout.[49,52] Moreover, current educational programs often overlook the specific needs of farmers, such as the seasonal nature of farm tasks and the specialised knowledge and skills required. To enhance farmers' capabilities, interventions should provide tailored opportunities for learning that align with their preferences. Pairing desired information with essential safety knowledge can be motivational, as it caters to their specific interests and needs. It is also evident that regardless of the approach adopted for the intervention, they need to be tailored and farmer-centric to effectively address the barriers and facilitators relevant to the local context.

The intervention strategies that emerged from the focus groups align with the BCW framework and the existing literature[6,52–55], highlighting the role of social opportunities and reflective motivation in shaping farmers' decision-making processes. Therefore, participants' recommendations primarily focused on leveraging social opportunities to enhance farmers' capabilities and reflective motivation. During the focus group discussions, participants occasionally digressed from the primary topic to engage in conversations about subjects they deemed relevant, often seeking advice or information about succession plans, financial schemes and appropriate operational measures. Furthermore, participants' inquiries about the possibility of similar focus group discussions on other safety topics underscores the farmers' keen interest in discussion groups. Additionally, the presence of younger farmers or family members motivates older farmers to invest in safety, as they perceive a responsibility to model safe behaviour for the younger generation. Recognising the relevance of social opportunities in fostering a culture of safety and knowledge exchange, interventions should promote mentoring opportunities, community spaces, and discussion groups focused on various safety topics. While some studies reported farmers' neutral stance towards advisors' involvement [11,56], current participants perceived that the involvement of farm advisors is crucial in enhancing risk perception and implementing customised solutions. By utilising

persuasion and education through discussion sessions and community spaces involving advisors, interventions can tap into the power of social influence and enable farmers to improve their motivation and capability.

Additionally, in line with previous research[12,57,58], proactive planning and organisation were recognised as important factors in mitigating stress, managing task overload, building safer habits and avoiding rushed situations. Farmers emphasised the effectiveness of plans that focus on well-being in addressing the demanding workload faced by farmers. By enabling farmers to plan and organise their tasks effectively, interventions can enhance their capability and motivation, thus highlighting the importance of localised approaches that consider the unique contextual factors of the Irish farming community for effective farm safety interventions.

Strengths and Limitations

This study has several strengths that contribute to its overall relevance and contribution. One notable strength is the inclusion of older farmers, a demographic whose perspectives are often overlooked in previous research on farm safety practices. The inclusion of a diverse sample of participants from different farming backgrounds provided a broad range of experiences and perspectives, enhancing the richness of the data collected. Additionally, the study utilised an audio-based online discussion format, which offered participants a level of anonymity and potentially encouraged more open and honest responses. This allowed authors to capture the agreements or disagreements within different farm types.

In this study, the COM-B framework was employed to delve into the key components of farmers' behaviour: capability, opportunity, and motivation. This approach aligns with the broader Behaviour Change Wheel (BCW) framework, which offers a systematic and evidence-based method for identifying strategies and tailoring interventions to effectively promote behaviour change.[17] By understanding the drivers of behaviour change through COM-B, interventions can be designed to resonate with farmers' preferences and increase their motivation and capabilities to adopt safer practices.

However, it is important to acknowledge certain limitations of the study. Firstly, the focus on older Irish farmers may restrict the generalizability of the findings to other populations or geographic regions. The underrepresentation of women farmers in the sample is another limitation. They could have had unique insights and experiences related to farm safety, which were not fully explored in this study due to their limited participation.

The voluntary nature of participation in our study could introduce selection bias, as participants may be more safety-conscious than the wider farming population. This phenomenon is not uncommon in research related to safety initiatives, where voluntary participation tends to attract individuals with an existing interest in safety practices.[59] To mitigate this bias, future studies could explore strategies that engage a wider spectrum of farmers. Furthermore, self-reported data are subject to social desirability bias, potentially affecting the accuracy of the responses provided by participants.

Despite these limitations, the findings of this study align with previous research[11,12,49,52,56], increasing the credibility of the current findings. The insights gained from this study can inform the development of tailored interventions that address the specific needs and challenges faced by older farmers in promoting farm safety practices.

Conclusion

Our study, driven by the COM-B model, demonstrates the intricate dynamics of safety behaviours in Irish farming. It offers a deep behavioural diagnosis of the barriers and facilitators shaping farm machine safety practices in this specific context. The findings emphasise the need for a holistic approach that tailors interventions to farmers' perceptions, needs, and capabilities. This approach allows for the targeted intervention to address specific challenges, recognising that a one-size-fits-all strategy often misses the mark in complex contexts like farming. Overall, these insights enable the design of theoretically sound, tailored interventions with a higher likelihood of success, particularly among vulnerable groups like older farmers and subsequently empower farmers to make safer choices.

Data Availability Statement[6]

The dataset supporting the conclusions of this article is included within the article. Additional data supporting the project is available in the OSF repository (Aswathi, O'Hora and Mc Sharry, 2022).

Author contribution statement

Conceptualisation and formal analysis: A.S., J.M. (Jennifer McSharry) and D.O.; Methodology: A.S., D.O., J.M. (Jennifer McSharry), D.M., J.M. (John McNamara) and F.B.; writing—original draft preparation: A.S.; writing—review and editing: A.S., J.M. (Jennifer McSharry), O.M., D.O, D.M, and J.M. (John McNamara); Validation: D.O., J.M. (Jennifer McSharry), D.M., J.M. (John McNamara) and F.B.; Project Administration—D.O., D.M., J.M. (John McNamara) and F.B.; Funding acquisition: D.O.; Supervision: D.O., J.M. (Jennifer McSharry), D.M. and O.M.

Reference

1. Forastieri V. The ILO Programme on Safety and Health in Agriculture: The challenge for the new century–providing occupational safety and health services to workers in agriculture1. *Top on the agenda: Health and safety in agriculture*. 2000;1:1.

2. DeRoo LA, Rautiainen RH. A systematic review of farm safety interventions. *American journal of preventive medicine*. 2000;18(4):51-62. doi:10.1016/S0749-3797(00)00141-0

3. Gil Coury HJC, Kumar S, Jones E. Farm related injuries and fatalities in Alberta. *International Journal of Industrial Ergonomics*. 1999;23(5):539-547. doi:10.1016/S0169-8141(98)00021-3

4. Health, Authority S. *A Review of Work-Related Fatalities in Agriculture in Ireland 2011-2020*. Health and Safety Authority; 2021. https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/a_review_of_work-related_fatalities_in_agriculture_in_ireland_2011-2020.pdf.

5. Sorensen JA, Tinc PJ, Weil R, Droullard D. Symbolic interactionism: A framework for understanding risk-taking behaviours in farm communities. *Journal of agromedicine*. 2017;22(1):26-35. doi:10.1080/1059924X.2016.1248306

6. Biesheuvel MM, Santman-Berends IMGA, Barkema HW, et al. Understanding Farmers' Behaviour and Their Decision-Making Process in the Context of Cattle Diseases: A Review of

[6] In the appendix, we have included most of the supplementary files published along with the journal. However, a few supplementary files that are not included here can be accessed on our Open Science Framework (OSF) profile or on the respective publisher websites.

Theories and Approaches. *Frontiers in Veterinary Science*. 2021;8. doi:10.3389/fvets.2021.687699

7. Narasimhan GR, Peng Y, Crowe TG, Hagel L, Dosman J, Pickett W. Operational safety practices as determinants of machinery-related injury on Saskatchewan farms. *Accident Analysis & Prevention*. 2010;42(4):1226-1231. https://doi.org/10.1016/j.aap.2010.01.016.

8. Glasscock DJ, Rasmussen K, Carstensen O, Hansen ON. Psychosocial factors and safety behaviour as predictors of accidental work injuries in farming. *Work & Stress*. 2006;20(2):173-189.

9. Glasscock DJ, Hansen ON, Rasmussen K, Carstensen O, Lauritsen J. The West Jutland study of farm accidents: A model for prevention. *Safety Science*. 1997;25(1):105-112. doi:10.1016/S0925-7535(97)00009-X

10. Rautiainen RH, Lehtola MM, Day LM, et al. Interventions for preventing injuries in the agricultural industry. *Cochrane Database Syst Rev*. 2008;(1):CD006398. doi:10.1002/14651858.CD006398.pub2

11. Colémont A, Van den Broucke S. Measuring determinants of occupational health related behaviour in Flemish farmers: an application of the theory of planned behaviour. *Journal of safety research*. 2008;39(1):55-64.

12. Murphy M, O'Connell K. Farm Deaths and Injuries: Changing Irish Farmer Attitudes and Behaviour on Farm Safety. 2017.

13. Regan Á, Douglas J, Maher J, O'Dwyer T. Exploring farmers' decisions to engage in grass measurement on dairy farms in Ireland. *The Journal of Agricultural Education and Extension*. 2021;27(3):355-380. doi:10.1080/1389224X.2020.1858892

14. Franklin RC, McBain-Rigg KE, King JC, Lower T. Exploring the barriers and facilitators to adoption of improved work practices for safety in the primary industries. *Barton ACT: Australian Government, RIRDC*. 2015.

15. Irwin A, Mihulkova J, Berkeley S. 'No-one else wears one:'Exploring farmer attitudes towards All-Terrain Vehicle helmets using the COM-B model. *Journal of safety research*. 2022;81:123-133. https://doi.org/10.1016/j.jsr.2022.02.004.

16. Surendran A, O'Hora D, McSharry J, Di Domenico R. *A Systematic Review of Interventions for Reducing Machine-Related Accidents in Farms.* https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=173834. Accessed February 6, 2023.

17. Michie S, Atkins L, West R. *The Behaviour Change Wheel: A Guide to Designing Interventions*. Silverback Publishing; 2014. https://silverbackpublishing.org/products/behaviour-change-wheel.

18. Sharpe T, Alsahlanee A, Ward KD, Doyle F. Systematic review of clinician-reported barriers to provision of smoking cessation interventions in hospital inpatient settings. *Journal of Smoking Cessation*. 2018;13(4):233-243.

19. Skivington K, Matthews L, Simpson SA, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ*. 2021;374. doi:10.1136/bmj.n2061

20. *Demographic Profile of Farm Holders - CSO - Central Statistics Office*. CSO https://www.cso.ie/en/releasesandpublications/ep/p-coa/censusofagriculture2020-preliminaryresults/demographicprofileoffarmholders/. Accessed October 29, 2022.

21. Ireland - Agricultural Sector. https://www.trade.gov/country-commercial-guides/ireland-agricultural-sector. Accessed September 27, 2022.

22. Agriculture in Ireland - Teagasc | Agriculture and Food Development Authority. https://www.teagasc.ie/rural-economy/rural-economy/agri-food-business/agriculture-in-ireland/. Accessed September 27, 2022.

23. Russell H. Trends and Patterns in Occupational Health and Safety in Ireland. :126.

24. Meredith D, Mohammadrezaei M, McNamara J, O'Hora D. Towards a Better Understanding of Farm Fatalities: Identification and Estimation of Farming Fatality Rates. *Journal of Agromedicine*. August 2022. doi:10.1080/1059924X.2022.2113196

25. Ramos AK, Girdžiūtė L, Starič J, Rautianinen RH. Identifying "Vulnerable Agricultural Populations" at Risk for Occupational Injuries and Illnesses: A European Perspective. *Journal of Agromedicine*. 2021;26(3):340-345. doi:10.1080/1059924X.2020.1771498

26. McNamara J, Kinsella A, Osborne A, Blake C, Meredith D, Kinsella J. Identifying farmer workplace injury risk factors in Ireland using farm accounts data. *Journal of agromedicine*. 2021;26(4):411-419.

27. Nilsson K. Interventions to reduce injuries among older workers in agriculture: a review of evaluated intervention projects. *Work*. 2016;55(2):471-480. doi:10.3233/WOR-162407

28. Whitman SD, Field WE. Assessing senior farmers' perceptions of tractor and machinery-related hazards. *Journal of agricultural safety and health*. 1995;1(3):199-214.

29. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International journal for quality in health care*. 2007;19(6):349-357.

30. Surendran A, Mc Sharry J, Di Domenico R, Meredith D, O'Hora D. *Enhancing Machine-Related Safety on Farms: A Systematic Review*. Open Science Framework; 2023. doi:10.31219/osf.io/rp9cj

31. Skype Support for All products | Skype Support. https://support.skype.com/en/skype/all/. Accessed October 30, 2022.

32. Etikan I, Musa SA, Alkassim RS. Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*. 2016;5(1):1-4. doi:10.11648/j.ajtas.20160501.11

33. Mays N. Qualitative research in health care: Assessing quality in qualitative research. *BMJ*. 2000;320(7226):50-52. doi:10.1136/bmj.320.7226.50

34. Mc Sharry J, Butler K, Bartlett YK, et al. Implementing a text message-based intervention to support type 2 diabetes medication adherence in primary care: A qualitative study with general practice staff. 2022.

35. Braun V, Clarke V. Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*. 2019;11(4):589-597. doi:10.1080/2159676X.2019.1628806

36. Clarke V, Braun V, Hayfield N. *Thematic Analysis*. Vol 222.; 2015. https://uk.sagepub.com/en-gb/eur/thematic-analysis/book248481.

37. Verbi S. MAXQDA. 2019. https://www.maxqda.com/new-maxqda-2020.

38. Ojo SO, Bailey DP, Hewson DJ, Chater AM. Perceived barriers and facilitators to breaking up sitting time among desk-based office workers: a qualitative investigation using the TDF and COM-B. *International journal of environmental research and public health*. 2019;16(16):2903.

39. Madhani A, Finlay KA. Using the COM-B model to characterise the barriers and facilitators of pre-exposure prophylaxis (PrEP) uptake in men who have sex with men. *British Journal of Health Psychology*. 2022;27(4):1330-1353. doi:10.1111/bjhp.12605

40. Courtenay M, Rowbotham S, Lim R, Peters S, Yates K, Chater A. Examining influences on antibiotic prescribing by nurse and pharmacist prescribers: a qualitative study using the theoretical domains framework and COM-B. *BMJ open*. 2019;9(6):e029177.

41. McNamara J, Mohammadrezaei M, Griffin P. Promoting childhood farm safety in Ireland. *Frontiers in public health*. 2022;10:1055082.

42. Shannon G. The Safety, Health and Welfare at Work Act 2005 Update. *Q Rev Tort L*. 2005;1:23.

43. McNamara J. Farm safety code of practice:

44. Europäische Kommission, ed. *The Magnitude Spectrum of Farm Injuries in the European Union Countries*. Luxembourg: European Communities; 2004.

45. Vogeler I. *The Myth of the Family Farm: Agribusiness Dominance of US Agriculture*. CRC Press; 2019.

46. Stave C, Törner M, Eklöf M. An intervention method for occupational safety in farming—evaluation of the effect and process. *Applied ergonomics*. 2007;38(3):357-368.

47. Hammersley C, Richardson N, Meredith D, Carroll P, McNamara J. "That's Me I am the Farmer of the Land": Exploring Identities, Masculinities, and Health Among Male Farmers' in Ireland. *American Journal of Men's Health*. 2021;15(4):15579883211035241.

48. Furey EM, O'Hora D, McNamara J, Kinsella S, Noone C. The Roles of Financial Threat, Social Support, Work Stress, and Mental Distress in Dairy Farmers' Expectations of Injury. *Front Public Health*. 2016;4. doi:10.3389/fpubh.2016.00126

49. Caffaro F, Lundqvist P, Micheletti Cremasco M, Nilsson K, Pinzke S, Cavallo E. Machinery-related perceived risks and safety attitudes in senior Swedish farmers. *Journal of agromedicine*. 2018;23(1):78-91.

50. West R, Gould A. Improving health and well-being: A guide to using behavioural science in policy and practice. *Public Health Wales*. 2022.

51. Sorensen JA, Jenkins PL, Emmelin M, et al. The Social Marketing of Safety Behaviours: A Quasi--Randomized Controlled Trial of Tractor Retrofitting Incentives. *American Journal of Public Health*. 2011;101(4):678-684. doi:10.2105/AJPH.2010.200162

52. Coman MA, Marcu A, Chereches RM, Leppälä J, Van den Broucke S. Educational interventions to improve safety and health literacy among agricultural workers: a systematic review. *International journal of environmental research and public health*. 2020;17(3):1114.

53. Mullen J. Investigating factors that influence individual safety behaviour at work. *Journal of safety research*. 2004;35(3):275-285.

54. Murphy M, O'Connell K. The Use of Mentoring To Effect Cultural Change: Irish Farm Deaths And Injuries. 2018. https://sword.cit.ie/cgi/viewcontent.cgi?article=1002&context=dptmecp.

55. Conway SF, Farrell M, McDonagh J, Kinsella A. 'Farmers Don't Retire': Re-Evaluating How We Engage with and Understand the 'Older'Farmer's Perspective. *Sustainability*. 2022;14(5):2533.

56. Mohammadrezaei M, Meredith D, McNamara J. Subjective norms influence advisors' reluctance to discuss farm health and safety. *The Journal of Agricultural Education and Extension*. 2022:1-25.

57. Kaustell KO, Mattila TEA, Rautiainen RH. Barriers and enabling factors for safety improvements on farms in Finland. *Journal of Agricultural Safety and Health*. 2011;17(4):327-342.

58. McNamara J, Reidy K. Survey of Safety and Health on Irish Farms. *Dublin, Ire: Teagasc*. 1997;61.

59. O. Nyumba T, Wilson K, Derrick CJ, Mukherjee N. The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and evolution*. 2018;9(1):20-32.

60. O'Reilly A, Meredith D, Foley R, McCarthy J. Continuity, change and new ways of being: An exploratory assessment of farmer's experiences and responses to public health restrictions during the COVID-19 pandemic in a rural Irish community. *Sociologia Ruralis*. 2023;63(S1):95-115. doi:10.1111/soru.12424

Chapter 5 Increasing Machine-Related Safety on Farms: Development of an Intervention Using the Behaviour Change Wheel Approach[7]

Authors: Aswathi Surendran [1], Jennifer McSharry [1], Oonagh Meade [1], Francis Bligh [2], John McNamara* [2], David Meredith [2], and Denis O'Hora [1]

[1]School of Psychology, University of Galway, H91 TK33 , Galway, Ireland;
[2]Irish Agriculture and Food Development Authority, R93 XE12, Carlow, Ireland;

*Correspondence: john.g.mcnamara@teagasc.ie

Abstract

Farming is essential work, but it suffers from very high injury and fatality rates. Machinery, including tractors, are a leading cause of serious injuries and fatalities to farmers and farm workers in many countries. Herein, we document the systematic development of an evidence-based, theory-informed behaviour change intervention to increase machine-related safety on farms. Intervention development progressed through four phases. Phase 1 defined the problem in behavioural terms based on a review of the literature, Phase 2 identified candidate intervention targets through a series of focus groups guided by the Capability–Opportunity–Motivation–Behaviour (COM-B) model and Phase 3 employed expert and stakeholder consultation guided by the Behaviour Change Wheel (BCW) to consider potential target behaviours and intervention components and finalise the intervention content. Phase 4 finalised the evaluation strategies with a team of agricultural advisors who supported the rollout and identified outcome measures for the first trial. The target intervention was the identification of blind spots of farm tractors, and three priority target behaviours (farm safety practices) were identified. Following Phase 3, the intervention comprised four components that are delivered in a group-based, face-to-face session with farmers. In Phase 4, the acceptability, feasibility, and fidelity of these components were identified as the outcome measures for the first trial of the intervention. The four-phase systematic method detailed here constitutes an initial template for developing theory-based, stakeholder-driven, behaviour-change-based interventions targeting farmers and reporting such developments.

Keywords: behaviour change intervention; farm safety intervention; tractors; peer-to-peer mentoring; COM-B; BCT; occupational safety and health; blind spots

[7] Surendran, A., McSharry, J., Meade, O., Bligh, F., McNamara, J., Meredith, D., & O'Hora, D. (2023). Increasing machine-related safety on farms: development of an intervention using the Behaviour Change Wheel approach. International Journal of Environmental Research and Public Health, 20(7), 5394.

Introduction

Despite the global effort to improve farm safety, injury and fatality rates remain high in the agricultural sector [1–4]. Farmers comprise only six percent of the Irish working population; however, the agriculture sector reports approximately half of the occupation-related fatalities [5,6]. The Irish Agriculture and Food Development Authority (Teagasc) National Farm Survey reported a 31% increase in farm incidents in the last decade in Ireland [7]. Furthermore, Mohammadrezaei et al. [8] observed that farm injury is more likely to lead to severe injuries and fatalities than other work-related injuries. More than half of the reported injuries occur from farm machines, vehicles and livestock. Tractors are linked to 55% of all vehicle work-related fatalities and 25% of reported injuries [9]. Given the global concern about persisting high fatality rates on farms, improving the safety of farms is a key health and safety policy issue. Policy-makers and researchers have therefore emphasised the importance of developing effective and affordable interventions to improve the safety behaviours of farmers [10–12].

The Medical Research Council (MRC) guidance for developing and evaluating complex interventions advocates for a systematic approach involving the best available evidence and appropriate theories [13]. Despite the growing evidence on the significant role of behavioural science in developing comprehensive injury prevention strategies, farm safety research has lagged behind other industries in the use and reporting of behavioural strategies [6,12]. Historically, farm research has relied on introducing technological and regulatory interventions and educational interventions focusing on informing farmers of the risks on farms [14–16]. However, the normalisation of the danger and persisting risky farm practices indicate a risk awareness to risk prevention behaviour gap [17–19]. The gap suggests that focusing on improving awareness alone cannot mitigate the potential risks on farms. Studies suggest that farmers' behaviour is a product of the interaction between cognitive factors, such as perceived efficacy and beliefs, and environmental and technological factors, such as the size of the farm and the type of machinery available [6,20]. Hence, recent reviews of the farm safety interventions call for research focusing on understanding the factors that influence farmers' safety behaviours and developing interventions targeting these factors [12,14,15].

A recent systematic review by the authors indicated that there are growing numbers of studies utilising behaviour change theories such as the Theory of Planned Behaviour [21] and the Health Belief Model [22] to understand the factors influencing farmers' behaviours [23,24]. However, safety literature indicates that intervention studies often fail to report the use and role of underlying behavioural theories in intervention development. They often provide little information on the intervention developments, its components and delivery, and even less on how the individual components influenced the target behaviour(s) [12,14,25]. The lack of empirical evidence on the active ingredients of these interventions and lack of focus on specific target behaviours (farm practices) make it difficult to draw a conclusion on what part of the intervention worked and how it worked [26–28]. This lack of clarity also reduces the potential for the interventions to be replicated or adopted.

Recent advancements in behavioural science have resulted in tools and techniques to develop interventions in a more systematic, evidence-based, theoretically informed way [29]. The objective of the current study is to use the systematic Behaviour Change Wheel (BCW) intervention development approach to use existing evidence, and farmer and other

stakeholder perspectives to develop an evidence-based, theoretically informed intervention to increase machine-related safety on farms.

Intervention Development Process

This study is part of a larger, multi-phase BeSafe project aimed at addressing the limitations of previous safety interventions targeting machine safety on farms. The study aimed to address gaps in the literature by developing an intervention using a systematic approach informed by the most relevant evidence, appropriate theories and stakeholder engagement.

Previous studies exploring farmers' safety behaviour employed behaviour models such as the Theory of Planned Behaviour (TPB), Capability, Opportunity, Motivation–Behaviour (COM-B) model and Health Belief Models to explain how farmers' intentions, beliefs and attitudes are developed and evolve through the interactions between internal and external factors [23,30–32]. One framework that has gained popularity in health research for intervention development is the Behaviour Change Wheel (BCW) [33]. The BCW framework was developed by synthesising 19 existing behaviour change frameworks and provides a systematic, comprehensive approach for diagnosing who (target population) needs to perform what (target behaviour) and which behaviour determinants (barriers and facilitators) need to be targeted by what type of intervention content [34]. Evidence from the health research indicates that BCW can provide guidance on mapping farmer-centric determinants into the existing behaviour change constructs and subsequently providing recommendations for the behaviour change components relevant to specific constructs and operationalising the intervention contents [27,34–36].

As illustrated in Appendix A1, at the hub of the wheel is the COM-B model, which describes behaviour as a function of capability (physical/psychological), opportunity (social/physical), and motivation (reflective/automatic). According to the BCW, the intervention must target one or more of these components to promote the desired behaviour. The next layer of the BCW outlines nine intervention functions that describe a broad category of interventions (education, persuasion, incentivisation, coercion, training, enablement, modelling, environmental restructuring and restrictions) [34]. These are then mapped to behaviour change techniques (BCTs), the observable, irreducible, replicable "active ingredients" of interventions. The BCT Taxonomy v1 [37] is a structured list of 93 BCTs with definitions. Once the BCTs are identified, the next step is operationalising the BCTs and identifying potential ways to put the selected BCTs into practice [33,37]. BCTs can be combined to form intervention components. The final intervention package may comprise different intervention components and act upon one or more mechanisms of behaviour mediators [29,34,35,38].

This paper outlines the systematic process used to develop the BeSafe intervention and constitutes a template for developing similar interventions and reporting development decisions. This paper describes a) the intervention development process b) the relevant output of phase 1–3 and how it was methodically mapped to the BCW framework, and 3) the content of the resulting intervention. It will not discuss in detail the evaluation strategies and outcomes of the evaluations as they are outside the scope of the current paper and will be published separately in detail.

Reporting of the intervention is in accordance with the TIDieR (Template for intervention description and replication) guidelines [39] and is available in Appendix C5. The authors also considered the best practice guidelines [40] on reporting intervention development.

Therefore, the rationale for the inclusion of behaviour change theory, the inclusion of existing evidence, the contribution of stakeholders, the modification of intervention components, etc., are included.

Method

The BeSafe project is a research programme funded by the Department of Agriculture, Ireland, and supported by the Health and Safety Authority (HSA) and Teagasc (the Irish state agency providing research, advisory and education in agriculture) to develop safety interventions to bring long-term changes to machine-related safety on farms. The current study commenced in October 2019. The research team consisted of a doctoral student (AS), two behavioural researchers (DOH. and JMS) and a Teagasc advisory team (FB, JMN and DM). The development of the BeSafe intervention involved four key phases, as illustrated in Table 1.

Table 1: Intervention Development Phases

Phase	Tasks	Outputs	BCW Steps
PHASE 1: Describe the problem in behavioural terms	Identify the evidence-practice gap Examine the Irish farm surveys and fatality reports to gain an understanding of the local context Identify the farm groups whose behaviour needs to change Identify the areas of machine safety that need to be addressed Review the available evidence on farm machine safety Identify the BCTs present in the available safety interventions	Identified older farmers (65+) as the potential target population Identified tractors and quad bikes as the major contributors to the fatalities Identified the most commonly used BCTs and their operationalisation	Step 1—Define the problem in behavioural terms Step 5—Identify the intervention functions Step 7—Identify BCTs
PHASE 2: Identify what needs to be changed and which barriers and enablers need to be addressed?	Use qualitative methods underpinned by the COM-B model, to identify the possible target behaviours (safe farm practices) Use qualitative methods underpinned by the COM-B model to identify barriers and enablers that likely influence the target behaviours.	Identified the farmers' recommended list of target behaviours Identified the farmers' recommended list of barriers and enablers to specific farm practices or general machine safety	Step 2—Select the target behaviour Step 4—Identify what needs to change Step 5—Identify the intervention functions Step 7—Identify BCTs
PHASE 3: Identification of potential target behaviours and intervention components 3.1 Co-design workshops 3.2 Feasibility screening with Teagasc advisory team	Identify the top two potential categories of target behaviours associated with machine-related incidents in Irish farms. Identify a list of specific target behaviours under the aforementioned categories that can be influenced by behaviour change-based interventions. Identify barriers and enablers that are likely to influence these specific target behaviours. Identify potential behaviour change techniques and their delivery mode to overcome the barriers and enhance the enablers.	Created a survey with potential categories of target behaviours Identified the top two categories Developed a list of specific target behaviours that can be targeted Developed a list of potential barriers and facilitators related to potential target behaviours Developed a list of potential ways of operationalisation and delivery method	Step 3—Specify the target behaviours Step 4—Identify what needs to change Step 5—Identify the intervention functions Step 7—Identify BCTs Step 8—Identify mode of delivery

		Finalised the specific target behaviours for the intervention
	Identify the available evidence from the previous tasks to inform the selection of potential target behaviours, behaviour change techniques and modes of delivery.	Finalised the BCTs, its operationalisation and delivery method into intervention components
	Identify what is likely to be feasible, locally relevant, and acceptable and combine identified components into an acceptable intervention that can be delivered.	Developed the draft of the BeSafe machine safety intervention by combining the intervention components
		Developed and refines the materials for the intervention.
PHASE 4: How can behaviour change be measured and understood? 4.1 Validating and refining evaluation strategy with stakeholders	Select appropriate outcome measures	Identified the outcomes to be measured
	Determine the feasibility of outcomes to be measured	Identified the tools and methods to measure the selected outcomes

Intervention development was an iterative process guided by the intervention development guidelines provided by the BCW framework [34], including the findings from the farm safety literature, stakeholder recommendations and expert opinions. As illustrated in Appendix C2, the intervention development process has been broadly categorised into three stages over eight steps [33]. As illustrated in Table 1, the current study had four phases, including the evaluation strategy development. Phase 1 described the problem in behavioural terms through a review of the evidence, Phase 2 identified what needs to be changed through a series of focus groups, Phase 3 explored the potential target behaviours and intervention components through expert and stakeholder consultation and finalised the intervention content, and Phase 4 finalised the evaluation strategies with the Teagasc advisory team.

Ethical approval was obtained from the Research Ethics committee (REC) of the National University of Ireland, Galway (NUIG), before the commencement of focus groups (#2020.10.022) and co-design workshops (#2021.01.013). Written/verbal consent was obtained from all the participants involved in the study.

The current paper was built on the evidence generated from the first three phases and described how the findings from these phases were methodically mapped onto the BCW framework and BCTTv1 to create lists of potential target behaviours and intervention components to address them. In this paper, the authors will explain how a behavioural change-based intervention to adopt preventive safety behaviours to address tractor-related blind spots at farms and improve farm safety was developed.

Phase 1: Describe the Problem in Behavioural Terms

The first phase involved identifying and analysing the existing relevant evidence base, and examining the injury and fatality reports [41] to understand farm safety in the context of Irish farms. A systematic review of the interventions targeting machine-related injuries safety on farms had four objectives:

What interventions have been employed to reduce machine-related incidents, injuries and fatalities among farmers?

How effective are interventions designed to improve machine-related safety on farms?

What BCTs and intervention functions comprise these interventions?

What are the gaps in the current interventions?

A systematic review protocol was developed per the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) guidelines and registered (Registration number: CRD42020173834) on PROSPERO, the International Prospective Register of Systematic Reviews [42].

In the review, as the first step, the general intervention categories were identified, such as safety education, financial assistance, regulations, etc. On further analysis, the behaviour change components targeting machine safety present in these interventions were identified and coded. Following the mapping of the components, the BCT used to implement these intervention functions was coded using the BCT taxonomy V1 [43]. A narrative synthesis of the evidence was conducted due to the heterogeneity of the included studies.

Reports of farm injuries and practices from HSA were examined to identify the potential broad categories of target population and behaviours for the intervention [41]. Reviewing the ground report along with the safety literature assisted the authors in identifying the existing conditions, tendencies and gaps within the safety intervention literature. A detailed description of the findings from the systematic review will be published separately.

Phase 2: Identify What Needs to Be Changed and Which Barriers and Enablers Need to Be Addressed?

In the next phase, between January and February 2021, we conducted a qualitative study involving four semi-structured focus groups with Irish farmers above 60 years of age. Purposive sampling [44] was adopted to ensure that farmers from all four farm types (dairy, beef, sheep and tillage) were represented. A topic guide informed by the COM-B model [34] and review findings was used flexibly to identify the target population and guide the focus groups to explore barriers to and facilitators to adopting safe practices linked to tractors and quad bikes. The study explored capability-related barriers, such as a lack of knowledge and ability to manage the demands of farm work; opportunity-related barriers, such as access to resources and market conditions; and motivation-related barriers, such as beliefs about the benefits of taking risks and perceived self-efficacy. The objectives of the focus group discussions were to:

- Explore participants' experiences of tractor and quad bike safety.

- Identify the potential barriers and facilitators to safety behaviours.

- Identify potential active components to address these behaviours.

A series of four focus group discussions conducted online via Skype [45,46] by the primary author had a total of 19 participants aged above 60, representing the four major farm systems of Ireland. Data were analysed inductively using thematic analysis [47] with MAXQDA 2020 software [48]. Inductively generated themes were then mapped to the COM-B domains [34]. A detailed description of the findings from the study will be published separately.

Phase 3: Identification of Potential Target Behaviours and Intervention Components

Before the commencement of this phase, the research team met to review Phase 1 and 2 findings and summarise the relevant findings. Subsequently, the potential target behaviours identified by the farmers were analysed and grouped into nine categories. The categorisation was guided by the findings from the review, survey reports [41] and safe work practice guidelines [5]. Categories and their breakdown are detailed in Appendix C1.

The current phase involves two steps: 1. Two co-design workshops with safety experts and stakeholders and 2. Feasibility screening with Teagasc advisory team

Phase 3.1 Co-Design Workshop

The current phase involved two stages involving one co-design workshop each, facilitated by AS, DOH and JMS. The session was conducted and recorded via the video conferencing tool, Zoom [49], with five to six participants per session. The objectives of these workshops were:

Identify potential target behaviours for the intervention.

Identify barriers and enablers that are likely to influence these target behaviours.

Identify the potential intervention components and delivery methods.

As a first step, international farm safety experts with expertise in farm safety and farmer behaviours and stakeholders such as safety inspectors, farm representatives, tractor dealers and other farm organisation representatives were invited to participate in the workshops. They were assigned to one of the two sessions based on their expertise and availability.

Identification of target behaviours

The research team created a web-based rank order survey using the Gorilla survey builder [50]. The survey included the nine categories of potential target behaviours as the survey items. The influence of these behaviours on fatal farm incidents among farmers aged over 60 from 2004 to 2018 and the examples of fatal incidents involving these behaviours were provided in the survey for reference (Appendix C1). A week before the co-design workshop, the research team shared the summary of findings from the previous phases with the participants of both workshops via email. They were also invited to identify the top categories of target behaviours to be considered for the workshop. Hence, a link to the survey was shared with them, and they were asked to place the items mentioned in rank order of relative importance. To determine the importance of each category, they were asked to consider the expected impact on the safety of farmers over 60 years old using farm tractors and machinery and whether these behaviours can be addressed effectively through behavioural intervention. The online workshop session began by sharing the findings from the web survey. The participants were informed that the top two categories would be considered for the current discussion, and they were encouraged to explore the specific safety behaviours under the top two categories that can be considered for a behaviour-based intervention. As the discussion progressed, the focus shifted to identifying the relevant

barriers and facilitators to be considered. They were encouraged to prioritise the barriers and facilitators that met the following criteria:

Relevance to older Irish farmers.

Effectively addressable through behavioural interventions.

Feasibility to address them within the project constraints such as funding and available time.

Significant influence on risky farm practices.

Influence more than one risky farm practice.

For example, extensive paperwork as a barrier was given low priority since that is more relevant to policy-based or organisational-level intervention than behaviour-based intervention. Likewise, whenever a participant suggested a barrier or facilitator, facilitators encouraged them to discuss its impact on the older farmers, how it impacts them and whether it influences more than one safety behaviour. For example, farmers indicated that having a succession plan not only reduces the workload but also motivates investment in safety. However, regardless of meeting the criteria, all the barriers and facilitators identified by the workshop will be made available separately for future reference.

Identification of potential intervention strategies and delivery methods.

After the first workshop, the research team met to analyse and summarise the relevant findings. The second workshop had a different set of participants but with similar expertise and knowledge. The key evidence from previous phases, along with the recommendations formulated based on the BCW framework, was presented to the workshop participants. Participants were then asked to narrow down the potential barriers and facilitators to be addressed by the intervention and identify the potential intervention strategies and delivery methods to address them.

Phase 3.2: Feasibility Screening with Teagasc Advisory Team

The objectives of the screening were to finalise the selection of target behaviours, behaviour change techniques and modes of delivery.

Once the key recommendations from the previous phases were consolidated (potential list of target behaviours, intervention strategies and delivery methods) and mapped to the BCW framework, the research team added their ideas to the list of potential modes of delivery for each BCT.

From the selected target behaviours, specific target behaviours were selected and finalised for the intervention based on the following criteria:

Availability of evidence on the influence of the target behaviour on fatal incidents.

Potentially modifiable at the farmer level.

Farmers' ability to carry out regardless of their age.

Part of the recommended safer practices guidelines for operating the tractor safely.

Relevant to every tractor-operating farmer regardless of age and farm type.

Once the target behaviours were finalised (see Appendix C2), the focus shifted to identifying the active ingredients and their delivery strategies from the consolidated list. The Acceptability, Practicability, Effectiveness, Affordability, Side-effects, and Equity (APEASE) [33,51] criteria were applied to remove the least preferred strategies. The authors prioritised a subset of the criteria; acceptability, practicability and affordability over others (effectiveness, spill over effects/safety, equity) that are more relevant for the full-scale trial [36]. The team tested the criteria as follows:

Acceptability: How likely will the farmers engage with the activity and were these intervention techniques familiar to them?

Practicability: How likely is it to be completed in the allocated time, how much training is required, is it safe to perform, how many facilitators are required and can this be transitioned well for the large-scale rollout in the future?

Affordability: How likely the interventions can be implemented within the allocated budget.

Effectiveness: What are the expected outcomes of the trial? Do these intervention components effectively educate the participants on completing the target behaviours at home?

Side effects/Safety: What are the other farm practices likely to be influenced by these interventions? Are there any negative effects expected to arise from the intervention?

Equity: How far the intervention or part of the intervention likely to affect equity of access?

After reaching a consensus on the finalised intervention components and implementation strategy within the BeSafe study team, the potential evaluation strategies were discussed. These discussions also determined the resources and funds available for the implementation and identified the ethical and bureaucratic approvals required for it.

Phase 4: How Can Behaviour Change Be Measured and Understood?

While the systematic and transparent reporting of methodology serves as a guide for developing interventions, a comprehensive evaluation is necessary to examine the feasibility and efficacy of the proposed behaviour change components. The systematic and transparent results presented in this paper will aid in conducting a thorough evaluation of the key components and their effectiveness. It was determined that the focus of the first trial would be on assessing the feasibility, fidelity and acceptability of the intervention components and their delivery.

At the final stage, the outcome measures to evaluate the feasibility and determine the behaviour change, which included the completion of target behaviours, were determined. The finalisation of the evaluation was guided by a pre-determined feasibility checklist, fidelity framework and theoretical framework of acceptability, respectively, to ensure a systematic evaluation of the intervention. The following outcome measures were proposed:

- An intervention checklist,

- Direct observation,

- Audio recording of the study,

- Reported experience of the facilitators,

- Exit survey,

- SMS survey,

- Personal interviews.

Evaluation strategies were identified for their potential to measure the feasibility, fidelity and acceptability of the active ingredients of the intervention, their delivery methods as well as the intervention as a whole. The tools for measurement were selected based on reliability, validity, availability and relevance. The potential list of recommended strategies was also judged against the subset of APEASE criteria considered previously. Other considerations were the suitability of digital tools such as online surveys for older participants and high attrition rates reported in farm interventions.

Based on the findings from the study, a large-scale effectiveness trial will be recommended for the future stages of the intervention evaluation.

Results

Phase 1: Describe the Problem in Behavioural Terms

The systematic review reiterated the findings of the previous reviews on the lack of theoretically informed behaviour change interventions, limiting the sustainability and efficacy of interventions [4,12]. Although reviewed studies had reported the inclusion of behaviour change strategies, the impact of these components was not explicitly investigated. This phase focused on defining the problem in behavioural problems; hence, the findings contributed to identifying the problem and specifying the target behaviours and population. The critical findings that guided the selection of potential target behaviours and populations in the subsequent phases were:

Studies often attempted to address a variety of farm risks via a single intervention.

Multi-faceted interventions often underreported the intervention details, making it difficult to isolate the mechanism of change.

Very few interventions prioritised high accident-prone areas such as machines and livestock.

Regardless of the significant role played by demographic factors such as age and farm types and the poor participation of vulnerable groups such as older farmers, interventions rarely focused on them [18,52].

Limited interventions reported the inclusion of stakeholders' insights in the intervention development phase.

Findings from the review highlighted the need for tailored interventions that address vulnerable populations and more narrowly targeted interventions for specific farm safety practices. Ireland has an ageing workforce, with the average age of a farmer being fifty-seven. The Irish farm safety reports that 45% of the fatal incidents on the farms involve farmers 65 years of age or older and they are reported to be eight times more vulnerable to fatal injuries than other working sectors [6,53]. While reviewing the evidence, the authors noted that various agencies and studies define "older farmers" as those over the age of 55 [54,55], 60 [56] or 65 [57], depending on the context. After considering the Teagasc's feedback on the feasibility of recruiting older farmers for online-based interviews and future in-person activities, the lower age limit of "older farmers" was set to 60 years for the scope of

the current project. The farm surveys reported that tractors and quad bikes were associated with 55% of the fatalities [41]. Hence, it was decided that the subsequent qualitative study would focus on the tractor and quad-bike-related practices among older farmers.

While a few studies employed behaviour change theories to develop interventions, most of the studies failed to report the intervention development process and components in detail. In addition, even while the intervention details were available, they were not described using the behavioural change terminologies. Hence, the authors identified the specific intervention components targeted at machine safety, analysed their descriptions, and then retrospectively coded them using the BCT taxonomy.

Phase 2: Identify What Needs to Be Changed and Which Barriers and Enablers Need to Be Addressed?

Farmers identified the risky practices prevalent in the Irish farming communities along with the prevalent and potential safety practices. They discussed the types of facilitators and barriers influencing the adoption of these practices. Some of these factors were specific to certain practices, and some were related to farm safety in general. Several inductive themes related to the challenges of adopting and adhering to safety practices were identified. They were further analysed in the context of the COM-B sub-domains [33].

Several of these barriers were consistent with the findings from the literature. For example, participants repeatedly highlighted rushing and lack of situational awareness as major contributors to farm incidents. On further exploration, some common risky practices associated with them were identified, such as poor maintenance of the power take-off (PTO) shaft and its protective covers, operating the tractor without checking the perimeter and climbing off the tractor without engaging the break. However, older farmers also talked about how the factors such as their perceived self-efficacy and perceived risk associated with the tasks influenced their decision to continue or modify their farm practices as they grew older. Several participants discussed discontinuing using quad bikes since they perceived them as dangerous machinery and found them challenging to operate.

The study also explored the farmers' attitudes towards the potential BCTs identified in the systematic review. For example, the participants were asked about their attitudes towards mentoring programs and farm discussion groups, and they shared their recommendations for potential intervention strategies.

Phase 3: Identification of Potential Target Behaviours and Intervention Components

The research team met to review the focus group findings and summarised the relevant findings from phases 1 and 2. Identifying specific barriers and facilitators and mapping them to the theoretical domain informed the identification of potentially effective intervention functions and behaviour change components. The focus group participants also suggested a few target behaviours and intervention strategies to address them, and the research team mapped them to the BCW intervention functions and BCTs using the BCW framework and BCT taxonomy V1, respectively [43].

Phase 3.1 Co-Design Workshop

Identification of target behaviours

The relevant findings from the previous phases and the web-based survey on target behaviour categories were shared among all participants a week before the first session. Once the participants provided their consent and completed the survey by ranking the candidate

behavioural change categories in terms of their relative priority, the top two were identified. Eleven participants completed the survey and selected the following two categories as the most appropriate ones: (1) allocating attention to machinery operation and the local environment and (2) installing and using appropriate safety devices on machinery.

After participants prioritised the appropriate target behaviours for the intervention via survey, the workshop started by exploring specific target behaviours under the shortlisted categories that could be potentially improved through behaviour-based interventions. While considering the specific target behaviours to be considered under the first category, participants highlighted the importance of self-evaluation of risks by farmers. They discussed increasing the habitual risk assessment in the immediate surroundings to ensure the tractor is in working order and that older people and children are not in the working area. While discussing the second category, participants discussed fitting the tractor with appropriate safety devices such as cameras and mirrors to improve visibility and awareness. They have also noted the significance of choosing appropriate and fitting implements and safety devices for farm operations; for example, the right-sized trailer and well-fitted protection covers and PPEs. After identifying the potential specific target behaviours, associated barriers and facilitators that can potentially be addressed by behaviour change-based interventions were discussed. Current participants reiterated the findings from the focus group on the prevalence of rushing and how it prompts the farmers to overlook the immediate dangers such as maintaining good conditions of equipment and a sensible pace for tractor operations. They also pointed out that raising awareness about specific risks associated with each task can encourage participants to be more alert. Likewise, the focus group participants also highlighted how the financial and time constraints along with the voluntary nature of the current safety regulations often encourage the farmers to prioritise productivity over safety. These behavioural determinants were identified as relevant for both categories.

While discussing the heterogeneous and seasonal nature of tasks, the participants raised the importance of seasonal safety messages and campaigns. Beyond the messages from the safety authorities, they described how personal stories and farm visits by friends highly resonate with their fellow farmers.

Identification of potential intervention strategies and delivery methods.

The summarised findings and recommendations that emerged from the previous phases were shared among the participants before the online session. The first half of the discussion focused on identifying potential barriers and facilitators that can be effectively addressed through behaviour-based interventions. While the financial constraints and voluntary nature of the regulations were major concerns, the consensus was that they were more effectively addressable by financial and regulatory-based interventions.

Participants agreed that a lack of knowledge is a major barrier and can be effectively tackled through targeted safety messages. While a few participants recommended peer-to-peer learning and buddy systems as effective strategies, others proposed marketing campaigns. One of the safety researchers explained her experience with implementing personalised safety messages through marketing campaigns. However, a few participants did raise concerns about the effectiveness of individual-level behaviour change strategies given the isolated nature of the farms and frequently reported risk habituation among farmers [6]. In the further discussion on effectively addressing these barriers, they observed that raising awareness among family members and co-workers may effectively tackle them.

The sample presentations and surveys used for the workshops are available under the BeSafe profile in the OSF [58].

Phase 3.2: Feasibility Screening with Teagasc Advisory Team

As the final step of the intervention design, multiple follow-up meetings were conducted among the authors. The intervention was designed for older farmers, but Teagasc brought up the possibility of including the younger adults in the first trial. It was agreed that, by including younger farmers, the trial could examine whether the intervention was suitable for a wider age range and whether the outcomes achieved among older farmers can be generalizable to younger farmers as well. The different perspectives and experiences of younger and older farmers regarding their health and wellbeing will be investigated since they may reveal new insights and possibilities for tailoring the intervention to meet the needs of different age groups. Hence, under the guidance of the Teagasc advisory team, it was decided that, for the first trial:

The length of the intervention program will be less than four hours.

Participants from all four major farm types will be invited to the program.

The ratio of older and younger farmers will be 50:50.

As summarised in Appendix C2, the target behaviours were related to improving awareness about the surrounding of a tractor, specifically blind spots. The first two target behaviours consisted of examining and locating blind spots of their regular tractors, and the third behaviour involved the regular check of blind spots before starting the tractor every day. The potential target behaviours considered at various stages are summarised in Table 2.

Table 2: Summary of potential target behaviours.

Specific Target Behaviour	Recommendation By *		
	Focus Group	**Co-Design Workshops**	**Teagasc Advisory Team/Research**
Whenever the farmer stops/parks the tractor, engage the handbrake securely	Y		
Farmer performs a self-risk evaluation before performing any tasks	Y	Y	
While operating a tractor, the farmer always makes sure that no one including other workers are standing near the vehicles or between thr vehicles and implements attached to it	Y		
Do not rush—farmers always perform tasks at a sensible speed taking account of working conditions and their own capabilities	Y	Y	
Always do an inspection before operating the machinery to make sure that the vehicle is in good working order	Y		
Farmers avoid phone calls while driving a tractor	Y		
Farmer always ensures that no one, including himself, stands on the farm vehicle or the implements attached to it when	Y		

1. The machine is running 2. The PTO rotator or any other moving parts is spinning			
Farmer follows the safe hitching/unhitching procedure each time he attaches an implement to the tractor	Y	Y	
Farmer retrofits the tractor with the recommended safety devices before using it next time	Y	Y	
Farmer retrofits the roll-over protective structures specific to quad bikes before he use it next time	Y		
Always watch out especially for children and elderly persons who may cross in your path or behind you before reversing and give additional attention to blind spots	Y	Y	
Farmer always makes sure that implements are fit with the recommended safety devices before connecting them to the farm vehicle	Y		
Farmer remains alert of the immediate environment while working	Y		
Farmer makes sure to put the lap seat belt in place before taking the tractor out	Y	Y	
Farmer makes sure that a copy of the SOP is present on the vehicle where easily accessible and highly visible	Y	Y	
Prompt farmers to estimate the breaking distance of the tractors			Y
Farmers make sure to check the perimeter before reversing	Y	Y	Y

* Y indicates "Yes".

The summary of the findings regarding the barriers and facilitators considered at various stages is illustrated in Table 3.

Table 3: Summary of barriers and facilitators identified.

Barriers/Facilitators	**Identified as Barrier/Facilitator ***	**Focus Groups ****	**Co-Design Workshops ****	**Included in the Final Intervention ****	**COM-B Domain *****
Costly replacements/retrofitting	B	Y	Y	N	PO
Perceived poor return from investment in safety	B	Y	Y	N	PO
Changing the age old habits/reluctance to learn new ways	B	Y	Y	N	AM
Lone working environment	B	Y	Y	N	SO
Risk habituation	B	Y	Y	N	AM
Time constraints	B	Y	Y	N	PO
Safety conscious co-workers	F	Y	Y	N	SO

Low priority of upgrading the machineries	B	Y	Y	N	RM
Knowledge about the right machinery	F	Y	Y	N	PC
Stories of near misses/vicarious consequences	F	Y	Y	N	RM
Low profit margin for dry stock farmers (financial constraints)	B	Y	Y	N	PO
Farm type	B/F	Y	Y	N	PO
Safety risks are often perceived as a distant threat/risk Perception	B	Y	Y	N	RM
Priority for planning	F	Y	Y	N	RM
Lack of mandatory safety guidelines in the insurance policies	B	Y	Y	N	PO
Higher safety awareness of contractors	F	Y	Y	N	SO
Part time non-farm jobs	B	Y	Y	N	PO
Lack of accountability	B	Y	Y	N	SO
Enforcement of safety regulations (NCT certification) and mandatory built-in safety features for tractors	F	Y	Y	N	PO
Costly upgrades	B	Y	Y	N	PO
Dependency on quad bikes as a mobility device	B	Y	Y	N	PO
Seasonal use of machineries	B	Y	Y	N	PO
Ability to assess and address immediate potential risks	F	Y	N	Y	PC
Cognitive and physical health decline associated with old age	B	Y	Y	Y	PC
Recognition that the equipment/task can be dangerous	F	Y	Y	Y	RM
Knowledge of best practice	F	Y	N	Y	PC
Poor engineering standards/design	B	Y	N	Y	PO
Ineffective communication messages/materials/channels	B	Y	N	Y	PO
Guidelines—good reference for best practice	F	Y	N	Y	PO
Setting a positive role model for children/lead by example	F	Y	Y	Y	SO
Lack of discussion about safety	B	Y	N	Y	SO
Best practice—a belief that all you need is “common sense”	B	Y	N	Y	RM

Belief that accidents and risky jobs cannot be avoided in the farms	B	Y	Y	Y	RM
Willingness to learn	F	Y	N	Y	PC
Partial towards engineering and legislative solutions	B/F	Y	N	Y	RM

* B: Identified as barrier, F: Identified as facilitator, B/F: Identified as barrier and facilitator. ** Y: Yes, N: No. *** PC: Psychological capability, SO: Social opportunity, PO: Physical opportunity, RM: Reflective motivation, AM: Automatic motivation.

Based on the findings from the first three phases, intervention functions, education, training, enablement and persuasion were finalised for the interventions. As noted in Appendix C3, some of the BCTs under consideration at that stage were 3.2, social reward; 13.1, identification of self as role model; 13.2, framing/reframing; 13.3, incompatible beliefs; and 16.3, vicarious consequences. However, a consensus on the operationalisation of the BCTs and delivery method was not reached by the end of the workshops. In the subsequent meetings with the Teagasc advisory team, different ways to operationalise and deliver were discussed and assessed against the feasibility criteria. For example, though the social reward was identified as a potentially effective BCT in public health safety research and endorsed by focus group participants, it was excluded based on the complexity involved in the implementation and evaluation. Another example is while considering the delivery methods for the demonstration activity, the initial consideration was one-on-one delivery of blind spot demonstration among the farmer and his/her family members. However, given the group-based activity structure of the Irish farm programmes and the difficulty in recruiting the whole farm families, it was decided that the demonstration will be delivered in a group setting through a peer-to-peer demo instead of a farmer-to-family demo activity.

As detailed in Table 4, the final draft of the intervention includes an in-person demo session, facilitated discussion, personalised safety training procedure and demonstration kit. The proposed active ingredients are 1.1, goal setting (behaviour); 1.2, problem solving; 1.3, goal setting (outcome); 1.4, action planning; 1.8, behavioural contract; 5.2, salience of consequences; 8.1, behavioural practice/rehearsal; and 13.1, identification of self as role model. The content and delivery method will be further refined during the dry run with a small group of stakeholders, if required.

Table 4: Intervention details.

Barriers and enablers of relevance identified (Codes identified in Focus group)	**Intervention components**	**BCW Function**	**BCTs (* Active Ingredients)**	**Target behaviours**	**COM-B**	**Intervention description**	**Expected output**	**Expected short term outcome**
Ability to assess and address immediate potential risks (F) *** Cognitive and physical health decline associated with old age (B) *** Recognition that the equipment/task can be dangerous (F) *** Knowledge of best practice(F) Poor engineering standards/design(B) *** Ineffective communication messages/materials/channels(B) Guidelines- Good reference for best practice (F) Setting a positive role model for children/lead by example(F) Lack of discussion about safety (B) Best practice - A belief that all you need is 'common sense' (B) Belief that accidents and risky jobs can't be avoided in the farms(B) Willingness to learn(F) Partial towards engineering and legislative solutions (B) ***	Estimation of the stopping distance of the tractor at various	Persuasion	5.1 Information about health consequences 5.2 Salience of consequences *	N/A	Reflective motivation : Demonstrate the consequence of standing near a moving tractor (1,2,3) Automatic motivation: Create concern about the well-being of family members (2,3)	Facilitator invite all the participants to stand near a parked tractor. Ask participants to stand where the they estimate the front of the tractor would be in 3 seconds at various speeds (5 km/hr, 20 km/hr, /50 km/hr).	Attendance Participation in the demonstration	Created negative feeling about the risk
	Demonstration of blind spots and setting up the zone of visibility	Education Training Persuasion	4.1 Instruction on how to perform a behaviour 5.1 Information about health consequences 5.2 Salience of consequences * 6.1 Demonstration of the behaviour 8.1 Behavioral practice/rehearsal * 13.1 Identification of self as role model	1,2,3	Psychological/Physical capability: Increase the knowledge of blind spots (1,2,3) Develop skill to set up the zone of visibility (4,5) Enable to pay more attention to the immediate environment (2,3,4,5) Social Opportunity: Develop skills to a model blind spots to family members (1-6) Reflective motivation: Demonstrate the consequence of overlooking blind spots(1,2,3) Create safe parking area to protect younger family members and workers (4,5) Automatic motivation: Create concern about the well-being of family members (2,3)	Facilitator invite three participants to demonstrate blind spot of demo tractor. One participant sit on the tractor and try to locate the position of the kid sized model that the second participant is holding. Third participant mark the spots that are identified as blind spots. As participants to determine the area of no/low visibility around the tractor and set up the no visibility zone. Repeat the procedure	Attendance Participation in the demonstration	Increased awareness of blind spots Improved skills to demonstrate blind spots to others Improved skills to set up the zone of visibility Reminded that they can model the safety behaviour to others

						with next 3 participants with another tractor model. The participants will be asked about to share their experience about blind spots and how blind spots differs with their family members.		
	Facilitated discussion	Enablement	1.2 Problem solving * 3.2 Social support (practical) 13.1 Identification of self as role model*	1,2, 3	Psychological capability: Increase knowledge on setting up the demonstration for the family members (1,2) Increase knowledge to set up the zone of visibility (3) Discussion about various strategies for the effective implementation (1,2,3) Social Opportunity: Develop skills to a model blind spots to family members(2)	Participants discuss about the demonstration experience and how they plan to complete the target behaviour.	Participation in the discussion	Reminded that they can model the safety behaviour to others Increased awareness of blind spots
	Safety training procedure	Enablement	1.1 Goal setting (behaviour) * 1.3 Goal setting (outcome) * 1.4 Action planning * 1.8 Behavioral contract * 1.9 Commitment 3.1 Social support (unspecified) 8.1 Behavioral practice/rehearsal * 8.3 Habit	1,2, 3	Psychological capability: Create an action plan for improving safety (1) Physical opportunity: Provision of personalised safety plan to secure the parking area (1) Social opportunity: Create social pressure to confirm with the protocol as agreed to the peers(3) Reflective motivation: Create action plans (1) Create opportunity to	Complete a tailored document for each participant based on the input from facilitated discussion. Rate their confidence on completing the activity. Participant and a peer who acts as a witness sign the contract	Individualised safety plan Voluntary agreement to complete the safety goals	Demonstration of blind spots to family members Setting up visibility zone Walk around the tractor before starting it.

			formation 12.1 Restructuring the physical environment 13.1 Identification of self as role model *		report their confidence (2)			
	Demonstration kit	Enablement	12.5 Adding objects to the environment	1,2	Physical opportunity: Provide the materials for the demo (1)	Provide the materials for the completion the demonstration and setting the no-visibility zone	Collection of materials	Demonstration of blind spots to family members Setting up no visibility zone

*Identified as active ingredients; **Target behaviours: (1) Demonstrate blind spots of tractors to family members/co-workers on their farm. (2) Mark the zone of visibility around their tractor in a parking. (3) Walk around the tractor before moving it from the parking area to ensure that nobody is near the tractor and no obstacles are present nearby; ***Participants identified these factors as directly related to blind spots/visibility.

Phase 4: How Can Behaviour Change Be Measured and Understood?

The detailed description of the trial design, evaluation strategies and data collection tools are available in the study protocol (pre-print) [59] and therefore, a summary is available in Appendix C4. In a separate publication, the findings from the feasibility study will be published, where the authors will examine how the active ingredients influenced the behaviours along with the reported feasibility, fidelity and acceptability of the program.

Discussion

This paper describes the systematic development of an intervention to improve tractor-related safety on farms and aims to fill the lack of theoretically based and adequately described behaviour change-based interventions in the relevant literature [4,12,60]. Tractor safety is a complex process involving the interactions between tractor design, farmers' behaviour and environmental factors [6,19,31]. The previous studies indicate that the focus of the safety interventions was on increasing the adoption of engineering solutions, introducing safety regulations and raising risk awareness [4,12]. The current study aimed to develop a safety intervention to improve the machine-related safety among Irish farmers, drawing on evidence from theoretical models, local contexts and target population. Under these criteria, a safety intervention was designed using a combination of education, persuasion, enablement and training to equip farmers with knowledge, skills, and resources to adopt preventive safety behaviours to address tractor-related blind spots at their farms and improve farm safety.

Evidence suggests that by targeting specific behaviour change mediators, the potential effectiveness of the intervention is likely to be increased [35]. Therefore, at the initial stage of the study, it was determined that it would focus on the high-accident-prone areas and vulnerable populations by looking at specific farm practices that may improve one or more areas of tractor safety. The BCW framework provided a systematic way to identify the potential intervention functions that might most likely address the enablers and facilitators, increase the adoption of target behaviours, and bring change in farmers' safety behaviours. While the health behaviour change literature suggests various strategies to inform the

selection of the intervention components, from public and patient involvement panels [27] to interviews [26], to our knowledge, there is no consensus on the most appropriate procedure. Interactions with key stakeholders and target populations provided the local context and information on specific farm practices that often lead to debilitating injuries or fatalities. Further, these interactions with the target population, key stakeholders, farm safety experts and the advisory team at various phases identified a list of the potential target behaviours and intervention components. However, the research team decided on the three specific target behaviours for the intervention based on their knowledge and recommendations of the Teagasc advisory team. For example, instead of considering the "checking the perimeter before reverse parking the tractor" as the target behaviour, "checking the blind spots before operating the tractor" was selected after these discussions. The decision was taken after considering the key criteria, such as the feasibility, safety and ethical considerations associated with the inclusion of a moving tractor in the intervention.

The decision processes, behaviours and environmental conditions leading up to a specific farm fatal incident are complex. Hence, it is unlikely that adding one safety pre-check practice to farmers' habits is not enough to reduce the potential dangers associated with blind spots. A combination of activities involving environment re-structuring, and raising the awareness of farmers and others farm workers and family members are required to improve the safety odds. That is why, while one of the target behaviours focused on improving the adoption of a safety pre-check into their daily practices, the other two target behaviours focused on setting up the no-visibility zone and performing the blind spot demonstration at their farms with family members or friends.

While reviewing the existing interventions, it was noted that education and training-based interventions often target farmers alone, even though farm surveys [41] indicate that non-farmers on the farms also fall victim to fatal farm incidents. Examination of factors influencing farmers' decisions making process repeatedly highlighted the significant role of their concerns regarding the well-being of their family members and social support [20,61,62], as family members from the family farms are often neglected [61]. These educational sessions are often conducted in a group using standard farm equipment, and takeaways are summarised in a leaflet or documents. However, the farmers and other stakeholders who participated in the current study repeatedly highlighted how unpopular paperwork and any documents, in general, are among farmers. The current study/intervention allows the participants to practice the assessment by themselves and thereafter encourages them to complete the risk assessment with the active participation of family members or co-workers on equipment that they use every day.

Before evaluating the effectiveness of a new intervention or piloting on a larger scale, it is recommended to assess the feasibility, fidelity and acceptability of the intervention [63]. A feasibility study [64] can help identify potential problems with a proposed project so that you can address them before doing a larger effectiveness trial [63,65]. The adoption of an intervention depends on the perceived acceptability because it indicates how much the intervention was thought to be appropriate by the target population [66]. If the current intervention or a part of it proves to be effective in the feasibility study, it could be introduced as part of the existing farm programmes or could proceed to a large-scale effectiveness trial.

The key findings and recommendations that will be published separately can inform future studies on the potential target behaviours, specific barriers and facilitators influencing them and potential BCTs that can be used to address and promote them effectively.

Strengths and Limitations

The main strength of the study is the systematic development of intervention through evidence-based, theoretically informed phases and strong stakeholder engagement. This enabled transparent reporting and may enable the replication or adoption of the intervention or one of its ingredients in future studies. This is one of the few studies that addressed the older farmers' needs while designing the intervention and ensured the participation of farmers from different age groups, thus making it suitable for both young and older farmers. Educational interventions are one of the most common strategies used by farm safety programmes; however, for the current study, the choices of the intervention components and their delivery modes were informed by the theoretical framework underpinned by behavioural models, local contexts and target population.

Rothman [67] observed that the use of a theoretical framework provides an important conceptual and analytical framework for determining why an intervention is effective or not. The current method allowed the authors to design an evidence-based, theoretically underpinned intervention that was informed by stakeholders' perspectives. The use of the BCW framework will also enable the study to explore the impact of each intervention component, identify the active ingredients, and conduct a detailed investigation of how the BCTs acted upon the barriers and enablers and whether it brought out the desired target behaviours or not.

The intervention focuses on a selected few target behaviours targeting the safety related to blind spots hence addressing the influencing factors associated with it. However, by describing the process in a systematic manner and reporting the findings in detail through multiple papers, the study added detailed context-specific information on prevailing machine operation and safety-related practices, factors influencing them and guidance on developing similar interventions based on the findings of the current study.

While the BCW framework gained popularity in public health research, there is limited information available on its adoption of it in the farm literature. Hence, there was a lack of available evidence to decide on the best approach to select the best target behaviours and operationalise the BCTs from the potential list of farm practices and intervention strategies identified through literature and interactions with experts and stakeholders. Therefore, the final draft of the target behaviours, selection, operationalisation and packing of intervention components were based on the researchers' experience, feedback from the advisory team and what is likely feasible within the current research context. As observed by Cadogan et al. [26], these barriers will not be resolved until the uptake in the behaviour change-based interventions, and the detailed description of intervention development, intervention components, and their delivery become standard practice.

All the participants who contributed to the various stages of the studies attended them voluntarily. Previous studies reported that the voluntary nature of these studies often encourages only the already safety-conscious farmers to participate [68]. As a result, our findings may be subjective and may not represent the entire workforce, especially most risk-taking farmers.

Conclusions

The study demonstrated the integration of various available evidence, such as reviews, field reports, stakeholder perspectives, and behaviour change theories, within an appropriate framework to provide a structure for integrating evidence and identifying and implementing the most appropriate behaviour change strategies. Detailed reporting of the intervention development can encourage future farm researchers to better document and report their own development process along with their key findings, thus generating a body of evidence that can be adopted as a whole or in parts by the safety agencies and researchers for developing farm safety programmes. The ongoing feasibility study will assess the potential of the intervention and modification required before progressing to a large-scale effectiveness study.

Data Availability Statement[8]

The dataset supporting the conclusions of this article is included within the article. Additional data supporting the project is available in the OSF repository [58].

Author contribution statement

Conceptualisation and formal analysis: A.S., J.M. (Jennifer McSharry) and D.O.; Methodology: A.S., D.O., J.M. (Jennifer McSharry), D.M., J.M. (John McNamara) and F.B.; writing—original draft preparation: A.S.; writing—review and editing: A.S., J.M. (Jennifer McSharry), O.M., D.O. and J.M. (John McNamara); Validation: D.O., J.M. (Jennifer McSharry), D.M., J.M. (John McNamara) and F.B.; Project Administration—D.O., D.M., J.M. (John McNamara) and F.B.; Funding acquisition: D.O.; Supervision: D.O., J.M. (Jennifer McSharry), D.M. and O.M.

References

Shortall, S.; McKee, A.; Sutherland, L.-A. Why Do Farm Accidents Persist? Normalising Danger on the Farm within the Farm Family. Sociol. Health Illn. 2019, 41, 470–483. https://doi.org/10.1111/1467-9566.12824.

Kennedy, A.; Maple, M.J.; McKay, K.; Brumby, S.A. Suicide and Accidental Death in Australia's Rural Farming Communities: A Review of the Literature. Rural. Remote Health 2014, 14, 230–243.

Mekkodathil, A.; El-Menyar, A.; Al-Thani, H. Occupational Injuries in Workers from Different Ethnicities. Int. J. Crit. Illn. Inj. Sci. 2016, 6, 25. https://doi.org/10.4103%2F2229-5151.177365.

DeRoo, L.A.; Rautiainen, R.H. A Systematic Review of Farm Safety Interventions. Am. J. Prev. Med. 2000, 18, 51–62. https://doi.org/10.1016/S0749-3797(00)00141-0.

Department of Agriculture, Food and the Marine Farm Safety. Available online: https://www.gov.ie/en/publication/4133b-farm-safety/?referrer=http://www.gov.ie/farmsafety/ (accessed on 26 July 2022).

Murphy, M.; O'Connell, K. Farm Deaths and Injuries: Changing Irish Farmer Attitudes and Behaviour on Farm Safety; Cork Institute of Technology: Cork, Ireland, 2017.

[8] In the appendix, we have included most of the supplementary files published along with the journal. However, a few supplementary files that are not included here can be accessed on our Open Science Framework (OSF) profile or on the respective publisher websites.

2018–Alarming Rise in Farm Accidents–Teagasc Survey–Teagasc|Agriculture and Food Development Authority. Available online: https://www.teagasc.ie/news--events/news/2018/rise-in-farm-accidents.php (accessed on 23 January 2023).

Mohammadrezaei, M.; Meredith, D.; McNamara, J. Beyond Age and Cause: A Multidimensional Characterization of Fatal Farm Injuries in Ireland. J. Agromedicine 2022, 1–11. https://doi.org/10.1080/1059924X.2022.2116138.

McNamara, J.; Kinsella, A.; Osborne, A.; Blake, C.; Meredith, D.; Kinsella, J. Identifying Farmer Workplace Injury Risk Factors in Ireland Using Farm Accounts Data. J. Agromedicine 2021, 26, 411–419. https://doi.org/10.1080/1059924X.2020.1837704.

Pollock, K.S.; Griffith, G.R.; Fragar, L.J. The Economic Cost of Farm-Related Fatalities in Australia. J. Agric. Saf. Health 2012, 18, 11–30. https://doi.org/10.13031/2013.41230.

Svennefelt, C.A.; Lundqvist, P. Safe Farmer Common Sense'-A National Five-Year Education-Based Program for Prevention of Occupational Injuries in Swedish Agriculture-Background, Process, and Evaluation. J. Agromedicine 2020, 25, 221–230. https://doi.org/10.1080/1059924X.2019.1659203.

Lehtola, M.M.; Rautiainen, R.H.; Day, L.M.; Schonstein, E.; Suutarinen, J.; Salminen, S.; Verbeek, J.H. Effectiveness of Interventions in Preventing Injuries in Agriculture—A Systematic Review and Meta-Analysis. Scand. J. Work. Environ. Health 2008, 34, 327–336.

Skivington, K.; Matthews, L.; Simpson, S.A.; Craig, P.; Baird, J.; Blazeby, J.M.; Boyd, K.A.; Craig, N.; French, D.P.; McIntosh, E.; et al. A New Framework for Developing and Evaluating Complex Interventions: Update of Medical Research Council Guidance. BMJ 2021, 374, n2061. https://doi.org/10.1136/bmj.n2061.

Sorensen, J.A.; Tinc, P.J.; Weil, R.; Droullard, D. Symbolic Interactionism: A Framework for Understanding Risk-Taking Behaviors in Farm Communities. J. Agromedicine 2017, 22, 26–35. https://doi.org/10.1080/1059924X.2016.1248306.

Narasimhan, G.R.; Peng, Y.; Crowe, T.G.; Hagel, L.; Dosman, J.; Pickett, W. Operational Safety Practices as Determinants of Machinery-Related Injury on Saskatchewan Farms. Accid. Anal. Prev. 2010, 42, 1226–1231. https://doi.org/10.1016/j.aap.2010.01.016.

Leppälä, J.; Griffin, P.; McNamara, J.; Rautiainen, R. Safety Culture and Risk Management in Agriculture: Sacurima Cost Action CA16123 Highlights and Conclusions; Natural Resources Institute Finland (Luke): 2021.

Beseler, C.L.; Rautiainen, R.H. Lack of Agreement between Safety Priorities and Practices in Agricultural Operators: A Challenge for Injury Prevention. Safety 2022, 8, 39. https://doi.org/10.3390/safety8020039.

Murphy, D.J.; Kiernan, N.E.; Chapman, L.J. An Occupational Health and Safety Intervention Research Agenda for Production Agriculture: Does Safety Education Work? Am. J. Ind. Med. 1996, 29, 392–396.

Svennefelt, C.E.A.; Hunter, E.; Palsdottir, A.M. Work Safety Interventions and Threat Complexity–a Formative Investigation into Why Farmers Do Not Act Safely. Ann. Agric. Environ. Med. 2019, 26, 280–289.

Furey, E.M.; O'Hora, D.; McNamara, J.; Kinsella, S.; Noone, C. The Roles of Financial Threat, Social Support, Work Stress, and Mental Distress in Dairy Farmers' Expectations of Injury. Front. Public Health 2016, 4, 126. https://doi.org/10.3389/fpubh.2016.00126.

Ajzen, I. The Theory of Planned Behavior. Organ. Behav. Hum. Decis. Process. 1991, 50, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T.

Green, E.C.; Murphy, E.M.; Gryboski, K. The Health Belief Model. Wiley Encycl. Health Psychol. 2020, 211–214.

Regan, Á.; Douglas, J.; Maher, J.; O'Dwyer, T. Exploring Farmers' Decisions to Engage in Grass Measurement on Dairy Farms in Ireland. J. Agric. Educ. Ext. 2021, 27, 355–380. https://doi.org/10.1080/1389224X.2020.1858892.

Irwin, A.; Mihulkova, J.; Berkeley, S. 'No-One Else Wears One': Exploring Farmer Attitudes towards All-Terrain Vehicle Helmets Using the COM-B Model. J. Saf. Res. 2022, 81, 123–133. https://doi.org/10.1016/j.jsr.2022.02.004.

McCallum, D.M.; Murphy, S.; Reed, D.B.; Claunch, D.T.; Reynolds, S.J. What We Know about the Effectiveness of Farm Safety Day Programs and What We Need to Know. J. Rural. Health 2013, 29, 20–29.

Cadogan, C.A.; Ryan, C.; Francis, J.J.; Gormley, G.J.; Passmore, P.; Kerse, N.; Hughes, C.M. Development of an Intervention to Improve Appropriate Polypharmacy in Older People in Primary Care Using a Theory-Based Method. BMC Health Serv. Res. 2016, 16, 1–10. https://doi.org/10.1186%2Fs12913-016-1907-3.

Walsh, D.M.; Hynes, L.; O'Hara, M.C.; Mc Sharry, J.; Dinneen, S.F.; Byrne, M. Embedding a User-Centred Approach in the Development of Complex Behaviour Change Intervention to Improve Outcomes for Young Adults Living with Type 1 Diabetes: The D1 Now Study. HRB Open Res. 2018, 1, 8. https://doi.org/10.12688/hrbopenres.12803.2.

Burton, A.; Burgess, C.; Dean, S.; Koutsopoulou, G.Z.; Hugh-Jones, S. How Effective Are Mindfulness-Based Interventions for Reducing Stress Among Healthcare Professionals? A Systematic Review and Meta-Analysis. Stress Health 2017, 33, 3–13. https://doi.org/10.1002/smi.2673.

French, S.D.; Green, S.E.; O'Connor, D.A.; McKenzie, J.E.; Francis, J.J.; Michie, S.; Buchbinder, R.; Schattner, P.; Spike, N.; Grimshaw, J.M. Developing Theory-Informed Behaviour Change Interventions to Implement Evidence into Practice: A Systematic Approach Using the Theoretical Domains Framework. Implement. Sci. 2012, 7, 38. https://doi.org/10.1186/1748-5908-7-38.

Mohammadrezaei, M.; Meredith, D.; McNamara, J. Subjective Norms Influence Advisors' Reluctance to Discuss Farm Health and Safety. J. Agric. Educ. Ext. 2022, 1–25. https://doi.org/10.1080/1389224X.2022.2125410.

Colémont, A.; Van den Broucke, S. Measuring Determinants of Occupational Health Related Behavior in Flemish Farmers: An Application of the Theory of Planned Behavior. J. Saf. Res. 2008, 39, 55–64. https://doi.org/10.1016/j.jsr.2007.12.001.

Franklin, R.C.; McBain-Rigg, K.E.; King, J.C.; Lower, T. Exploring the Barriers and Facilitators to Adoption of Improved Work Practices for Safety in the Primary Industries; RIRDC: Barton ACT, 2015.

Michie, S.; Atkins, L.; West, R. The Behaviour Change Wheel: A Guide to Designing Interventions; Silverback Publishing: Shropshire, UK, 2014.

Michie, S.; van Stralen, M.M.; West, R. The Behaviour Change Wheel: A New Method for Characterising and Designing Behaviour Change Interventions. Implement. Sci. 2011, 6, 42. https://doi.org/10.1186/1748-5908-6-42.

Michie, S.; Johnston, M.; Francis, J.; Hardeman, W.; Eccles, M. From Theory to Intervention: Mapping Theoretically Derived Behavioural Determinants to Behaviour Change Techniques. Appl. Psychol. 2008, 57, 660–680. https://doi.org/10.1111/j.1464-0597.2008.00341.x.

Power, B.T.; Kiezebrink, K.; Allan, J.L.; Campbell, M.K. Development of a Behaviour Change Workplace-Based Intervention to Improve Nurses' Eating and Physical Activity. Pilot Feasibility Stud. 2021, 7, 1–14. https://doi.org/10.1186/s40814-021-00789-0.

Michie, S.; Richardson, M.; Johnston, M.; Abraham, C.; Francis, J.; Hardeman, W.; Eccles, M.P.; Cane, J.; Wood, C.E. The Behavior Change Technique Taxonomy (v1) of 93 Hierarchically Clustered Techniques: Building an International Consensus for the Reporting of Behavior Change Interventions. Ann. Behav. Med. 2013, 46, 81–95. https://doi.org/10.1007/s12160-013-9486-6.

Prestwich, A.; Webb, T.L.; Conner, M. Using Theory to Develop and Test Interventions to Promote Changes in Health Behaviour: Evidence, Issues, and Recommendations. Curr. Opin. Psychol. 2015, 5, 1–5. https://doi.org/10.1016/j.copsyc.2015.02.011.

Hoffmann, T.C.; Glasziou, P.P.; Boutron, I.; Milne, R.; Perera, R.; Moher, D.; Altman, D.G.; Barbour, V.; Macdonald, H.; Johnston, M. Better Reporting of Interventions: Template for Intervention Description and Replication (TIDieR) Checklist and Guide. BMJ 2014, 348, g1687. https://doi.org/10.1136/bmj.g1687.

Duncan, E.; O'Cathain, A.; Rousseau, N.; Croot, L.; Sworn, K.; Turner, K.M.; Yardley, L.; Hoddinott, P. Guidance for Reporting Intervention Development Studies in Health Research (GUIDED): An Evidence-Based Consensus Study. BMJ Open 2020, 10, e033516.

Health and Safety Authority. A Review of Work-Related Fatalities in Agriculture in Ireland 2011–2020; Health and Safety Authority: Dublin, Ireland, 2021.

Shamseer, L.; Moher, D.; Clarke, M.; Ghersi, D.; Liberati, A.; Petticrew, M.; Shekelle, P.; Stewart, L.A.; PRISMA-P Group Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015: Elaboration and Explanation. BMJ 2015, 350, g7647. https://doi.org/10.1136/bmj.g7647.

Michie S, Johnston M, Carey R. Behavior Change Techniques. In: Gellman MD, ed. Encyclopedia of Behavioral Medicine. Cham: Springer International Publishing; 2020:206-213. doi:10.1007/978-3-030-39903-0_1661 Etikan, I.; Musa, S.A.; Alkassim, R.S. Comparison of Convenience Sampling and Purposive Sampling. Am. J. Theor. Appl. Stat. 2016, 5, 1. https://doi.org/10.11648/j.ajtas.20160501.11.

Etikan, I.; Musa, S.A.; Alkassim, R.S. Comparison of Convenience Sampling and Purposive Sampling. Am. J. Theor. Appl. Stat. 2016, 5, 1. https://doi.org/10.11648/j.ajtas.20160501.11.

Lo Iacono, V.; Symonds, P.; Brown, D.H. Skype as a Tool for Qualitative Research Interviews. Sociol. Res. Online 2016, 21, 103–117. https://doi.org/10.5153/sro.3952.

Skype Support for All Products|Skype Support. Available online: https://support.skype.com/en/skype/all/ (accessed on 30 October 2022).

Clarke, V., Braun, V. and Hayfield, N. (2015) Thematic Analysis. In: Smith, J.A., Ed., Qualitative Psychology: A Practical Guide to Research Methods, SAGE Publications, London, 222–248.

Verbi, S. MAXQDA 2019. Available online https://www.maxqda.com/new-maxqda-2020 (accessed on 1 December 2022)

Inc, Z.V.C. Security Guide; Zoom Video Communications Inc.: San Jose, CA, USA, 2016; Volume 9, p. 2020.

Gorilla. Available online: https://support.gorilla.sc/support/reference/questionnaire-widgets#ranking (accessed on 11 January 2023).

West, R.; Michie, S.; Atkins, L.; Chadwick, P.; Lorencatto, F. Achieving Behaviour Change: A Guide for Local Government and Partners; Public Health England: London, UK, 2019.

McCallum, D.M.; Reed, D.B.; Claunch, D.T.; Davis, C.M.; Conaway, M.B. Farm Dinner Theater: Testing an Innovative Health and Safety Intervention among Older Farmers and Their Families. J. Rural. Health 2022, 38, 433–441. https://doi.org/10.1111/jrh.12601.

Lee, M.J.; Cawley, D.T.; Ng, J.P.; Kaar, K. Trends in the Fractures and Fatalities of Farmyard Injuries in Ireland: A 10 Year Analysis. Ir. Med. J. 2017, 110, 494. https://doi.org/10147/621063.

Nilsson, K. Interventions to Reduce Injuries among Older Workers in Agriculture: A Review of Evaluated Intervention Projects. Work 2016, 55, 471–480. https://doi.org/10.3233/WOR-162407.

Myers, J.R.; Layne, L.A.; Marsh, S.M. Injuries and Fatalities to US Farmers and Farm Workers 55 Years and Older. Am. J. Ind. Med. 2009, 52, 185–194.

Nilsson, K.; Pinzke, S.; Lundqvist, P. Occupational Injuries to Senior Farmers in Sweden. J. Agric. Saf. Health 2010, 16, 19–29.

Health and Safety Authority. Farm Safety Action Plan 2021-2024; Health and Safety Authority: Dublin, Ireland, 2021. Available online: https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/a_review_of_work-related_fatalities_in_agriculture_in_ireland_2011-2020.pdf (accessed on 23 January 2023).

Surendran, A.; O'Hora, D.; Mc Sharry, J. BeSafe Tractor: Developing Behavioural Based Interventions to Reduce Machine Related Accidents on Farms. OSF 2022. https://doi.org/10.17605/OSF.IO/AYXVS

Surendran, A.; McSharry, J.; Bligh, F.; McNamara, J.; Meredith, D.; O'Hora, D. Assessing the Feasibility, Fidelity and Acceptability of a Behaviour Change Intervention to Improve Tractor Safety on Farms: Protocol for the BeSafe Tractor Safety Feasibility Study; Research Square 2022.https://doi.org/10.21203/rs.3.rs-2113603/v1.

Afshari, M.; Karimi-Shahanjarini, A.; Khoshravesh, S.; Besharati, F. Effectiveness of Interventions to Promote Pesticide Safety and Reduce Pesticide Exposure in Agricultural Health Studies: A Systematic Review. PLoS ONE 2021, 16, e0245766. https://doi.org/10.1371/journal.pone.0245766.

Meredith, D.; Mohammadrezaei, M.; McNamara, J.; O'Hora, D. Towards a Better Understanding of Farm Fatalities: Identification and Estimation of Farming Fatality Rates. J. Agromedicine 2022, 1–15. https://doi.org/10.1080/1059924X.2022.2113196.

Murphy, M.; O'Connell, K. The Use of Mentoring to Effect Cultural Change: Irish Farm Deaths and Injuries; Cork Institute of Technology: Cork, Ireland, 2018.

Craig, P.; Dieppe, P.; Macintyre, S.; Michie, S.; Nazareth, I.; Petticrew, M. Developing and Evaluating Complex Interventions: The New Medical Research Council Guidance. BMJ 2008, 337, a1655. https://doi.org/10.1136/bmj.a1655.

Bowen, D.J.; Kreuter, M.; Spring, B.; Cofta-Woerpel, L.; Linnan, L.; Weiner, D.; Bakken, S.; Kaplan, C.P.; Squiers, L.; Fabrizio, C. How We Design Feasibility Studies. Am. J. Prev. Med. 2009, 36, 452–457. https://doi.org/10.1016/j.amepre.2009.02.002.

De Silva, M.J.; Breuer, E.; Lee, L.; Asher, L.; Chowdhary, N.; Lund, C.; Patel, V. Theory of Change: A Theory-Driven Approach to Enhance the Medical Research Council's Framework for Complex Interventions. Trials 2014, 15, 267. https://doi.org/10.1186/1745-6215-15-267.

Sekhon, M.; Cartwright, M.; Francis, J.J. Acceptability of Healthcare Interventions: An Overview of Reviews and Development of a Theoretical Framework. BMC Health Serv. Res. 2017, 17, 88. https://doi.org/10.1186/s12913-017-2031-8.

Rothman, A.J. "Is There Nothing More Practical than a Good Theory?": Why Innovations and Advances in Health Behavior Change Will Arise If Interventions Are Used to Test and Refine Theory. Int. J. Behav. Nutr. Phys. Act. 2004, 1, 11. https://doi.org/10.1186/1479-5868-1-11.

Robson, L.S. Guide to Evaluating the Effectiveness of Strategies for Preventing Work Injuries: How to Show Whether a Safety Invervention Really Works; DHHS Publication: Atlanta, GA, USA, 2001.

Chapter 6 Assessing the feasibility, fidelity and acceptability of a behaviour change intervention to improve tractor safety on farms: Protocol for the BeSafe tractor safety feasibility study[9]

Authors: Ms. Aswathi Surendran MSc[1], Dr Jenny McSharry[1], Dr David Meredith[2], Dr John McNamara[2], Mr Francis Bligh MSc[2], Dr Oonagh Meade[1], Dr Denis O'Hora[1]

[1]School of Psychology, University of Galway, Ireland
[2]TEAGASC, Ireland

Corresponding Author: Dr John McNamara Email: john.g.mcnamara@teagasc.ie

Abstract

Background

In Ireland, the agriculture sector reports the highest number of fatalities even though farmers constitute only 6% of the working population. Tractor-related behaviours are implicated in 55% of all vehicle work-related fatalities and 25% of reported injuries, and many of these occur in farmyards. There is limited research on the feasibility and acceptability of behaviour change interventions to improve tractor safety. Target behaviours that promote safe operation in farmyards, determining and addressing blind spots of tractors, were identified, and an intervention was developed following the Behaviour Change Wheel Approach. The objective of the study is to examine the feasibility, fidelity and acceptability of a behaviour change intervention to enhance the safe operation of tractors in farmyards with a particular focus on tractor blind spots.

Method

A single group feasibility study will be undertaken. Approximately 16 farmers from four major farm types will be recruited for the study between August and September 2022. The intervention involves an in-person demo session, facilitated discussion and personalised safety training procedure with safety goals. The study will collect data from participants at three time points: baseline (3–10 days prior to the intervention), during the intervention and at the follow-up session (7–30 days post-intervention). Quantitative data will be collected through a pre-intervention interview and feedback surveys. A pre- and post-intervention qualitative interview will also be conducted with the participants and will be supplemented with qualitative data from recruitment logs, observational memos and logs and feedback from recruiters. Evaluation of the feasibility, acceptability and fidelity of the intervention will be guided by a pre-determined feasibility checklist, fidelity framework and theoretical framework of acceptability, respectively. Interviews will be analysed using the content analysis.

Discussion

The current study can determine the feasibility and fidelity of delivering a systematic, theoretically driven, tailored behaviour change intervention. It will also assess whether the

[9] Surendran, A., McSharry, J., Meredith, D., McNamara, J., Bligh, F., Meade, O., & O'Hora, D. (2023). Assessing the feasibility, fidelity and acceptability of a behaviour change intervention to improve tractor safety on farms: protocol for the BeSafe tractor safety feasibility study. Pilot and feasibility studies, 9(1), 1-17.

intervention, its ingredients, and delivery are acceptable to the farming population. This study will also inform the development of a future larger trial to test the effectiveness of the intervention.

Trial registration:

ISRCTN Identifier: ISRCTN22219089. Date applied 29th July 2022

Keywords: Behaviour change intervention; Farm Safety intervention; blind-spots; Tractors; peer-to-peer mentoring; feasibility study; Farmers

Introduction

Background

Farming is considered a dangerous occupation globally, accounting for a high number of occupational accidents and fatalities [1]. In Ireland, the farming industry makes up only 6% of the workforce [2]. Yet, for decades, the agricultural sector reported the highest number of fatal incidents of any other economic sector [3]. The Irish Agriculture and Food Development Authority (Teagasc) National Farm Survey (NFS) reported a 31% increase in farm accidents in the last decade in Ireland [4]. Farm machines, vehicles and livestock are linked to most of the serious incidents on farms [4, 5].

While there have been a variety of initiatives and interventions to tackle farm accidents and fatalities, a number of limitations with these studies have been identified. For example, intervention targets have been limited to adopting technical solutions or safety guidelines, and demographic factors like age and psychosocial factors have been often overlooked [6–9]. Farm safety research has also historically relied on safety education; however, recent reviews have raised questions about the effectiveness of education programmes to change farm operations and individual behaviours [1, 9].

Small-scale farms and family-run farms are regularly exempted from compliance with safety regulations, even though they work in an isolated environment with little to no oversight [10–12]. The lone-working nature of farming results in farmers' being their own bosses; along with day-to-day farming responsibilities, they are often burdened with the identification of risks and the development and implementation of safety plans [9]. This often results in farmers prioritising the risk of financial failure over the risk of their own injuries by working long hours and taking unnecessary risks. These factors also act as barriers to adopting preventative safety behaviours such as routine maintenance activities [13]. Hence, a change in farm operation and farmers' behaviour is required to improve the safety in farms.

Recent reviews indicate that safety interventions have been largely focused on the "Three Es"—"Education, Engineering and Enforcement" to prevent hazard exposures. Farm research literature clearly indicates that psychosocial factors play a crucial role and repeatedly indicates to focus on behavioural-based interventions targeting farmers' attitudes and behaviours [14, 15]. The Medical Research Council (MRC) guidance for developing and evaluating complex interventions underscores the importance of integrating theory and available evidence in developing interventions [16]. Evidence emerging from public health research also indicates that behavioural theories and models can help to understand the determinants of behaviours, explain the behaviour change process to shape the behaviour and environment and identify potential behaviour change strategies to facilitate long-term changes [17–20]. Injury prevention literature also reports that successful strategies incorporated behavioural and environmental approaches [18, 19].

Analysis of risk factors and farm accidents indicates that demographic factors (e.g. age), farm characteristics, psychosocial factors (e.g. normalisation of farm accidents among farming communities and stress) and external factors (e.g. seasons and market pressures) influence farm safety [3, 21]. With an ageing farming population and age-related decline in physical and cognitive health, the older age (aged 65 +) group have been identified as having more injuries than any other age group [4, 8, 22]. A recent review by Nilsson [8] highlighted a lack of focus on older farmers in the intervention literature and that older farmers are less likely to participate and more likely to drop out of the safety initiatives. Previous studies have also indicated that the risk factors, behavioural practices and motivational factors differ across age groups [3, 13, 22]. Given that the pattern and impact of accidents vary across demographic

groups, the needs of these vulnerable groups should be taken into account in the design of targeted intervention programmes in the future.

Development of BeSafe Intervention

BeSafe project is a research programme funded by the Department of Agriculture, Food and the Marine (DAFM), Ireland, supported by the Irish Health and Safety Authority (HSA) and operated by Teagasc (the Irish state agency providing research, advisory and education in agriculture) to develop safety interventions to bring long-term changes to machine-related safety on farms. A lack of clear behavioural targets, limited integration of theory and limited reporting of the content of interventions have been identified as a major gap in existing farm safety literature [3, 15]. The BeSafe intervention was developed as a novel, theory-driven, tailored intervention that aims to address these gaps.

The Behaviour Change Wheel (BCW) framework was developed by synthesising 19 existing behaviour change intervention frameworks to provide a comprehensive and systematic approach for developing behaviour change interventions [19]. The BCW framework is based on the Capability-Opportunity-Motivation-Behaviour (COM-B) model, which suggests that for behaviour to change, an individual needs to have the capability, opportunity and motivation to engage in the target behaviour. These three components are interdependent and influence behaviour through multiple interacting factors. The COM-B model is linked to the BCW framework as it provides a theoretical understanding of behaviour change and helps to identify intervention functions, policy categories behaviour change techniques (BCTs) to support behaviour change. Intervention functions are the broad categories of strategies that can be used to change behaviour, such as education, training and environmental restructuring. BCTs are the observable, replicable and irreducible active ingredients of an intervention that can be used to change behaviour, such as goal setting, action planning and behavioural contract. This framework provides a structured approach for identifying the target population, target behaviour and the barriers and facilitators that need to be targeted by the intervention. This approach ensures that the intervention is tailored to the specific needs of the target population, is stakeholder-focused and is grounded in theory [23, 24]. Moreover, this approach allows for the evaluation of the feasibility, fidelity and acceptability of the active ingredients in a systematic and rigorous manner [19, 23].

As the first step of the intervention development, we systematically reviewed the interventions targeting machine related accidents on farms [25]. Behavioural components present in these selected studies were then mapped to the BCW framework, and the behaviour change techniques to deliver these intervention functions were coded using the BCT taxonomy V1 [24]. Though the review identified nine intervention functions and twenty-one BCTs, the effectiveness of the BCTs was not assessed for various reasons, including the heterogeneity of the selected studies and missing information about the intervention components. Findings from the review encouraged the research team to create a tailored intervention that addresses vulnerable populations such as older farmers and is targeted at specific farm safety behaviours. Based on the review findings and Irish farm fatality reports, it was decided that the qualitative study would focus on the safe handling of tractor and quad-bike-related among older farmers. In the next phase, we conducted a qualitative study involving focus group discussions with older farmers (60 years and above). The focus group explored the barriers and facilitators to adopting safer tractor and quadbike-related behaviours. The findings were then thematically analysed and mapped to the COM-B domains. Participants have also suggested a few intervention strategies to address them, and the research team has mapped them to the BCW intervention functions and BCTs using the BCW framework and BCT taxonomy V1, respectively. In the next phase, we shared the

findings from the review and focus groups with the panel members of the co-design workshops. Co-design workshops with experts and stakeholders identified the top target behaviours for the intervention, the potential behaviour techniques to address these behaviours and strategies for delivering these interventions. The subsequent meetings with the Teagasc representatives guided the selection and fine-tuning of the target behaviours (specific farm practices) and the intervention components. This exercise determined the usefulness and practicality of the intervention components and delivery strategies in the Irish farm context and ensured that they aligned with the Irish occupational safety approach. A detailed description of the intervention development is published elsewhere [26]. Intervention content was then mapped to the appropriate intervention functions of the BCW.

The BeSafe tractor safety intervention aims to equip farmers with knowledge, skills and resources to adopt preventive safety behaviours to address tractor-related blind spots on their farms and improve farm safety. To ensure the participation and feedback of older farmers, the study will ensure that at least 50% of the participants are aged above 60 years. The primary researcher, Teagasc representatives (FB and JM) and agricultural machine instructors conducted multiple mock demos and informally tested various aspects, timing and administration, of the intervention components to determine the timeline and resources for the intervention. The target behaviours (farm practices) targeted by the intervention are as follows:

1. Farmers to demonstrate blind spots of tractors to family members/co-workers on their farm

2. Farmers to mark the zone of visibility around their tractor in a parking area

3. Farmers are to complete a walk around the tractor each time before starting the tractor to check that there are no people or obstacles.

The BeSafe intervention is comprised of five intervention functions (Education, Training, Persuasion, Modelling and Enablement) and nine BCTs, selected to target barriers and facilitators associated with target behaviours (see Appendix D1 for the detailed breakdown of the intervention and Appendix D2 for a breakdown of the intervention components). The intervention involves an in person peer-to-peer demonstration session, facilitated discussion and personalised safety training procedure with safety goals delivered (see Appendix D4 for an example safety training procedure form). The Template for Intervention DEscription and Replication (TIDieR) checklist [27] was used to describe the intervention.

Before evaluating the effectiveness of new interventions, it is recommended that intervention feasibility, fidelity and acceptability be assessed [16]. Complications that arise from the delivery, fidelity and acceptability can be effectively identified during a feasibility study, thus providing an opportunity to refine or modify before a larger effectiveness trial [16, 28]. Guided by Bowen et al.'s [29] framework for conducting feasibility studies, the current study will focus on the feasibility of implementing the intervention in an Irish farm setting, implementation of the intervention as intended (fidelity) and acceptability and adoption among recipients [29–31].

Findings from the study have the potential to inform the development of a full-scale randomised trial to evaluate its effectiveness in increasing safety practices on farms.

Evidence emerging from the study also can inform future farm safety research on the feasibility and fidelity of implementing behaviour-change-based interventions and the acceptance of BCTs among farmers.

Method/design

Aim

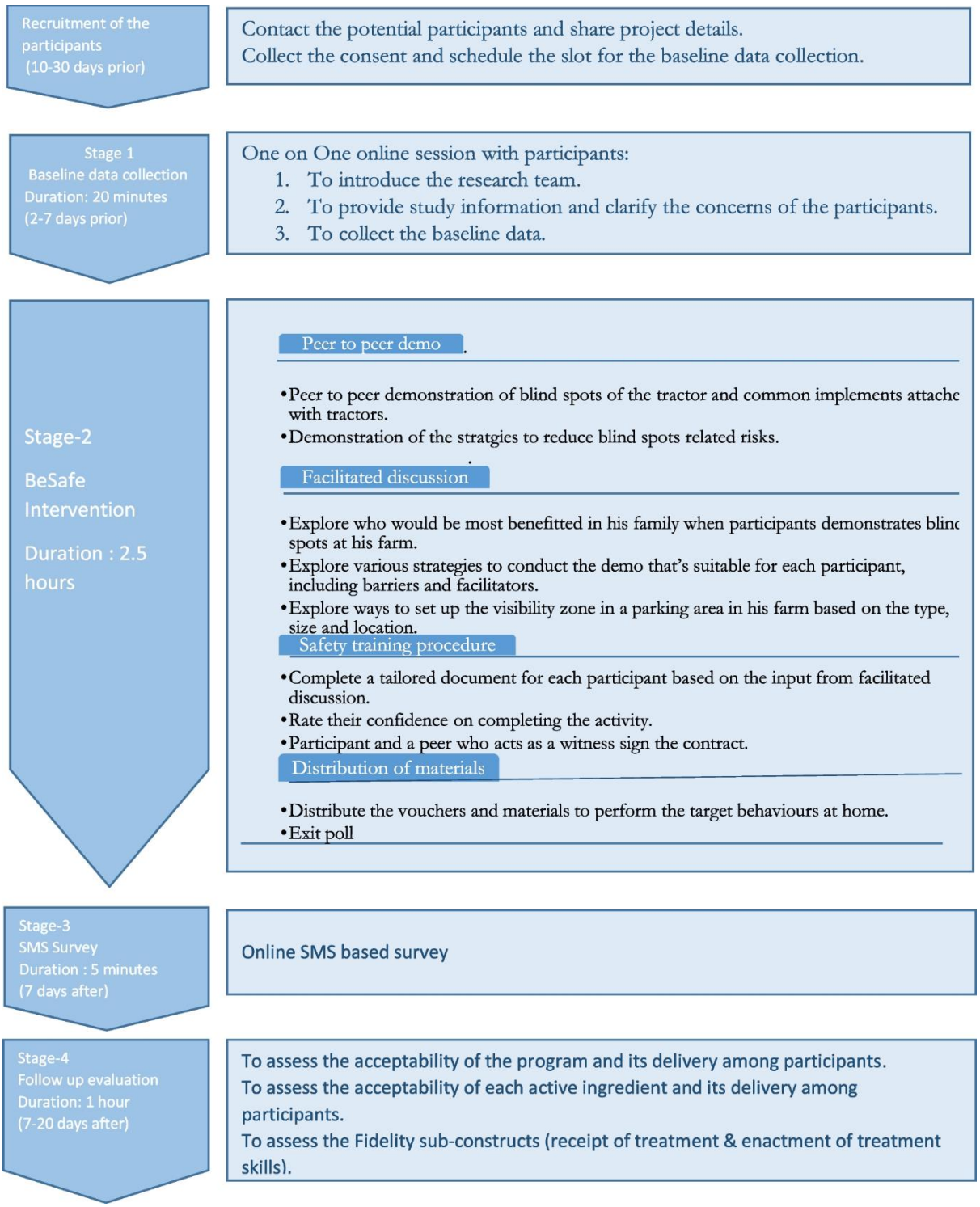
This feasibility study protocol aims to outline the evaluation plans of the BeSafe intervention programme and provide a comprehensive description of the methods that will be used to assess its feasibility, fidelity and acceptability. The manuscript is structured in a way that describes the intervention and its theoretical underpinnings, the study design and methods, recruitment and participant selection criteria, proposed outcome measures and data analysis plans. The objectives of the feasibility study are:

1. To assess the feasibility of recruiting the participants and delivering the intervention, which includes the recruitment, retention, adherence and completion of the intervention
2. To assess the fidelity of the design, training, delivery, receipt and enactment of the intervention
3. To evaluate the acceptability of the active components of the intervention among the participants
4. To identify participants' perceived barriers and enablers to participating in, and completing, the intervention

Study Design

This is a single-group feasibility trial. The study will use a combination of quantitative and qualitative methods to evaluate the intervention, including an exit survey and in-depth interviews with participants to gain insight into their experiences. Therefore, as per the guidance provided by the MRC framework for the feasibility trial, a mixed methods approach will be taken, as it will enable the integration of both quantitative and qualitative data to provide a more comprehensive understanding of the intervention [32–34]. The duration of the study will be 30–45 days based on the recommendation of stakeholders and the time limitation of the project. Baseline data collection will start at the beginning mid of August 2022, and the post-intervention interview sessions are estimated to be completed in approximately 2 months. The flow chart of the study is shown in Fig. 1. This protocol is reported according to Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) reporting guidelines [35].

Figure 1: The timeline and components of the BeSafe intervention.



The participants' demographic information will be collected during the pre-intervention interview, and descriptive statistics will be used to summarise the data. Short message service (SMS) surveys and exit surveys will explore the immediate feedback of the participants and the adoption of skills in their farm settings after the intervention. Post-intervention qualitative interviews will explore the feasibility of adopting the target behaviour, perceived acceptability and sub-constructs of fidelity. Content analysis [36] will be used to analyse the

interview and survey data. Details of the data collected are provided in the 'data collection' section.

The AgriDemo-F2F (Agricultural Demonstrations and Farmer-to-Farmer Learning towards Sustainable Agriculture) is a European Commission-funded project that aims to enhance peer-to-peer learning within the farming community by building an interactive agridemo-hub community to promote practices and research-based farming solutions. The project is built on the principles of participatory and experiential learning, recognising that farmers learn best by seeing and doing [35, 37, 38]. The community provides guidelines and tools to design, implement and evaluate effective farmer-to-farmer learning approaches [35, 39–41]. As the current study involves peer-to-peer demonstration, we have incorporated participatory elements by following the recommendations and tools provided by the initiative. This will enhance participant engagement and comfort, and increase the effectiveness of the demonstration.

Sample size

No formal sample size calculation was performed. There are several rules of thumb, ranging from 12 to 35 participants per group, for the pilot and feasibility studies [42, 43]. This study aims to recruit a minimum of 16 participants, just in excess of the minimum recommended sample size of 12, to compensate for the anticipated dropout. Other determining factors of the size were the availability of local resources and the maximum number of participants the research team could address in a session.

Study setting

Teagasc is the semi-state authority in the Republic of Ireland responsible for research and development, training and advisory services in the agro-food sector. Teagasc personnel will assist the research team with:

1. Recruitment of the participants
2. Facilitation of in-person event
3. Arranging the demo site
4. Securing the site of intervention

All participants will be Irish farmers in contact with the Teagasc in the Republic of Ireland. The study will be conducted in selected Teagasc centres in the Republic of Ireland. To ensure the safety of the participants, the risks associated with each farm equipment that will be used in the intervention along with the preventive measures will be discussed during the session. Teagasc facilitators will be present on the demo site from the time of the preparation of the demo site to the conclusion of the event. One day before each demo, Teagasc safety officers will do a mandatory risk assessment and ensure that the demo site is safe for everyone. Safety checks will be done according to the HSA farm safety code of practice for risk assessment [44].

Eligibility criteria

The average age of farmers in Ireland is 57, and fatal incidents involving farmers aged 65 or older account for 45% of farm safety incidents [3, 45]. In the previous interventions, the age range for "older farmers" varies between 55 [8, 46] and 65 [47], depending on the context of the study, but for this project, it was defined as those aged 60 and above. The intervention is primarily designed for older farmers, but younger farmers will be included in the trial to examine the generalizability of outcomes and tailor the intervention for different age groups.

Inclusion criteria

- Currently working on farms part/full time
- Aged 18 years or older
- Have access to facilities and opportunities to share their learning from the study with someone who is not part of the study, such as a family member, neighbour or co-worker

Exclusion criteria

- Participants who report emotional distress about farm incidents and safety
- Intend to participate in any other farm interventions during the study period
- Non -English speakers

Recruitment strategy

Previous farm studies reported low participation and high attrition among older farmers [8, 22]. To ensure the participation of older farmers, at least half of the participants will be above 60 years of age. Details on the involvement of older farmers at the development stage of the study will be discussed in a separate publication.

The recruitment will be primarily carried out with the help of the Teagasc farm advisors using a purposive sampling strategy. At the beginning of the recruitment process, advisors will contact the eligible farmers to discuss the benefits of the research for farmers. To maximise the representation of different demographic groups, 50% of the participants will be aged above 60 years, and farmers from four major farm types, dairy, beef, sheep and tillage, will be recruited. The refusal rate and the reason for refusal cited by the farmers will be recorded. The research team will send the information sheet and consent form to the interested candidates. The contact details of the research team will be provided in case the participants have any questions. Once the participants sign the consent form and send it via post or email to the research team, the team will arrange a convenient time to conduct the pre-intervention phone call. During the call, before proceeding with baseline data collection, the researcher will talk the participant through the procedure to ensure they fully understand what they are consenting to and is comfortable talking about fatal incidents and safety. This will be then followed by demographic data collection (see Appendix D3 for an example topic guide).

To ensure maximum retention, participants will be offered vouchers at the completion of each stage of the study. Every participant who completes all stages of the study will receive vouchers worth 100 euros by the end of the study. The introduction session is also intended to create a rapport between the research team and the participants.

Withdrawal of study participants

Participants will be given a minimum of 2 weeks to make the decision about their participation and every opportunity to clarify any enquiries they have related to the project. Participants will be informed at every stage of the programme that they can withdraw from the study without any penalty and without giving any reason. Participants may get re-allocated to a different session or removed from the study by the researcher if they exhibit any symptoms or test positive for COVID-19 infection. The data collected from that participant up to that point will be considered for evaluation unless specifically requested by the participant to delete it.

Procedure

Participation in the study includes four stages. The stages and their timeline is as shown in the flow diagram. Once the participant expresses interest and provides consent, the primary

author will contact them to collect the baseline data and confirm their attendance at the in-person event. The intervention involves a half-day in-person event and identical demo sessions with a maximum of six participants in each session will be conducted. The maximum number of participants per session was determined per the recommendation of agridemo guidelines [35, 48] and feedback from the informal demo session. Participants can choose to participate in any one of the sessions based on their convenience. At the end of the intervention, participants will be asked to complete an exit survey to share their feedback about the intervention (see Appendix D5 for an example exit survey). The primary author will send an SMS survey after 7 days to monitor the participant's progress in the adoption of safety goals (target behaviours). All participants will be invited to take part in an online interview within 20 days of the intervention to assess the perceived acceptability of the intervention among participants.

Materials

The participants will be provided with all materials to implement the safety strategies demonstrated and discussed in the intervention session.

Data Collection

Baseline assessments

The primary author will collect demographic data and the safety devices currently used by the participant during the introductory session (stage 1) using a pre-prepared questionnaire (see Appendix D 1 for an example questionnaire).

Follow-up assessments

Immediately after completing the intervention session, participants will be requested to fill out an anonymous exit survey. An exit survey is a modified version of the feedback form provided as a part of the EU H2020 AgriDemo [35, 40, 48]. The objective of this survey is to gather participants' immediate feedback on the acceptability of intervention components. This information may also help to gain the feedback of participants who may drop out before the post-intervention interview and is expected to support the researchers in refining the interview guide for the qualitative interview. The convenient time to receive the SMS survey and set up the interview would also be collected at the end of the session.

The SMS survey is intended to remind and track the progress made by the participants on the adoption of the safety goals at their farms. The follow-up evaluation interview will be a 1-h semi-structured online interview to explore perceived acceptability, measure receipt of treatment and enactment of skills (see Appendix D3 for an example topic guide). While the SMS survey measures the progress on the completion of safety goals (home-based tasks), the interview will further explore their experience with performing the tasks at home and if they faced any barriers to completing the activities.

Study outcomes and measures

A summary of the objective, measures and tools to assess the outcomes are provided in the Table 1.

Feasibility outcomes

Consideration of feasibility criteria was guided by the agriculture literature and feasibility study guidelines [29, 49]. Feasibility will be measured based on the criteria detailed in Table 1.

These criteria will be evaluated through an intervention checklist, direct observation, audio recording of the inperson intervention sessions and reported experience of the facilitators.

Additionally, the current study will recruit farmers who have opportunities to demonstrate the learnings from the intervention to a non-participant person. During the feasibility evaluation, the authors will examine the report from the recruiters to determine whether this criterion came up as a barrier to recruitment or retention. This is especially relevant as farming in Ireland is generally small scale, with an average farm size of fewer than 14 ha, and farmers regularly meet through discussion groups or similar events [50, 51]. Peer-to-peer demonstration and facilitated discussion present a unique opportunity for knowledge sharing and learning within the community.

Fidelity of the intervention

Existing reviews indicate that the fidelity of the interventions is not often measured, reported or accounted for in the research [52, 53]. Measuring fidelity can not only ensure that core components are delivered as intended but also measure how it is delivered, the quality of the delivery and participants' engagement [52]. Following international guidance, five components of fidelity, treatment design (the degree to which the delivery adhered to the behaviour change theory that informed the design), provider training (adequacy of the training and resources to deliver intervention), intervention delivery (the degree to which the intervention components were delivered as intended), intervention receipt (the degree to which the recipients demonstrate the ability to understand and perform the safety practices), and enactment (the degree to which recipients execute the practices in their own farms), will be assessed [54, 55]. By systematically assessing different aspects of the fidelity of the intervention, researchers can identify where there might be gaps or discrepancies between what was intended and what is actually delivered. Moreover, measuring receipt helps to ensure that the intervention was delivered as intended and to the correct audience. Enactment, on the other hand, provides an accurate representation of participants' actual performance of intervention skills or implementation of the core intervention components in the intended situation. This information is important for improving the intervention's replicability and generalizability [54].

In order to measure how well the intervention is delivered as intended, the fidelity of design, training and delivery will be assessed by the primary author using a pre-established checklist. To evaluate the participants' understanding of the intervention components and application of the intervention skills in their day-to-day life, the fidelity of receipt and enactment will be explored in the follow-up assessment [54, 56].

Since the intervention is delivered by the research team, no training is required. However, the authors will be publishing an intervention manual for future studies, which will address the resources, skills and training required.

Acceptability of the intervention

A review of farm safety interventions observed that even when the researchers report the intervention and its delivery, they provide little to no information on perceived acceptability for the programme among participants [57]. Given that perceived acceptability reflects the extent to which the intervention was perceived as appropriate, the successful adoption of the intervention relies on it [58, 59].

During the intervention development phase, the study utilised the BCW framework to identify BCTs for inclusion in the intervention. As part of this process, the APEASE (Acceptability, Practicability, Effectiveness, Affordability, Spill-over effects, and Equity) criteria were utilised to ensure that the selected BCTs met the necessary criteria of being acceptable, practical and effective [23]. However, to evaluate the acceptability of the intervention and its components among participants, the study will use the Theoretical

Framework of Acceptability (TFA) framework. The TFA framework is a comprehensive and flexible framework that provides a structured approach to understanding the acceptability of interventions. It enables researchers to explore how participants feel about the intervention and why they feel that way. The study will explore the seven component constructs of TFA: Affective attitude, Burden, Ethicality, Intervention coherence, Opportunity costs, Perceived effectiveness and Self-efficacy [59]. By breaking down the concept of acceptability into several domains, the TFA framework allows researchers to identify which aspects of the intervention are most important to participants and where there might be issues with acceptability. This information is essential for tailoring the intervention to meet the needs and preferences of the target population, which can increase its uptake and effectiveness.

The follow-up assessment involves an in-depth interview that will explore the participant's retrospective perceptions of the acceptability of the intervention, the expectations and experiences of the intervention, and its key components.

Table 1: Data collection and evaluation plan.

Objective	**Indicators and outcome measures**	**Data collection method**	**Measure of success**
Feasibility Checklist			
Feasibility	Recruitment rate : % of participants recruited/time	Recruitment report by the Teagasc.	**Recruitment:** Successfully recruit a minimum two farmers from each of the four farm types: Dairy, Beef, Sheep and tillage **Retention Rate:** 80% of the participants complete the in-person session & A minimum of 12 participants complete follow up interviews. **Program structure :** At least 80% of the participant rate the program structure and content as satisfactory
	Retention and follow-up rates : % of participants completed the stage 1, stage 2, stage 3, stage 4 (Figure 1)	Audio recording of the in-person sessions Intervention checklist (Appendix D 1)	
	Time required to recruit target sample size: 16 participants recruited/time	Recruitment report by the Teagasc	
	Adherence rates: % of participants completed the stage 1, stage 2, stage 3, stage 4	Field notes and Memos from the in-person sessions	
	Rate of completion of the intervention: % of intervention activities completed by the participants	Field notes and Memos from the in-person sessions SMS Survey	
	Representation of farm population: % of participants recruited from four farm types/Total participants	Pre-intervention interview data	
	Barriers & facilitators to set up the in-person event: Factors identified by the facilitators	Recruitment report by the Teagasc Audio recording of the in-person sessions Field notes from the in-person sessions	
	Is the structure of the programme (length of the event, structure and content of the intervention) realistic, clear and reasonable for the participants? : Average score	Exit survey Post-intervention interview	

	for each of the responses in the exit survey		
	The ability of the participants to carry out the target behaviours (safety behaviours) addressed in the study: Participants' feedback about their experience	Safety training procedure Exit survey Post-intervention interview	
Fidelity Checklist (1)			
Fidelity- Intervention Design	1 - Provide information about treatment dose in the intervention condition: Detailed information about the intervention is presented in the intervention checklist, such as , a. Length of session b. Number of sessions c. Content of each session d. Duration of contact over time	Intervention checklist	**Intervention report**: Detailed report on the development of the intervention, content of the intervention and BCTs included in it using TiDier checklist. **Trial registration:** Register the study on ISRCTN registry.
	2 Theoretical model upon which the intervention is based is clearly articulated in the methodology paper and includes following information: a. The active ingredients are specified and incorporated into the intervention b. Use of experts or protocol review group to determine whether the intervention protocol reflects the underlying theoretical model or clinical guidelines	A manuscript describing the development of BeSafe Intervention	
	c. Plan to ensure that the measures reflect the hypothesized theoretical constructs/mechanisms of action		
	3 Potential confounders that limit the ability to make conclusions at the end of the trial are identified?	Post-intervention interview	
	4 Plan to address possible setbacks in implementation (i.e., back-up systems or providers)	Risk assessment document	
Fidelity- Treatment providers*	1 Description of how providers will be trained (manual of training procedures)	Intervention manual	**Intervention manual:** Complete and upload the intervention manual in a public repository.

Fidelity- Treatment delivery	1 Method to ensure that the content of the intervention is delivered as specified (content, dose, process): Number of intervention components delivered as intended/Number of intervention components expected to be delivered.	Audio recording Intervention checklist Field notes	**Delivery**: A minimum of 80% of the intervention components presented in the intervention checklist is delivered.
	2 Assessment of non-specific treatment effects: Participants report on the experience of the program vs expected outcome	Post-intervention interview	
	5 Use of Intervention manual	Project information sheet	
	6 There is a plan for the assessment of whether or not the active ingredients were delivered: Number of active ingredients delivered as intended/Number of active ingredients present in the BeSafe intervention	Audio recording Intervention checklist Field notes	
	7 There is a plan for the assessment of whether or not proscribed components were delivered. (e.g., components that are unnecessary or unhelpful)	Audio recording Intervention checklist Field notes	
	8 There is a plan for how will contamination between conditions be prevented.	N/A	
	9 There is an a priori specification of treatment fidelity (e.g, providers adhere to delivering >80% of components): Reference to 'measure of success ' column	Data collection and evaluation plan	
Fidelity- Receipt of Treatment	1 There is an assessment of the degree to which participants understood the intervention: Participants' report on their understanding of the intervention skills	Safety training procedure Exit poll Post-intervention interview	**Receipt:** A minimum of 60% of the participants complete the target behaviours at home.
	2 There are specification of strategies that will be used to improve participant comprehension of the intervention: Completion of tailored plan using the safety	Safety training procedure Exit poll Post-intervention interview	

	training procedure document & participants' feedback		
	3 The participants' ability to perform the intervention skills will be assessed during the intervention period : Self report on the confidence in completing the target behaviours and participants' feedback	Safety training procedure Exit poll Post-intervention interview	
	4 A strategy will be used to improve subject performance of intervention skills during the intervention period: Hands-on practise session on demonstration, Completion of tailored plan using the safety training procedure & participants' feedback	Peer to peer demo Safety training procedure	
	5 Multicultural factors considered in the development and delivery of the intervention (e.g., provided in native language; protocol is consistent with the values of the target group).	N/A	
Fidelity- Enactment of Treatment Skills	1 Participant performance of the intervention skills will be assessed in settings in which the intervention might be applied: Participants' self-report on the completion rate of safety goals (target behaviours)	SMS Survey Post-intervention interview	
	2 A strategy will be used to assess performance of the intervention skills in settings in which the intervention might be applied: Participants' reported experience on completing the safety goals at home	Post-intervention interview	
Acceptability checklist			
Retrospective acceptability	1 Affective attitude (How did the participant feel about the programme) : Average satisfaction score for the program in the exit survey	Safety training procedure Exit survey Follow up evaluation interview	A minimum of 80% of the participants rate the program on exit survey as "Agree" or "Strongly agree" A minimum of 80% of the participants rate their confidence in
	2 Burden (What did the participants say about the structure and ease to understand): Average satisfaction score for the		

	program structure in the exit survey and participants feedback		completing safety goals at least 7 out of 10. Evidence for perceived benefits and effectiveness of the intervention in the follow up interview.
	3 Ethicality (To what extent the strategy helped in performing the farm tasks) : Average satisfaction score for the program and topics covered in the programme in the exit survey		
	4 Intervention coherence (How did participant feel in terms of understanding the tasks and performing it by himself) : Participants' report on what they learned during the program		
	5 Opportunity costs (What were the benefits the participants perceived) : Participants' feedback		
	6 Perceived effectiveness (To what extent did the participant felt that strategy was effective) : Participants' report on what they learned during the program		
	7.Self-efficacy (How confident and comfortable was the participant at performing the task) : Average confidence score for each the target behaviours in the safety training procedure document		

* Treatment is delivered by the research team. Hence no training sessions required.

Data analysis

As per the pilot and feasibility studies guidelines, quantitative data analysis will be descriptive [60, 61]. The demographic characteristic of participants and the use of safety devices on their farms will be summarised using descriptive analysis. Qualitative data will be audio-recorded and transcribed verbatim using a third-party transcription service. Transcribed data, along with survey data, documented field notes and memos, will be managed using MaxQDA 2020 [62] and analysed by the primary author using content analysis to explore the feasibility, fidelity and perceived acceptability. To ensure the accuracy and reliability of the data analysis, a rigorous process will be followed. To begin with, half of the transcripts will undergo double coding by two independent researchers. The remaining transcripts will be coded by AS alone. In case of any discrepancies in the coding, the researchers will discuss and arrive at a consensus.

During the evaluation design phase, reported outcomes of previous farm interventions were considered while determining the factors for measuring the programme's success. For example, farm safety literature suggests that 25–77% of the farmers contacted could be expected to agree to participate [63–67], and an average of 80–100% satisfaction was

reported among the participants with the previous farm safety intervention programmes [9, 67, 68]. Since the study will be conducted in the summer, farmers' busy work schedules and vacation plans are also expected to influence participation and retention [69]. To measure treatment fidelity, the study will adhere to the National Institutes of Health Behavior Change Consortium guidelines, which define high treatment fidelity as having more than 80% adherence to the intervention checklist [49]. The researchers will use the intervention checklist, which provides a clear outline of the key components of the intervention and serves as a guide for implementation. The researchers will evaluate adherence by comparing the actual implementation of the intervention to the checklist and assessing the percentage of key components that were successfully implemented. The criteria outlined in Table 1 are established a priori to evaluate the success of the study, specifically the feasibility of implementing the intervention, the extent to which participants received the intended intervention and the acceptability of the intervention among participants. If some of the criteria are not met, the authors will investigate the potential causes of failures and consider changes to the intervention components and its delivery methods before deciding whether to recommend the development of a future larger trial to test the effectiveness of the intervention.

Data management and monitoring

All participants will be assigned an identification number and a pseudonym, which will be used for the discussion of transcripts by the research team and in the publication of the study results. Consent forms and audio/video/electronic recordings could all contain information that could be used to identify a participant. Audio and video recordings will be deleted after transcribing them. Forms and transcribed data will be retained for 7 years. Hard copies, if any, will be stored in a locked filing cabinet within a restricted area. Access to this filing cabinet will be restricted to the study personnel and will be overseen by the principal investigator. Soft copies and Electronic recordings of meetings will be password protected and will be stored on a OneDrive/SharePoint network of the research sponsor. Access to these files will be overseen by the principal investigator. Due to the low risks associated with this behavioural intervention, there are no pre-specified interim analyses or stopping rules. Due to the low risks associated with this behavioural intervention, the study anticipates minimal occurrence of adverse events directly associated with the intervention. Any adverse events will be reviewed by the study team according to the Teagasc Advisory Discussion Group safety guidelines.

Discussion

This paper describes the protocol for a feasibility study that explores the feasibility, fidelity and acceptability of a novel intervention to address blind spots of tractors.

Evidence indicates that behavioural interventions have the potential to address the health habits of the population at a low cost [70]. Yet, the active adoption of behavioural change techniques in farm research has been slow. This study will provide useful information that will aid in adopting various BCTs to increase the knowledge, intention to adopt and adherence to preventive farm practices. Previous reviews and our own review of the farm safety literature identified a gap in theory-driven intervention development as well as the reporting and assessment of its active ingredients [1, 6, 7, 71]. The intervention content and the evaluation procedure are described in this study, which will enable the replication or adoption of the intervention or one of its ingredients in future studies.

Conclusions

This study is limited, in generalisation, due to the small sample size. However, by evaluating intervention content and delivery, the study is expected to provide evidence of the feasibility of each ingredient, its delivery and its acceptance among participants. This could facilitate farm safety researchers to create and implement behavioural change theory-centred, tailored, and targeted strategies to address farm safety.

Availability of data and materials[10]

The dataset supporting the conclusions of this article is included within the article. Additional data supporting the project is available in the OSF repository.

Author contribution statement

AS, JMS and DOH conceptualised and designed the study. AS drafted the initial manuscript. AS, JMS, OM and DOH reviewed and revised subsequent versions. FB, JMN and DM provided expertise in the study design, evaluation strategies and logistics of the study. JMN and FB helped with the implementation of the study. DOH is the grant holder.

Reference

1. Rautiainen RH, Lehtola MM, Day LM, Schonstein E, Suutarinen J, Salminen S, et al. Interventions for preventing injuries in the agricultural industry. Cochrane Database Syst Rev. 2008 Jan 23;(1):CD006398.
2. Department of Agriculture, Food and the Marine. Farm Safety [Internet]. Department of Agriculture, Food and the Marine. 2022 [cited 2022 Jul 26]. Available from: https://www.gov.ie/en/publication/4133b-farm-safety/?referrer=http://www.gov.ie/farmsafety/
3. Murphy M, O'Connell K. Farm Deaths and Injuries: Changing Irish Farmer Attitudes and Behaviour on Farm Safety. In 2017. p. 15. Available from: https://sword.cit.ie/dptmecp/2/
4. Health, Safety Authority. A Review of Work-Related Fatalities in Agriculture in Ireland 2011-2020 [Internet]. Health and Safety Authority; 2021. 44 p. Available from: https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/a_review_of_work-related_fatalities_in_agriculture_in_ireland_2011-2020.pdf
5. Hard DL, Myers JR, Gerberich SG. Traumatic injuries in agriculture. Journal of Agricultural Safety and Health. 2002;8(1):51.
6. DeRoo LA, Rautiainen RH. A systematic review of farm safety interventions. American journal of preventive medicine. 2000;18(4):51–62.
7. Lehtola MM, Rautiainen RH, Day LM, Schonstein E, Suutarinen J, Salminen S, et al. Effectiveness of interventions in preventing injuries in agriculture—a systematic review and meta-analysis. Scandinavian journal of work, environment & health. 2008;327–36.
8. Nilsson K. Interventions to reduce injuries among older workers in agriculture: a review of evaluated intervention projects. Work. 2016;55(2):471–80.
9. Stave C, Törner M, Eklöf M. An intervention method for occupational safety in farming -- evaluation of the effect and process. Appl Ergon. 2007 May;38(3):357–68.
10. McCurdy SA, Carroll DJ. Agricultural injury. American journal of industrial medicine. 2000;38(4):463–80.
11. Nag PK, Gite LP. Farm Accidents and Injuries. In: Human-Centered Agriculture [Internet]. Singapore: Springer; 2020. p. 175–204. (Design Science and Innovation). Available from: https://link.springer.com/chapter/10.1007/978-981-15-7269-2_8

[10] In the appendix, we have included most of the supplementary files published along with the journal. However, a few supplementary files that are not included here can be accessed on our Open Science Framework (OSF) profile or on the respective publisher websites.

12. Shortall S, McKee A, Sutherland LA. Why do farm accidents persist? Normalising danger on the farm within the farm family. Sociology of Health & Illness. 2019;41(3):470–83.
13. Alwall Svennefelt CE, Hunter E, Palsdottir AM. Work safety interventions and threat complexity-a formative investigation into why farmers do not act safely. Annals of agricultural and environmental medicine [Internet]. 2019;26(2). Available from: https://agro.icm.edu.pl/agro/element/bwmeta1.element.agro-91269381-f265-4b01-8e47-2b8307316a80
14. Narasimhan GR, Peng Y, Crowe TG, Hagel L, Dosman J, Pickett W. Operational safety practices as determinants of machinery-related injury on Saskatchewan farms. Accident Analysis & Prevention. 2010;42(4):1226–31.
15. Sorensen JA, Tinc PJ, Weil R, Droullard D. Symbolic interactionism: A framework for understanding risk-taking behaviors in farm communities. Journal of agromedicine. 2017;22(1):26–35.
16. Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. Bmj [Internet]. 2008;337. Available from: https://www.bmj.com/content/337/bmj.a1655.short
17. Bluethmann SM, Bartholomew LK, Murphy CC, Vernon SW. Use of theory in behavior change interventions: an analysis of programs to increase physical activity in posttreatment breast cancer survivors. Health Education & Behavior. 2017;44(2):245–53.
18. Gielen AC, Sleet D. Application of Behavior-Change Theories and Methods to Injury Prevention. Epidemiologic Reviews. 2003 Aug 1;25(1):65–76.
19. Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implementation science. 2011;6(1):1–12.
20. Moore SA, Avery L, Price CI, Flynn D. A feasibility, acceptability and fidelity study of a multifaceted behaviour change intervention targeting free-living physical activity and sedentary behaviour in community dwelling adult stroke survivors. Pilot and Feasibility Studies. 2020;6(1):1–13.
21. McNamara J, Kinsella A, Osborne A, Blake C, Meredith D, Kinsella J. Identifying farmer workplace injury risk factors in Ireland using farm accounts data. Journal of agromedicine. 2021;26(4):411–9.
22. McCallum DM, Reed DB, Claunch DT, Davis CM, Conaway MB. Farm Dinner Theater: testing an innovative health and safety intervention among older farmers and their families. The Journal of Rural Health. 2022;38(2):433–41.
23. Michie S, Atkins L, West R. The behaviour change wheel: a guide to designing interventions [Internet]. Silverback Publishing; 2014. Available from: https://silverbackpublishing.org/products/behaviour-change-wheel
24. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Annals of behavioral medicine. 2013;46(1):81–95.
25. Surendran A, Mc Sharry J, Meade O, Bligh F, McNamara J, Meredith D, et al. Increasing Machine-Related Safety on Farms: Development of an Intervention Using the Behaviour Change Wheel Approach. [cited 2023 Apr 4]; Available from: https://www.mdpi.com/1660-4601/20/7/5394
26. Hoffmann TC, Glasziou PP, Boutron I, Milne R, Perera R, Moher D, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. Bmj [Internet]. 2014;348. Available from: https://www.bmj.com/content/348/bmj.g1687
27. De Silva MJ, Breuer E, Lee L, Asher L, Chowdhary N, Lund C, et al. Theory of change: a theory-driven approach to enhance the Medical Research Council's framework for complex interventions. Trials. 2014;15(1):1–13.
28. Bowen DJ, Kreuter M, Spring B, Cofta-Woerpel L, Linnan L, Weiner D, et al. How we design feasibility studies. American journal of preventive medicine. 2009;36(5):452–7.

29. Arain M, Campbell MJ, Cooper CL, Lancaster GA. What is a pilot or feasibility study? A review of current practice and editorial policy. BMC medical research methodology. 2010;10(1):1–7.
30. Lancaster GA, Thabane L. Guidelines for reporting non-randomised pilot and feasibility studies. Pilot and Feasibility Studies. 2019;5(1):1–6.
31. Loft MI, Poulsen I, Martinsen B, Mathiesen LL, Iversen HK, Esbensen BA. Strengthening nursing role and functions in stroke rehabilitation 24/7: A mixed-methods study assessing the feasibility and acceptability of an educational intervention programme. Nursing Open. 2019;6(1):162–74.
32. Fetters MD, Curry LA, Creswell JW. Achieving Integration in Mixed Methods Designs—Principles and Practices. Health Services Research. 2013;48(6pt2):2134–56.
33. Skivington K, Matthews L, Simpson SA, Craig P, Baird J, Blazeby JM, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. BMJ [Internet]. 2021 Sep 30 [cited 2022 Dec 23];374. Available from: https://www.bmj.com/content/374/bmj.n2061
34. Tickle-Degnen L. Nuts and bolts of conducting feasibility studies. The American Journal of Occupational Therapy. 2013;67(2):171–6.
35. Patton MQ. Qualitative research & evaluation methods [Internet]. 4th ed. sage; 2002. Available from: https://us.sagepub.com/en-us/nam/qualitative-research-evaluation-methods/book232962
36. Cawley A, Heanue K, Hilliard R, O'Donoghue C, Sheehan M. How Knowledge Transfer Impact Happens at the Farm Level: Insights from Advisers and Farmers in the Irish Agricultural Sector. Sustainability. 2023 Feb 10;15(4):3226.
37. Murphy M, O'Connell K. Systemic Behaviour Change: Irish Farm Deaths and Injuries. 2018;
38. Koutsouris A, Papa E, Chiswell H, Cooreman H, Debruyne L, Ingram J, et al. AGRIDEMO: The Analytical Framework: Demonstration Farms as Multipurpose Structures, Providing Multi-Functional Processes to Enhance Peer-to-Peer Learning in the Context of Innovation for Sustainable Agriculture. 2017; Available from: . https://agridemo-h2020. eu/publications-deliverables
39. i2connect - Interactive Innovation [Internet]. i2connect. [cited 2021 Nov 10]. Available from: https://i2connect-h2020.eu/
40. Marchand F, Chiswell H, Ingram J, Pappa E, Alexopoulos Y, Koutsouris A, et al. Best Practice for on-Farm Demonstration Activities [Internet]. p. 1–85. Available from: https://agridemo-h2020.eu/docs/D6.1_Best%20practical%20approaches_final.pdf
41. Sutherland LA, Marchand F. On-farm demonstration: enabling peer-to-peer learning. The Journal of Agricultural Education and Extension. 2021;27(5):573–90.
42. Bell ML, Whitehead AL, Julious SA. Guidance for using pilot studies to inform the design of intervention trials with continuous outcomes. Clinical epidemiology. 2018;10:153.
43. Hertzog MA. Considerations in determining sample size for pilot studies. Research in nursing & health. 2008;31(2):180–91.
44. Health, Authority S. Farm Safety Code of Practice Risk Assessment Document [Internet]. Health and Safety Authority; 2017. https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/a_review_of_work-related_fatalities_in_agriculture_in_ireland_2011-2020.pdf. Available from: https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/a_review_of_work-related_fatalities_in_agriculture_in_ireland_2011-2020.pdf
45. Lee MJ, Cawley DT, Ng JP, Kaar K. Trends in the Fractures and Fatalities of Farmyard Injuries in Ireland: A 10 year analysis. 2017; Available from: https://www.lenus.ie/handle/10147/621063
46. Myers JR, Layne LA, Marsh SM. Injuries and fatalities to US farmers and farm workers 55 years and older. American journal of industrial medicine. 2009;52(3):185–94.
47. A Review of Work-Related Fatalities in Agriculture in Ireland 2011-2020. :44.
48. Tools for evaluation and follow-up [Internet]. FarmDemo Training kit. 2021 [cited 2022 May 4]. Available from: https://trainingkit.farmdemo.eu/tools-for-evaluation-and-follow-up/

49. Tickle-Degnen L. Nuts and bolts of conducting feasibility studies. Am J Occup Ther. 2013;67(2):171–6.
50. Dillon E, Hennessy T, Moran B, Lennon J, Lynch J, Brennan M, et al. Teagasc National Farm Survey: the sustainability of small farming in Ireland. Teagasc; 2017.
51. O'Connor T, Meredith D, McNamara J, O'Hora D, Kinsella J. Farmer discussion groups create space for peer learning about safety and health. Journal of agromedicine. 2021;26(2):120–31.
52. Lorencatto F, West R, Bruguera C, Michie S. A method for assessing fidelity of delivery of telephone behavioral support for smoking cessation. Journal of Consulting and Clinical Psychology. 2014;82(3):482.
53. Toomey E, Currie-Murphy L, Matthews J, Hurley DA. Implementation fidelity of physiotherapist-delivered group education and exercise interventions to promote self-management in people with osteoarthritis and chronic low back pain: a rapid review part II. Manual therapy. 2015;20(2):287–94.
54. Bellg AJ, Borrelli B, Resnick B, Hecht J, Minicucci DS, Ory M, et al. Enhancing treatment fidelity in health behavior change studies: best practices and recommendations from the NIH Behavior Change Consortium. Health psychology. 2004;23(5):443.
55. Borrelli B, Sepinwall D, Ernst D, Bellg AJ, Czajkowski S, Breger R, et al. A new tool to assess treatment fidelity and evaluation of treatment fidelity across 10 years of health behavior research. Journal of consulting and clinical psychology. 2005;73(5):852.
56. Borrelli B. The assessment, monitoring, and enhancement of treatment fidelity in public health clinical trials. Journal of public health dentistry. 2011;71:S52–63.
57. Dyreborg J, Lipscomb HJ, Nielsen K, Törner M, Rasmussen K, Frydendall KB, et al. Safety interventions for the prevention of accidents at work: A systematic review. Campbell Systematic Reviews. 2022;18(2):e1234.
58. Proctor E, Silmere H, Raghavan R, Hovmand P, Aarons G, Bunger A, et al. Outcomes for implementation research: conceptual distinctions, measurement challenges, and research agenda. Administration and policy in mental health and mental health services research. 2011;38(2):65–76.
59. Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC health services research. 2017;17(1):1–13.
60. Grimes DA, Schulz KF. Descriptive studies: what they can and cannot do. The Lancet. 2002;359(9301):145–9.
61. Lancaster GA, Dodd S, Williamson PR. Design and analysis of pilot studies: recommendations for good practice. Journal of evaluation in clinical practice. 2004;10(2):307–12.
62. Verbi S. MAXQDA [Internet]. Berlin: VERBI Software; 2019. Available from: https://www.maxqda.com/new-maxqda-2020
63. Kim JS, Yoon SY, Cho SY, Kim SK, Chung IS, Shin HS. Effectiveness of participatory training for the promotion of work-related health and safety among Korean farmers. Industrial health. 2017;
64. Rasmussen K, Carstensen O, Lauritsen JM, Glasscock DJ, Hansen ON, Jensen UF. Prevention of farm injuries in Denmark. Scandinavian journal of work, environment & health. 2003;288–96.
65. Rasmussen K, Carstensen O, Lauritsen JM. Incidence of unintentional injuries in farming based on one year of weekly registration in Danish farms. American journal of industrial medicine. 2000;38(1):82–9.
66. Brison RJ, Pickett CWL. Non-fatal farm injuries on 117 eastern Ontario beef and dairy farms: A one-year study. American journal of industrial medicine. 1992;21(5):623–36.
67. Alwall Svennefelt C, Lundqvist P. Safe farmer common sense'-A national five-year education-based program for prevention of occupational injuries in Swedish agriculture-background, process, and evaluation. Journal of agromedicine. 2020;25(2):221–30.

68. Reed DB, McCallum D, Claunch DT. Changing health practices through research to practice collaboration: the Farm Dinner Theater experience. Health Promotion Practice. 2021;22(1_suppl):122S-130S.
69. Horsburgh S, Langley JD. Recruitment and retention of farm owners and workers for a six-month prospective injury study in New Zealand: a feasibility study. Journal of Occupational Medicine and Toxicology. 2011;6(1):1–10.
70. Michie S, Carey RN, Johnston M, Rothman AJ, De Bruin M, Kelly MP, et al. From theory-inspired to theory-based interventions: a protocol for developing and testing a methodology for linking behaviour change techniques to theoretical mechanisms of action. Annals of behavioral medicine. 2018;52(6):501–12.
71. Colémont A, Van den Broucke S. Psychological determinants of behaviors leading to occupational injuries and diseases in agriculture: a literature overview. Journal of agricultural safety and health. 2006;12(3):227–38.

Chapter 7 The Feasibility, Fidelity and Acceptability of BeSafe- a Behaviour Change Intervention Targeting Tractor Safety Among Irish Farmers: A Mixed Methods Study[11]

Authors: Aswathi Surendran[1], Sandra Malone[2], Oonagh Meade[1],David Meredith[3], Francis Bligh[3], John McNamara[3], Jenny McSharry[1] and Denis O'Hora[1]

[1]School of Psychology, University of Galway, H91 TK33 Galway, Ireland
[2]School of Health and Human Performance, Dublin City University, D09 V209, Dublin, Ireland
[3]Irish Agriculture and Food Development Authority, R93 XE12 Carlow, Ireland

*****Correspondence: Author: Aswathi Surendran; Email: s.aswathi@nuigalway.ie

Abstract

Background

Farm-related injuries and fatalities remain a significant concern, necessitating the development of effective behaviour change interventions. This manuscript presents the findings of a feasibility study that evaluates BeSafe, a stakeholder-informed, theory-driven intervention to improve tractor safety among Irish farmers. The study explored the (1) feasibility of recruiting and retaining participants throughout the trial, including individuals from diverse demographic backgrounds, (2) the fidelity of the intervention design, treatment delivery, treatment receipt, and the enactment of treatment skills, and (3) the acceptability of the intervention and its components among Irish farmers.

Methods

A mixed-methods design was used, including field notes, exit surveys and qualitative interviews as data sources. Quantitative data were analysed descriptively, and qualitative data were explored using Directed Content Analysis with abductive coding.
*Results***:** Twenty participants were recruited, and seventeen participants completed the trial. The intervention was well-received by the participants, who expressed appreciation for its farmer-centric approach. Participants actively engaged with the intervention and demonstrated interest in sharing their experiences. The feasibility and fidelity of the intervention components were confirmed. Specifically, peer-to-peer demonstrations were highly accepted, indicating the potential for promoting safer farm practices through a peer-to-peer learning approach. While certain components, such as the SMS component, had varying levels of engagement and acceptance, overall, the intervention received high acceptability among participants.

Conclusion

The positive feedback and active engagement from participants support the potential effectiveness of the intervention in enhancing tractor safety among Irish farmers. The intervention's multifaceted approach showed promising results in increasing awareness of

[11] Surendran, Aswathi and Malone, Sandra and Meade, Oonagh and Meredith, David and Bligh, Francis and McNamara, John and McSharry, Jenny and O'Hora, Denis, The Feasibility, Fidelity and Acceptability of Besafe for Tractor Operations - a Behaviour Change Intervention Targeting Tractor Safety Among Irish Farmers: A Mixed Methods Study. Available at SSRN: https://ssrn.com/abstract=4751475 or http://dx.doi.org/10.2139/ssrn.4751475

safety risks and a greater sense of responsibility for their safety and that of their families. Further research is warranted to evaluate the long-term impact and scalability of the intervention.

Practical Application

The intervention's adaptability to various farm settings and demographics and potential as a train-the-trainer model suggest broader applicability within the farming community. These findings contribute to the evidence for farmer behaviour change interventions, guiding future evaluations and policy decisions.

ISRCTN Identifier: ISCTN22219089[1]. Date applied 29th July 2022
Keywords: Farm safety, demonstration, intervention fidelity, Theoretical Framework of Acceptability, peer-to-peer learning, tractor, agriculture, farmers.

Introduction

Vehicles and machinery are one of the main causes of farm fatality in Ireland, accounting for approximately 50% of all farm deaths in the past ten years.[2] Roll-overs, crushing, and collisions with other vehicles or objects are among the primary causes of machinery-related incidents and fatalities on Irish farms.[2–4] Blind spots on tractors play a crucial role in these incidents due to the restricted visibility of objects, vehicles, or persons in the vehicle's path, especially while reversing.[5,6] Despite the implementation of enhanced safety measures in tractors, such as roll-over protection structures (ROPS), rear-view cameras, and mirrors, tractor-related incidents persist as a critical safety concern. Notably, these incidents are especially alarming for vulnerable groups, such as elderly farmers and children, who face a disproportionately higher risk of injuries and fatalities.[2,7] This highlights the urgent need for interventions seeking to enhance tractor safety and increase awareness of associated risks.[5,7,8]

To date, most machinery-related farm safety interventions employed educational approaches that informed farmers of (i) the risks of injury and (ii) safer machinery handling practices to reduce those risks. Farmers were provided with knowledge regarding practices that could eliminate, reduce, and control physical hazards, along with an understanding of the risks associated with maintaining their current practices or transitioning to safer practices.[9] Therefore, these education-based approaches are heavily dependent on farmers figuring out the local implementation of these best practices. However, the implementation of such best practices solutions can be challenging due to the heterogeneous nature of farm contexts and the predominance of small farm operations (often sole operators) and lone workers. The dependence on individuals to localise best practice safety interventions to their farming content increases the potential influence of socio-psychological factors as barriers and facilitators of farm safety behaviour and the long-term adoption of safe work practices. Such factors, including individual characteristics (e.g., age and gender), social norms, knowledge, attitudes, and external pressures, can significantly impact farmers' ability to engage in safe behaviours.[10–13] It has been consistently demonstrated within health behaviour change research that such barriers need to be identified and accommodated for, in order for interventions to be implemented successfully.[14,15] The current intervention, BeSafe, aims to increase safety awareness and adoption of safer work practices amongst Irish farmers, particularly older farmers. Intervention development was informed by the Behaviour Change Wheel[16] and recommendations from key farming stakeholders[17] to facilitate implementation.

The Medical Research Council's guidance framework for evaluating complex interventions in health research proposes that feasibility trials should be conducted on a small scale prior to the large-scale rollout of interventions.[18] A small-scale feasibility study primarily focuses on assessing the intervention's delivery and acceptability in the target population and identifying potential issues that need to be addressed before a large-scale evaluation.[18–20] Fidelity, which refers to the degree to which an intervention is delivered as intended, is a crucial aspect to consider when evaluating the feasibility of an intervention. By examining the feasibility and fidelity of an intervention, we can determine whether it can be delivered as intended and sustained over time on a larger scale.[19,21] Furthermore, evaluating the acceptability helps determine if the intervention is relevant, meaningful, and valuable to the target audience, which can increase engagement and uptake.[22]

The manuscript presents findings from a mixed-method feasibility study that assessed the acceptability, feasibility, and fidelity of the BeSafe intervention and components. The objectives were to:

1. Assess the recruitment and retention of participants until trial completion

2. Assess the feasibility of recruiting participants from diverse demographic backgrounds and of recruiting a manageable group size that facilitates effective communication and engagement.
3. Evaluate the fidelity of intervention design (ensuring that the intervention was implemented as intended), fidelity of treatment delivery (ensuring that the intervention was delivered consistently and accurately), fidelity of treatment receipt (ensuring that participants received the intervention as intended), and fidelity of enactment of treatment skills (assessing the extent to which participants successfully applied the skills taught in the intervention).
4. Assess the acceptability of the intervention and its components among participants.

Method

The pre-print of the protocol that describes the feasibility trial has been published, which includes a detailed description of the study design, inclusion criteria, sample size, measure of success (progression) criteria, data analysis and evaluation procedures.[23] The Good Reporting of a Mixed-Methods Study (GRAMMS)[24] and the Template for Intervention Description and Replication (TIDieR) checklist [25] were followed (Appendix 1, 2). As detailed in the protocol, specific criteria were established a priori to assess the success of the study in terms of feasibility, fidelity, and acceptability, aligning with recommended guidelines for conducting feasibility studies.[19]

Theory and Development

The intervention development was guided by the Behaviour Change Wheel (BCW)[16] and followed a four-phase process. In Phase 1, the problem of tractor safety was defined based on a comprehensive literature review.[9] Phase 2 involved conducting focus group discussions with older farmers to identify the barriers and facilitators to farm safety and acquire suggestions for intervention strategies using the Capability–Opportunity–Motivation–Behaviour (COM-B) model. Phase 3 included expert and stakeholder consultation, guided by the BCW, to determine target behaviours and intervention components. The intervention aimed to increase farmers' awareness of tractor safety and address blind spots to improve overall farm safety. It incorporated appropriate Behaviour Change Techniques (BCTs)[14] to promote safer tractor handling and blind-spot identification. The intervention components and delivery strategies were designed to align with the existing occupational safety approach in Ireland, ensuring relevance and effectiveness within the local context. Phase 4 focused on finalising evaluation strategies with agricultural advisors and identifying outcome measures for the current trial. Further details of the intervention development and specific BCTs used in the intervention have been published previously.[17,23]

The BeSafe intervention consisted of five components that were delivered in one day at Teagasc facilities and an online component that was delivered one week later (Figure 1). This study employed a single-group feasibility trial, and the intervention was delivered in person.

Study Design

To comprehensively evaluate the intervention, a mixed-method approach was employed, chosen for its flexible data collection and integration of quantitative and qualitative data,[26] in line with prior research highlighting its advantages in feasibility trials.[27–29]

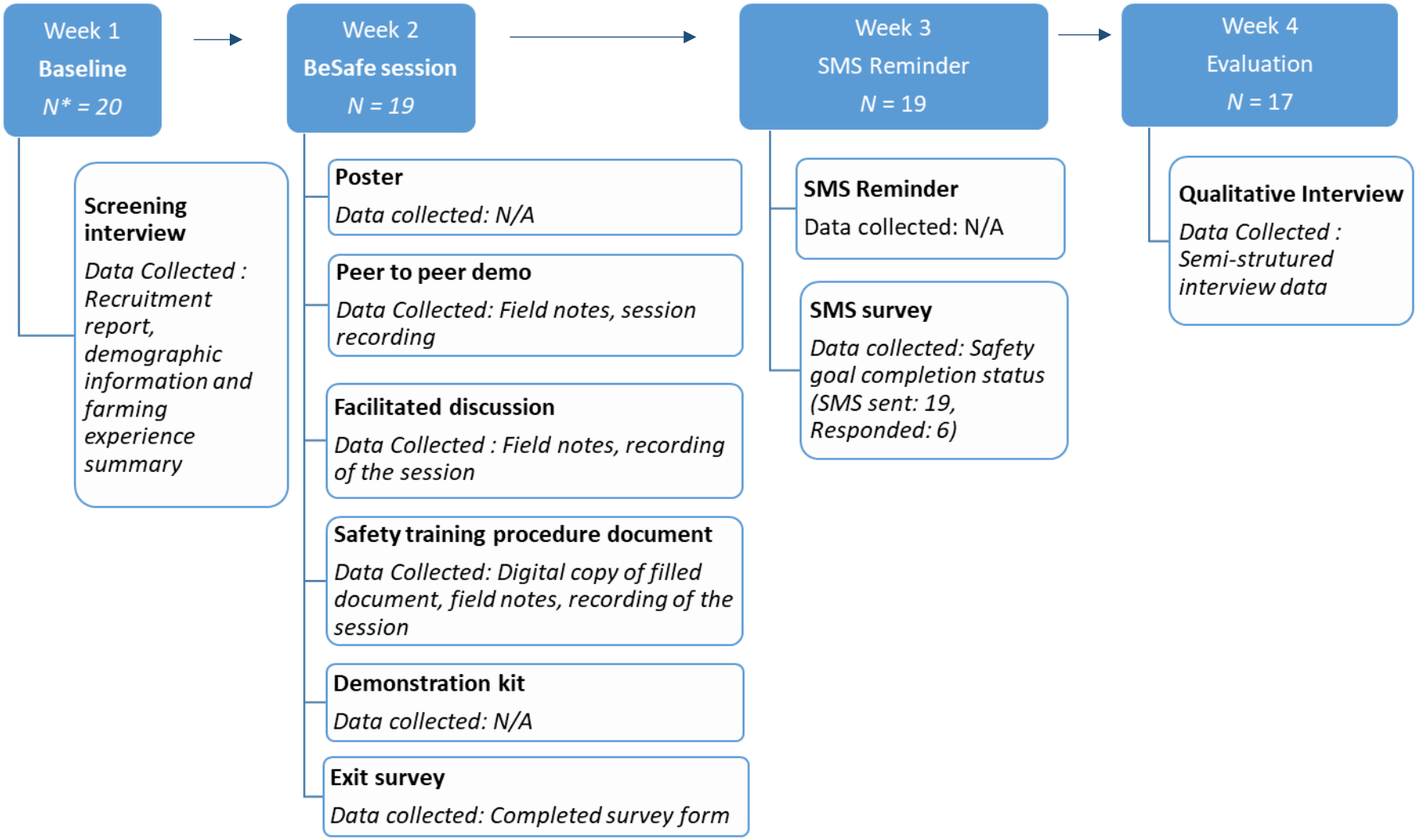
Setting

BeSafe is a research project funded by the Department of Agriculture, Food and the Marine (DAFM), Ireland, supported by the Irish Health and Safety Authority (HSA) and operated by Teagasc (the semi-state body in the Republic of Ireland responsible for research and

development, training and advisory services in the agro-food sector) to develop safety interventions to enable long-term changes to machine-related safety on farms. BeSafe was designed and delivered by researchers from the University of Galway (AS, DOH, JMS) and Teagasc farm researchers (DM, FB, JMN). Teagasc supported and managed participant recruitment and intervention delivery. Two Teagasc facilities (Athenry and Kildalton campuses) were selected for the in-person sessions based on availability and resources. One doctoral student (AS), two Teagasc advisory team members (JMN and FB) and on-campus safety instructors facilitated the intervention sessions. During the preparation phase, multiple practice runs were conducted with the advisory team (JMN and FB) and a farm representative to refine the intervention components further.

JMN and FB contacted the eligible farmers directly. Purposive sampling ensured the inclusion of a diverse range of farmers representing various sectors such as dairy, beef, sheep, and tillage. Eligible participants who expressed interest received invitations, along with study information sheets and consent forms. Online Skype screening interviews (~15 minutes) conducted by AS established rapport, collected baseline data and assessed participant suitability based on factors such as comfort in discussing farm fatalities and the availability of necessary facilities to execute the target behaviours. Participants were invited to attend one of three in-person intervention sessions held at Teagasc centres based on their convenience. After the in-person session, participants were invited to participate in post-intervention qualitative interviews (~ 30-40 minutes), allowing for detailed feedback collection. A gratuity of €40 and €60 One4All gift vouchers were given to participants for their participation in the in-person session and post-intervention qualitative interview, respectively.

Figure 1: Intervention and data collection summary.



*N = Number of participants who completed the session.

Trial Registration and Ethical Approval:
The study received ethical approval from the Research Ethics Committee of the University of Galway (#2022.05.009), and participants provided informed written consent for participating in this study.

Participants

In total, 20 farmers from two Irish counties were recruited. They completed the screening interview approximately three days before the in-person sessions. The screening interview collected demographic information and participants' farming experience, including the farm vehicles and safety devices they own and operate. To obtain prevalence data on farm-related incidents among participants, their family members and close friends, participants were encouraged to report their 'accident history' in this interview.

Data Collection

Recruitment took place from August to September 2022, with evaluations at four different time points (Figure 1) to evaluate various aspects of the intervention. First, participants completed a screening interview, where baseline data (socio-demographic information and farming experience) was collected. At the in-person intervention delivery session, in the Safety training procedure template (previously referred to as the safety agreement document in the protocol)[23], participants indicated their confidence in executing the target behaviours at home to measure their understanding and ability to execute target behaviours at home.

At the end of the in-person session, an anonymous paper-based exit survey[23] was administered to gauge participants' opinions on the session's structure, intervention components, and topics discussed. Acceptability was measured using a 5-point Likert scale ranging from 1 "*strongly disagree"* to 5 "*strongly agree*". One week later, participants received an SMS survey with yes-or-no questions to monitor their progress at home, that is, the enactment of safety goals.

Approximately 14 days post-intervention, AS conducted individual semi-structured qualitative interviews via Skype, each lasting 15-40 minutes. These online audio-recorded interviews aimed to explore participants' understanding and enactment of target behaviours, as well as their perceived acceptability of the intervention. Participants reflected on their experiences with home-based demonstrations and no-visibility zone marking on tractors, discussing the barriers and facilitators to the enactment of target behaviours and developing a habit of the regular 360-degree check around the tractor. The interview schedule was informed by the Theoretical Framework of Acceptability (TFA)[22] and the National Institutes of Health Behaviour Change Consortium (NIH BCC) Treatment Fidelity Framework checklist.[21] The interview schedule was further refined based on initial exit survey findings, ensuring a comprehensive exploration of participant experiences. Assessing participants' perspectives at multiple time points (i.e., immediately post-intervention and 14 days post-intervention) allowed for a nuanced understanding of the intervention's acceptability as participants engaged in the intervention in their home environment.

To assess intervention feasibility, data was gathered through multiple sources that included field notes, recruiter reports, exit surveys, and interview transcripts. The fidelity assessment employed the criteria outlined in the fidelity checklist[21], including design, delivery, receipt, and enactment. The analysis of design and delivery involved a thorough review and analysis of audio recordings of the intervention sessions, as well as field notes and project documentation. The focus was to ensure that the intervention was delivered as intended and adhered to the established protocols. Training fidelity was not analysed as the research team themselves delivered the intervention. Data collected from the exit survey and post-

intervention qualitative interviews informed the assessment of receipt of treatment and enactment of treatment skills.

Data Analysis

The quantitative data from the baseline interview, safety training procedure template and surveys were inputted into Microsoft Excel and analysed using descriptive statistics. The qualitative data from the interviews were recorded, transcribed verbatim and anonymised by AS. Participants were assigned identification numbers during transcription to ensure anonymity and confidentiality (e.g., P1= participant 1). Directed content analysis with abductive coding was used to allow for the discovery of new patterns or themes from the data, enhancing the understanding of participants' experiences and perceptions within the study.[30,31] Abductive content analysis was conducted in the following phases: preparation, organisation, and reporting. The first phase identified the data collection and sampling strategy as well as the unit of analysis. The second phase involved data categorisation and abstraction, interpretation, and checking the representativeness of the sample data collected. The final phase was the systematic and logical reporting of the abstractions.
During the organisation phase, the data were systematically organised and categorised. Using MAXQDA version 25 software[32], AS analysed the entire qualitative data set while SM analysed 50 percent of the data as part of the quality assurance process. Initially, codes were developed based on constructs from the TFA and two constructs of the NIH BCC fidelity checklist (Receipt of Treatment and Enactment of Treatment Skills) (Appendix E1).

Following the coding schema preparation, AS and SM independently coded a subset of transcripts. A subsequent meeting discussed the codes, identifying agreements, disagreements, and potential additions to the schema. These meetings fine-tuned the schema, addressing ambiguity and disagreements while enhancing clarity. For example, there were challenges in differentiating between references to intervention coherence and perceived effectiveness in participant discussions. Multiple discussions and references to similar studies helped clarify and define the definition and scope of each code. After resolving any discrepancies, AS coded all transcripts and SM double coded 50% of the transcripts. This iterative process allowed for continuous refinement and improvement of the coding schema. Additionally, SM's farming background proved invaluable in understanding and clarifying farm-specific situations described by participants during the interviews.

Results

A total of 20 participants were recruited. Among the 20 recruited participants, nineteen attended one of the three in-person intervention sessions. Six participants responded to the SMS survey, while seventeen participated in the post-intervention evaluation online interview (Figure 1). The topic guide is available in Appendix D3. With regards to attrition, one participant dropped out of the session after baseline data collection without providing a reason, and another two dropped out post-intervention due to time constraints.

Demographic information is displayed in Table 1, while responses to the exit survey are illustrated in Figure 2-4.

Table 1: Demographic and Farm Accident History Information of Participants (N=20).

Variable	Category	Total %, (*n*)
Age	18-30	15 (3)
	31-54	35 (7)
	55+	50 (10)
Farm Type	Dairy	65 (13)
	Beef	55 (11)
	Sheep	20 (4)
	Tillage	10 (2)
Working Status	Contractor	1
	Part-time	0
Farm Accident History	None	45 (9)
	Self	45 (9)
	Others	40 (8)
Farm Accident Classification	None	47.4 (9)
	Machinery	36.8 (7)
	Animal	31.6 (6)
	Chemical	10.5 (2)
	Other accidents	5.3 (1)
	Fatality	10 (2)

Figure 2: Responses to the Exit Survey (N=19).

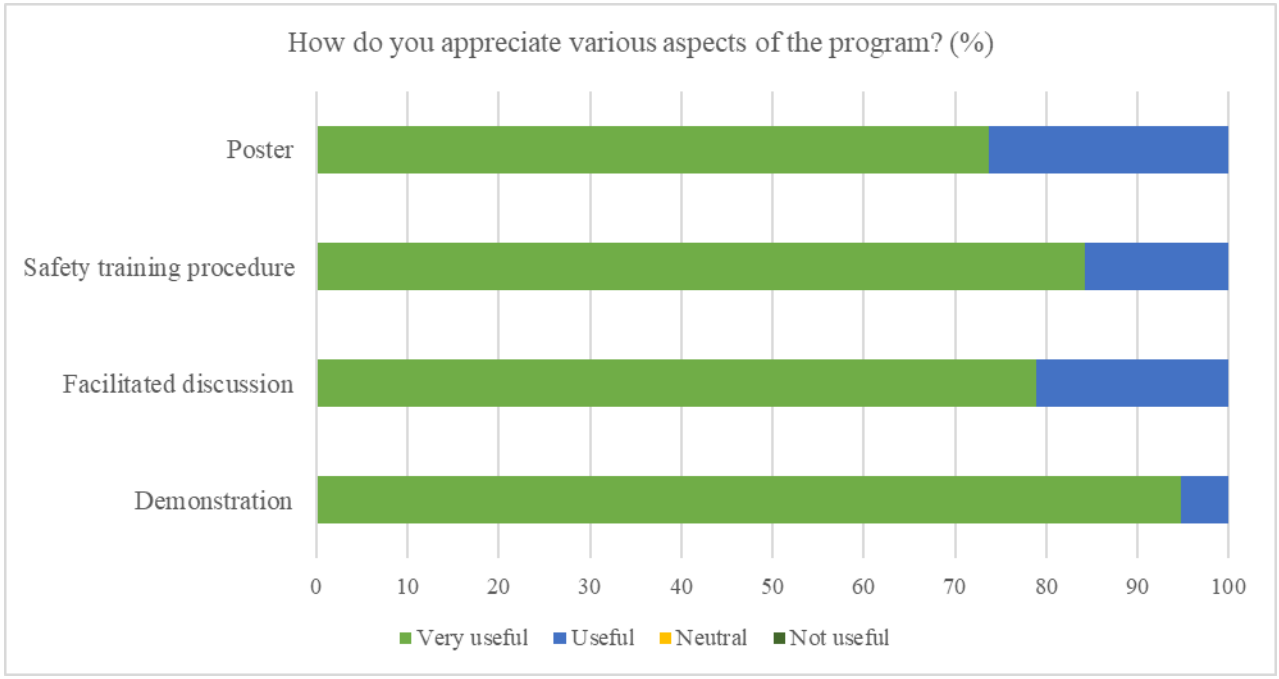


Figure 3: Responses to the Exit Survey (N=19).

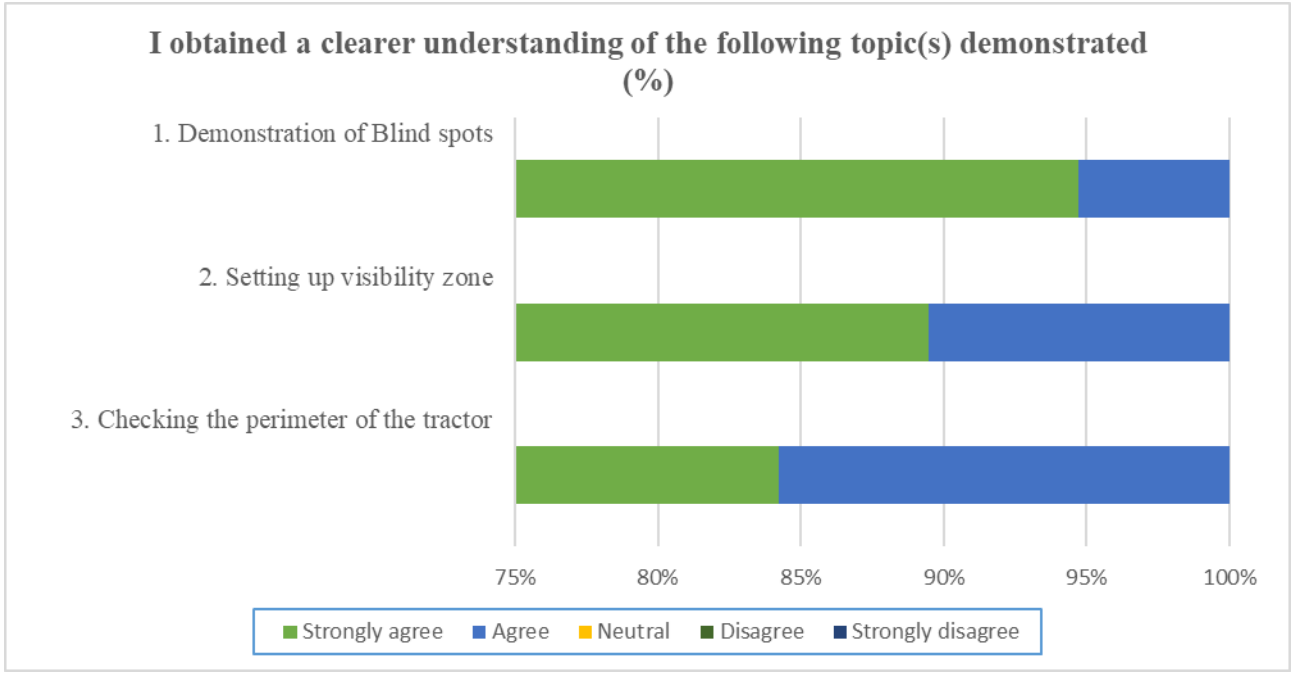
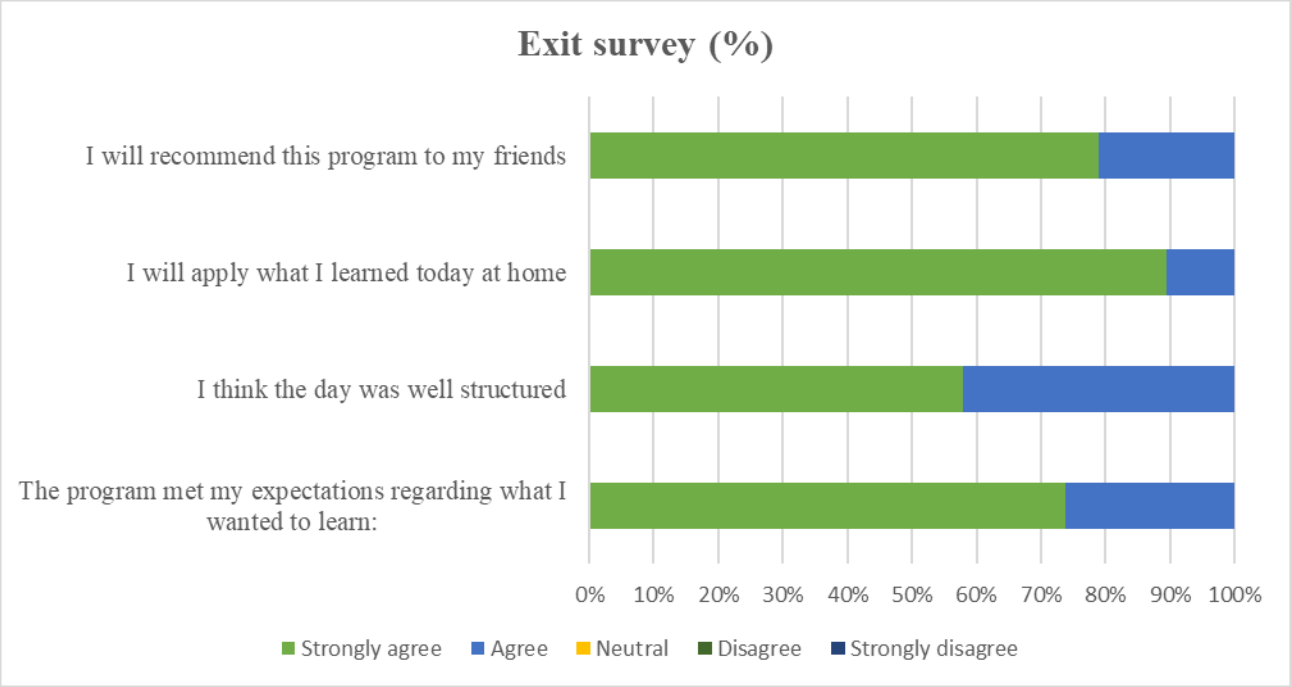


Figure 4: Responses to the Exit Survey (N=19).



Feasibility

Feasibility data was assessed against predefined progression criteria (Appendix E3), determining the intervention's feasibility for future rollout and larger-scale trials.

Facilitators reported that the intervention components were feasible to deliver within the proposed timeline. Participant feedback demonstrated that the presentation and organisation of the intervention were well-received. Participants stated that it was well-run, and the topics were addressed satisfactorily, with clear and concise instructions (Figure 4).

"*I think the course was very interesting. I think you have done everything very well. I think just to get farmers to do it because they learn a lot from the course as I said. I don't know. I know I learned a lot anyway. I think you've it well organised*."(P16)

Recruitment and Retention of Participants Until Trial Completion

The study reported an overall 85% retention rate, with 17 of the 20 participants completing the trial. With eight out of the ten older participants recruited, a retention rate of 80% was observed among older participants (55 years or above) (Table 1).

During the qualitative interview, some participants reported that they agreed to participate due to their familiarity with the recruitment team. The recruitment reports from facilitators also support this finding.

*"Now ***(JMN) had asked me would I do it and I said I would do it. Even though I know it was well worth doing, if I saw that just advertised somewhere I probably wouldn't."* (P8).

The participants from the Kildalton session were familiar with JMN. However, at Athenry, FB had difficulty in recruiting participants, especially older farmers, and had to seek assistance from local Teagasc officers. Some concerns with regard to larger-scale recruitment were noted. Participants were sceptical of the feasibility of large-scale recruitment for a half-

day safety programme and therefore suggested integrating the intervention components with existing farm initiatives such as marts, for example.

"I'd say having the demonstration where the people are rather than going looking for them to come".(P19)

During the qualitative interviews, participants repeatedly highlighted that they enjoyed the hands-on sessions and discussions, indicating that the format increased engagement. During the practice run, farm representatives shared insights on strategies to increase participant retention. They emphasised that when participants were given specific tasks to complete at their own farms and asked to report their progress during the interview sessions, they were more likely to return and actively engage in sharing their experiences. To facilitate this, clear expectations were set while participants prepared the safety training procedure template, outlining the tasks they were required to perform at home and the specific observations they needed to make, such as blind spots unique to their own tractors. The effectiveness of this strategy was supported by the high retention rate and participants' interest in sharing their experiences with completing home-based activities.

Feasibility of the Group Composition and Size

Group composition: In the qualitative interview, participants reported that the age composition of the group was highly effective, providing an opportunity to interact and learn from others who had different perspectives, experiences, and attitudes towards safety. They acknowledged that younger farmers are vulnerable due to their limited experience, while older farmers are also vulnerable due to declining health. This highlights the relevance and applicability of the programme for farmers of all age groups. Additionally, the diversity of participants facilitated the transfer of knowledge related to both general and specific farm safety scenarios. The presence of older farmers had the added benefit of raising awareness among younger farmers and fostering learning through shared experiences and stories. According to older participants, this relationship was mutual as older farmers could learn about modern tractors and machinery from the younger farmers. Furthermore, participants expressed that the session was highly relatable as it mirrored their farm environments, where generations of fathers and sons work together. This aspect created a strong connection and resonance, allowing participants to easily relate to the programme and apply the learnings to their farming contexts.

"*The big advantage of that is that you had different experiences and different mindsets because people have different lives and think about things slightly differently. So by having a bigger age group, you'd probably get more views of the cohort of farmers that might be around from young to old as well".*(P6)

Group size: During the qualitative interviews, participants were asked about their experiences with the group size, its impact on their engagement and focus during the sessions and their preferred group size. Participants provided positive feedback regarding the group size, stating that the small number of participants allowed them to remain focused on the tasks at hand. Most participants found the current group's size apt, but a few suggested that a group size of up to 15 participants would be acceptable for effective communication and engagement.

"It probably worked well because there wasn't too big a group. If you've too many at a thing like that, the people around in the background probably lose interest a bit, or they're not listening so they might be chatting among themselves or something."(P8)

The feasibility assessment indicated that the intervention components were well-received and effectively implemented. Participants actively participated in the activities and were enthusiastic to share their experiences with the home-based demonstrations. Aside from the

concerns regarding recruitment for larger-scale trials, the intervention had high feasibility in terms of structure, organisation, group composition and size.

Fidelity Assessment: Analysing Design, Delivery, Receipt, and Enactment

Fidelity of Design and Delivery

To evaluate the fidelity of design and delivery, audio recordings of the intervention sessions, field notes, and intervention protocol were carefully reviewed and analysed. All intervention components were delivered consistently and in line with the intervention checklist across the three sessions, except for the facilitated discussion in session three (Appendix E3). The discussion session in the third session deviated from the intended topics of interest as participants spent considerable time discussing other safety features of the tractors, such as three-point hitches, safety insurance and policies.

Fidelity of Receipt and Enactment – Understanding the Intervention Skills and Practices

This study thoroughly assessed the fidelity of treatment receipt and enactment through multiple data sources (exit survey, safety training procedure template, and post-intervention qualitative interviews), providing a comprehensive view of participants' confidence and progress in implementing the intervention strategies.

Figure 5: Reported confidence on the safety goal completion

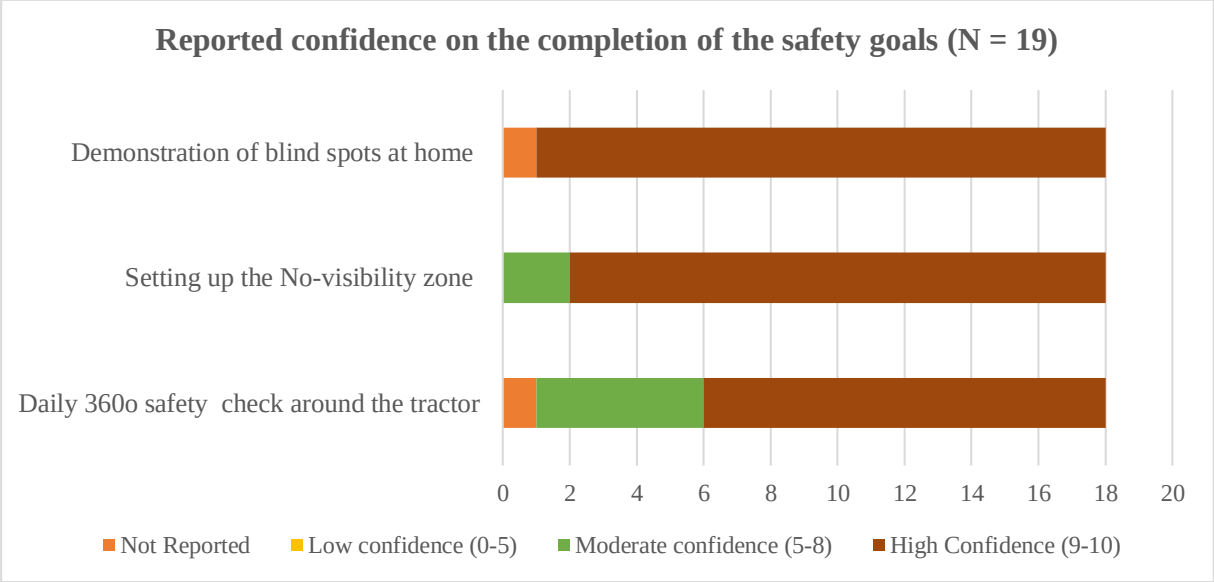
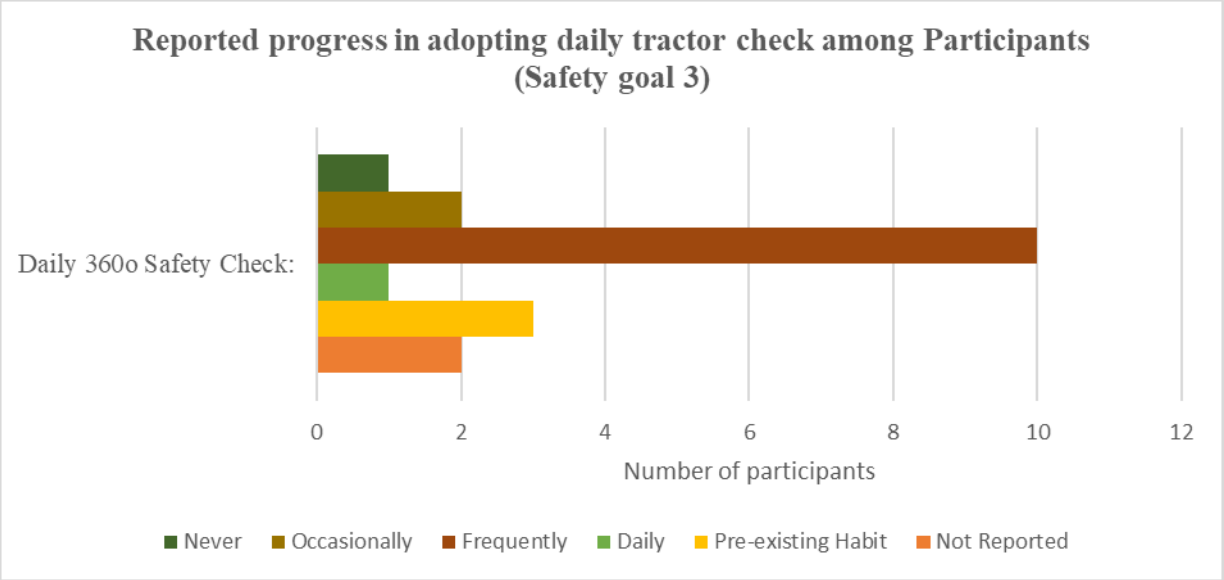


Figure 6: Completion status of safety goals among participants



In the safety training procedure template, participants self-reported their confidence levels on a scale of 1-10 in executing designated tasks at home, revealing higher confidence in the initial safety goals, particularly blind spot demonstration and creating a no-visibility zone. In contrast, confidence was relatively lower for the third goal, involving daily tractor pre-operation checks (Figure 5). This self-assessment aligned with participants' reported progress at home.

Of the 17 participants who completed interviews, all successfully accomplished the first two safety goals. The third goal, establishing a daily habit of pre-operation tractor checks, exhibited slightly varied results, with approximately 60% of participants reporting frequent or regular safety checks (Figure 6). This 100% completion rate for the initial safety goals demonstrates participants' ability to transfer learned skills to their home settings, indicating a high level of treatment receipt and enactment.

"I wouldn't have done that before (360-degree check). That was the first time that was actually mentioned to me. I'm more aware of it. I mightn't be doing it every time, but I definitely wasn't aware of it before"(P4)

Participants' experiences of conducting demonstrations at home revealed another layer of fidelity. They shared that they conducted these sessions with a diverse range of individuals, including family members, friends, employees, and neighbours. On average, each participant engaged 2.47 people in home demonstration sessions, totalling 42 individuals involved in these sessions. Feedback from participants highlighted the positive reception of the home demonstrations, with several expressing intentions to repeat these sessions with new employees, students, or visiting family members in the future.

"*We have done on the practical side of it (demonstration). We have it done three or four evenings now…Also, in the summertime when you've young lads in big silage trailers, obviously, they're dealing a lot with these blind spots, so you know we'd probably use it to that advantage. We'd use it in our own situation to demonstrate that just because you're sitting up on a tractor, it doesn't mean you can see everything. You realise that there's a blind spot when you view it from a distance.. I suppose that's what we have picked out, and we're hoping to use that to go forward ourselves*."(P17)

While exploring their experience of performing the demonstration at home, they indicated the concept of sending them back to educate their own families as an effective and beneficial approach. They recognised the value of not only acquiring knowledge and skills themselves but also being able to impart this knowledge to their family members. They perceived it as an opportunity to enhance farm safety awareness and promote safer practices among their loved ones.

"[My father]thought it was a very good idea because it was an eye-opener for him. He wasn't aware that there was so many blind spots. Even in relation to the loader when I was out the front with the little Jimmy [cardboard cut-out of a child] as we called him he found it interesting that there was some places where he thought he would have been able to see him he wasn't. He said it was very good from that point of view that even going forward if he was standing out in front of me let's say and we were attaching some implement to the loader that he's more aware that he'd have to stand further out so I can actually see his hand signals when he's guiding me compared to where he thought he should be."(P15)

This study primarily focused on participants' experiences during the intervention sessions. It also yielded noteworthy data regarding home demonstrations, their influence, and suggestions for future topics. Some participants reported insights/impacts from their home demonstrations, such as increased awareness of hidden dangers around machinery and ensuing discussions on safer practices. These observations, while valuable, will be further explored in future analyses.

"[At home] when I sat in that tractor and when we put out our cones and the yellow man, you obviously think well, I'm going to see that, but as you showed, blind spot is there, and you can't see it. Now I brought one of my..long time employees.and I got him to do it, and he couldn't believe it. He couldn't believe you know. And to be fair to him, he would have a great knowledge of machinery because he's working twenty years at it and.he can see the need, I suppose, to try and show some bit of safety."(P17)

Acceptability of the BeSafe intervention

The findings from the acceptability evaluation are presented for each intervention component (demonstration, facilitated discussion, safety training procedure document, demonstration kit, BeSafe poster, and SMS reminder), as well as the overall intervention.

Peer to Peer Demonstration

The demonstration played a crucial role in highlighting the dangers of blind spots and educating farmers about blind spot safety measures. This section discusses the overall acceptability and effectiveness of the demonstration, which comprised two distinct sessions: 1) Estimation of stopping distance and 2) Blind spot demonstration. While some participants considered these sessions as a single demonstration and discussed them together, others provided separate feedback for each component.

Blind spot demonstration was deemed the most effective and useful component, generating positive feedback from participants in the exit survey. During qualitative interviews, participants demonstrated a positive affective attitude towards the demonstration, especially the hands-on nature of the demonstration.

"The fact that it was a hands-on approach more so and that everybody got an opportunity to see and talk about what was going on, I found it very practical and very interesting".(P17)

In addition, participants enjoyed the on-farm location, which enhanced engagement and mirrored their own everyday work environment:

"Farmers are used to being outside [and] will only fall asleep inside in a warm or an air-conditioned room. That's not what they're used to...When farmers are out in an environment they're used to, they'll be more inclined to engage".(P14)

The estimation of stopping distance sessions evoked shock among some participants, who were taken aback by the distance covered by the tractor in a short period of time.

"We were surprised at how far the tractor did go and would go in that length of time, you know what I mean. You wouldn't realise it."(P9)

Participants also found the hands-on blind spots demonstration enjoyable, straightforward and easy to comprehend. In the interview, participants reported it as a valuable learning experience, and some recollected their enthusiasm when they were invited to do the demonstration. The reported burden for the demonstration was low, with no major challenges reported in performing the demonstrations at the event or at home. Participants appreciated the breakdown of information into shorter tasks, preventing information overload and reducing subsequent burdens.

"I think it is a good way of doing it and breaking it down, and it is not too much information in the one go. It's manageable bits. The worst thing you can do is overload with too much information and none of it is retained, whereas this was to the point, and it is got the message". (P15)

In terms of ethicality, participants viewed the demonstration as an appropriate method of raising safety awareness and reported no discomfort with the demonstration. As mentioned previously, participants strongly favoured an outdoor or field demonstration rather than an uncomfortable and unfamiliar classroom setting. Some farmers emphasised the importance of including children, mothers, and younger farmers in future sessions to increase the impact of the intervention.

"We need to have a mother on the next course, especially a mother who is familiar with farmyards and machines as well. Mothers need to be aware because then they can educate the children at home and also educate the fathers."(P5)

A few participants also recommended using older tractors in future demonstrations, as not all farmers have or are familiar with the modern tractor used in the demonstration.

"... you had top tractors there ... You wouldn't find them on every farm".(P13)

Regarding intervention coherence, participants reported a clear understanding of the underlying strategy to promote farm safety. Participants found the stopping distance demonstration with the stopping distance details displayed on the chart a practical and meaningful way to convey the dangers associated with a moving tractor. They further emphasised the benefits of active, hands-on participation, enabling them to observe real-life hazards associated with tractor blind spots.

"I mean, everyone can read, and we all have our health and safety booklets. You got the warning? When you put it into action and see it on the ground. It makes you more aware."(P4)

Participants observed that the demonstration component was highly effective in increasing participants' awareness of blind spot dangers and the importance of implementing safety

checks. The participants' shock, which was explained earlier, illustrated its effectiveness in demonstrating the potential dangers associated with tractor stopping distance.

"...the distances is done out for you. You were able to read out the speed. You were able to stand at it. And it was surprising the distances as the speed went up on the tractor the distance it took to stop. And I'd say it surprised a lot of the rest of them as well". (P13)

This activity successfully conveyed the importance of being aware of one's surroundings while operating a tractor, encouraging participants to pay attention to blind spots. Participants expressed a clearer understanding of blind spot locations and reported increased confidence in performing safety measures.

"And it showed a lot of the things, I'll be honest, I didn't realise, and I'm all my life driving tractors, that somebody can be standing so near to you and that they don't have to be a child and there's a blind spot. That's what I found. There's a lot of common sense in this".(P18)

Observing the demonstration from both ground level and the operator's seat gave participants a comprehensive understanding of the risks from different perspectives.

"I have seen it even on the day we were doing it up there with ye that sitting on the tractor is grand, but it is nice to be able to get down on the ground and do both, and you can see both. You can nearly see it as the person that the other person mightn't see." (P15)

However, one participant found that the no-visibility zone area (as shown in the poster and marked by the participants) was too narrow and constricted. They suggested extending the zone by 20 metres, as even those who are in the immediate surroundings but outside of the no-visibility tractor zone are also in danger. They suggested that demonstrations should include a red, yellow, and green zone in the future, for example, each highlighting a specific area and level of danger around the tractor.

"I would broaden the area way outside. I wouldn't concentrate at all inside the red area... We shouldn't have been concentrating so near on the tractor, that red area."(P5)

Participants reported high self-efficacy in executing the demonstration on the day and at home (Figure 6). The clear and concise instruction, accompanied by the practice during the session, facilitated a clear understanding of how to perform the demonstration at home.

"*It was [easy] because I explained it like as you have done for us. You showing it made it easier to explain and simpler ...Once we were shown what to do, it made it easier to show someone else*." (P9)

Even participants who typically felt uncomfortable in front of others reported feeling at ease and comfortable while performing the demonstration in the current setting.

"I wouldn't be someone entirely comfortable with getting up in front of a crowd to teach ... but I didn't mind doing it."(P12)

When asked for improvements for the demonstration, the participants did not suggest any improvement other than the aforementioned suggestion of including additional zones and the inclusion of older tractors for the demonstration. In fact, participants reported that this hands-on format not only effectively addresses the specific blind spot demonstration but also holds the potential for addressing a range of safety concerns prevalent on the farm. Their suggestions included utilising similar demonstrations to address diverse safety aspects such as the timely replacement of brakes, proper installation and management of power take-off

(PTO) covers and proper linkage of trailers. They further highlighted its suitability for incorporation into varied educational settings, such as farmer discussion groups, farm markets, and training courses like the Green Certificate.

'"I think if you can come back with as good a demonstration as you gave us for other areas, absolutely it would work. I think it is a good concept ".(P12)

Overall, the demonstration effectively increased participants' awareness of blind spot dangers, enhanced their self-efficacy, and provided them with practical skills to implement safety measures on their farms. The practical and experiential nature of the demonstration was found to be highly acceptable among participants.

Facilitated Discussion

The exit survey indicated that all participants found the facilitated discussion useful. The interviews further support this finding, with participants describing the discussion as informative, interesting, and engaging. Participants noted that they learned a lot from others and were allowed to share their experiences. One participant reported that the session was shorter than they would have liked.

In terms of coherence, participants' feedback indicated that they understood the purpose of the discussion. They viewed the discussion as an opportunity for farmers to share their diverse experiences and learn from each other. They highlighted the importance of learning from their peers, as hearing first-hand stories of close accident encounters or hazards experienced is the most effective way of highlighting the importance of farm safety.

"...a different viewpoint for different farms you know. Because they might have a danger in their particular situation that I wouldn't have." (P11)

The facilitated discussion was perceived as effective in summarising key learning points and addressing other safety topics by some participants. Overall, farmers perceived the discussion as an effective means of knowledge transfer. However, there were a few instances in the last session where the discussion deviated from the intervention's focus as participants brought up unrelated safety topics. While most participants were interested in those topics, a few others were not. They proposed that facilitators need to ensure that the discussions remain on blind spots.

"I found it good, but one or two kind of went off topic and were talking about things that..yes, they were in relation to safety, but they weren't quite what we were there for. We were there to discuss blind spots, and I think they just ran away with talking about trailers...which is all relevant in the greater scheme of safety, but it wasn't relevant to the topic. Maybe suggest that there is someone there to chair the meeting and ensure that people aren't rambling off and going off topic."(P15)

Overall, the findings from the facilitated discussion session understood the importance of creating spaces for farmers to share experiences, exchange knowledge, and collectively work towards improving farm safety.

Safety Training Procedure Document

Survey findings indicated that all participants found the document useful, but in the follow-up interviews, the majority had difficulty recalling the document and its content. Regarding affective attitude, participants generally found the safety training procedure template useful and practical, noting that it provided clear guidelines and tangible goals to work towards. Participants also understood the underlying aim of the co-signing process and acknowledged that signing the agreement instilled a sense of ownership and accountability, motivating them

to actively complete the safety goals at home. Participants acknowledged that signing the agreement made them feel "contractually obliged" to carry out the tasks. Participants did not express concerns about their ability to complete the documents during or after the session, indicating perceived ease of use, although a few older participants expressed concerns about the burden of additional paperwork.

"it definitely did [help].. And it kind of gives you a timeline as well. It definitely helps to give you that goal and to make you more accountable, I suppose, for actually partaking in the task…. Three goals is a manageable number. Whereas if you go too many, it sometimes will deter people. They'll think oh, that's an awful lot for me to do."(P15)

Most participants completed the tasks within 4-5 days post-intervention and did not refer to the document post-intervention. Participants observed that the goal setting and timeline for completion helped them to be prompt in executing the tasks. Some participants suggested that providing a short period for task completion was beneficial, considering farmers' tendency to postpone safety obligations. Some proposed to assign an accountability partner who co-signs the agreement and follows up about completing the required tasks.

"You would explain to them that you're going to ask you to pair up … you say can you pair up who do you think you're comfortable with. You should do it with the permission of the participants that I would contact the other person by the deadline of two weeks' time. I would either text him or call him and say hello P1, I presume you have your form filled out and your [goals] finished. I think it would be way better and stronger by asking them".(P5)

Despite some difficulty in recalling the content of the document, the majority of participants (89.5%, *n*=17) completed the safety goals (Figure 6), demonstrating the document's effectiveness in summarising the safety goals. Overall, the safety training procedure template was viewed as an effective tool to assist in planning the tasks, outlining the safety goals and creating a sense of accountability. However, the dislike of paperwork and poor recall of its content highlighted its short-term impact.

Demonstration Kit

Participants found the cardboard cut-out and spray paints highly effective and engaging visual aids. The use of the aids at home suggested a clear understanding of the purpose and use of the materials provided. One participant noted that immediate access to the materials allowed for a prompt demonstration at home without delay and procrastination.

"It was a lot easier to do and carry out when you had everything you needed in that pack. Because otherwise you'd be trying to source something to mark it on the ground and you mightn't have it, and then you mightn't bother doing the task".(P15)

They also found the cut-out effective as it could be customised according to family members' height, although there were differing opinions on its size. For example, while some participants found the size sufficient, others felt it was too small and suggested alternative items like safety cones or wooden logs that could be used in place of the cut-out. Participants thought the spray paint was highly effective as it allowed them to mark blind spots on the ground around their tractor, thus creating a lasting and visible outline, ensuring that blind spots were easily identifiable even after a few days. A few participants showed the markings to family members who visited their farms in the days following the demonstration.

"I suppose the thing with that is you can adjust the height of it [cardboard cut-out] in terms of the different sizes of people or objects. I couldn't think of any alternative way of doing it to be honest with you. It seems to be as good a method as there is to do it. And then

you can get out of the tractor, and especially with the spray paint you can see the outline of the blind spots. it is probably the handiest way of showing it." (P14)

Apart from one participant who displayed the poster at home for his workers, others did not mention their use of the other materials in the kit, such as the posters and project information document. Overall, the findings suggest that the resources encouraged task completion at home and allowed for customisation according to their farm environment. However, similar to the safety training procedure template document, participants lacked interest in the documents shared in the demonstration kit.

"That poster is actually up in the student's canteen where they have their dinner. So, we put them up just to help the awareness and keep it fresh in their mind as well." (P6)

BeSafe Poster

In the exit survey, participants reported the BeSafe poster as useful (Appendix E2). Similar to the previous document component (safety procedure document), the majority had difficulty recalling the document and its content in the follow-up interview.

"*I probably do need to refresh myself on the poster, to be honest".* (P12)

Those who could recall the poster found the use of statistics and visual aids effective as it made the information easier to comprehend. While most viewed the posters as an effective means of illustrating safety messages and summarising the statistics, others believed that farmers were tired of seeing and hearing about fatality statistics. Participants suggested that highlighting the severe consequences of farm accidents, such as crush injuries and disabilities, could increase the effectiveness of the poster. They emphasised the importance of not solely focusing on fatalities but also highlighting the higher numbers of individuals who experienced severe injuries.

"*you should try and get some figures about the people got crushed or were rolled over.… maybe you don't have the [high number of] fatalities but maybe you have another higher figure for serious injuries where people sustained serious injuries. You don't have to say that people got killed but look at the people that got crushed that were disabled that broke legs, that got crushed."(P5)*

SMS Reminder

Despite all participants receiving an SMS text message reminder to report their safety goal progress and a survey link to report their safety goal progress, only six participants engaged with the survey. Out of these six respondents, all reported completing all three safety goals.

During the interview, only eight participants reported seeing the reminder. Participants completed the activities at home without waiting for the SMS reminder, mentioning that they did so while the details were fresh in their minds post-intervention. Few participants found the reminder beneficial and viewed it helpful to complete the safety goals, whilst others did not see its purpose. Interestingly, one participant noted that while young people may benefit from receiving a reminder through their mobile phone, a letter from Teagasc or the Irish Farmers' Journal may be more effective for older farmers. No one reported difficulty with accessing the SMS survey or filling it out.

"I suppose it was a reminder. It did remind us to be safety conscious all the time. For young people, getting a gentle reminder through your phone every now and again would be a help to safety. For older people...it is as much as a letter from Teagasc or the farmer's journal or with the 1 o'clock news on a Sunday".(P14)

A few participants preferred a sticker to be included in the demonstration kit to remind them to complete the 360-degree safety check (safety goal 3) as they found it hard to build a habit of the routine check around the tractor. Another participant requested another reminder SMS three months post-intervention.

Overall, the findings suggest that the SMS had not served its intended purpose as a reminder and future trials should consider age-appropriate mediums for the reminder.

Overall Acceptability of the Programme

Farmers' overall perception of the acceptability of the BeSafe programme was highly positive, according to the exit survey and participant feedback. All participants expressed high satisfaction with the intervention, reporting confidence in their skills and knowledge related to implementing blind spot safety behaviours on their farms.

All interview participants (*n*=17) reported that they were happy and comfortable in demonstrating blind spots and setting up the no-visibility zone at home. Participants showed great enthusiasm about demonstrating the programme at home to their family and friends, highlighting its acceptability. Some reported the applicability of intervention content to demonstrate other safety topics, noting that they will use the skills they acquired to educate their workers and students on placement.

"When I set up that system with the yellow man one lad that's twenty years driving tractors, he laughed, but he couldn't believe the knowledge that was learned from that."(P17)

Participants appreciated that the programme was farmer-centric and based on common sense. They found the peer-to-peer demonstrations particularly effective in promoting farm safety awareness and believed the programme could address other farm safety issues as well. Participants did not encounter difficulties participating in the programme and perceived it as practical and manageable due to its short duration and practical nature.

" you're doing excellent work. I would say, why didn't someone do it before this, you know, with farmers throughout the ages, no one ever bothered their heads going as far as you've gone with it."(P13)

In summary, the BeSafe intervention showed promise in terms of feasibility, fidelity, and acceptability. Its hands-on, practical components were particularly well-received and effective.

Discussion

The current study employed a mixed-methods approach to evaluate the feasibility, fidelity, and acceptability of the BeSafe intervention. This multifaceted evaluation not only encompassed the intervention as a whole but also examined the acceptability of its individual components at two distinctive time points. This approach allowed for a detailed assessment of the intervention components and their contributions to overall acceptability as well as the revealing of the evolving nature of participant perceptions. This is the first study to integrate an acceptability framework into the feasibility assessment of a farm machine safety intervention, enriching our understanding of farmers' attitudes toward farm safety interventions. These insights offer valuable guidance in selecting suitable intervention components and appropriate delivery methods aligned with specific objectives, thereby facilitating the development of targeted strategies for maximum engagement.

Overall, the intervention was well-received by participants. This acceptability was reflected in positive remarks about the program's affective attitude, perceived effectiveness, and overall coherence. Importantly, participants reported few concerns regarding the burden or

opportunity costs associated with the intervention, indicating that they found it engaging and valuable without major drawbacks.[22] The hands-on nature of the demonstration and facilitated discussion aligned well with farmers' preference for practical and relatable learning experiences. However, positively regarded in the exit survey, the poster and SMS reminder components showed less acceptability in qualitative interviews, highlighting the evolving acceptability and differential impact of intervention elements over time. This understanding can guide future interventions by identifying components suited for short-term communication and longer-term impact, contributing to a more tailored and effective approach to promoting farm safety awareness.

Furthermore, participants demonstrated strong receipt of the intervention, showcasing a clear understanding of the core concepts and how to apply the skills taught in BeSafe. This understanding extended to skill enactment, as participants actively applied the demonstration and modelling skills they acquired in real-world farm situations. This practical application underscores the real-world relevance and applicability of the program.

Our findings align with previous research emphasising the importance of considering farmers' unique characteristics, such as age and receptiveness to change, in designing effective interventions.[12,33] Previous education-based interventions[8,34] primarily aimed to raise awareness among farmers about the risks associated with machinery use and promote safer handling practices. While these efforts are important, they do not account for the demographic factors that influence farm safety behaviour and the long-term adoption of safe work practices.[10,11,35,36] Age, for instance, has been identified as a significant factor in farm safety. Older farmers are potentially more resistant to change[37] and less receptive to safety interventions, resulting in poor participation and retention of older farmers in farm safety interventions.[38,39] The present study sought to fill this gap by adopting a multifaceted approach beyond traditional educational strategies such as lectures, videos and newsletters.[8,34] The intervention development process incorporated various sources of knowledge, including evidence from the literature, expert advice, and the input of older farmers themselves.

The active involvement of farmers throughout the development process was crucial in ensuring the acceptability and appropriateness of the intervention, particularly for older farmers who may have unique needs and preferences. Their feedback played a vital role in shaping the intervention, from the initial design stages to making amendments for refining protocol and materials in the practice run. Notably, our study observed a high retention rate among older participants during the evaluation phase, contrary to challenges often reported in retaining older individuals.[38,39] Our findings suggest that the farmer-centric nature of the program may have contributed to sustained engagement and fostered positive experiences throughout the intervention, leading to higher participant retention. The positive responses and recognition of the farmer-centric approach underscore the success of the stakeholder-informed development process.

Farmers perceived the BeSafe programme as highly effective and distinct from previous safety programmes. The hands-on nature of the program, particularly the peer-to-peer demonstration, resonated well with farmers' preferences for experiential learning.[40–43] By sitting on the tractors themselves and experiencing the limitations of visibility and blind spots firsthand, participants gained a deeper understanding of the safety risks associated with operating a tractor. This experiential learning process was a critical element that heightened safety awareness and equipped participants with the knowledge and skills needed to address these risks effectively in their everyday farming practices. It is essential to note that, while

this is effective, benefits greatly from knowledgeable facilitators. Facilitators play a vital role in ensuring that safe practices are effectively communicated and shared among peers during these demonstrations. Findings suggest that future farm safety interventions may benefit from including immersive and interactive components in an outdoor farm environment, such as a farmyard, to promote engagement and acceptance of safety training for farmers.

The facilitated discussion aligned with farm literature emphasising the efficacy of vicarious learning and word-of-mouth dissemination in promoting behaviour change and improving farm safety outcomes.[34,44–46] BeSafe capitalised on the trust and value stakeholders placed on the insights of their peers and advisors during the intervention development stage[17]. The programme's short and practical nature was also appreciated, as participants did not find it burdensome.

The safety training procedure template played a crucial role in promoting planning and clear safety goals. Participants found that setting specific completion timelines prompted prompt implementation of safety tasks, addressing farmers' tendency to postpone safety responsibilities.[12] Furthermore, the peer-to-peer agreement further enhanced the participant's sense of accountability. Future studies could explore the dynamics and impact of accountability partnerships within the farming community further.

Despite newsletters, safety documents, and leaflets being popular tools in educational safety interventions,[34] the farming community have been reported to dislike documents, paperwork and filling in forms[37,47–50]. The findings from the current study and from the focus groups conducted in the development phase support this stance. For example, most participants had difficulty recalling the content of the posters and did not refer to the safety training procedure template post-intervention. Despite this, most participants completed the safety goals, suggesting that their completion of tasks was not necessarily reliant on continuous reference to the documents. Furthermore, participants reported completion of target behaviours before receiving the SMS reminder. These two findings suggest that completing safety behaviours is more influenced by hands-on practical learning experiences and setting clear and concise goals than learning from written words. The high acceptability of the spray paint and cardboard cut-out further supports this finding. Although participants were enthusiastic about using these tools, there was limited interest in the remaining materials in the kit, such as the poster and project information document. While it is possible that participants remembered the safety goals and did not feel the need to refer to the physical paper documents post-intervention, it may be more likely that participants preferred the practical materials. Therefore, future interventions may benefit from minimising paperwork and emphasising interactive and engaging components that align with farmers' preferences and promote practical learning experiences. Instead, these materials can be utilised to summarise or visually display important information for a short engagement, supplementing more interactive and engaging components.

Overall, farmers noted how the current intervention exceeded previous efforts to address tractor safety in Ireland. Participants felt the intervention resonated with their expectations, experiences and needs. The findings have implications for future interventions, emphasising the importance of considering demographic factors, inclusion of hands-on intervention components, and farmer involvement in programme design and development. By empowering farmers to become safety educators, the BeSafe programme has the potential to foster a culture of safety and reach a wider audience.

Future Recommendations

The high acceptability of the BeSafe intervention components, along with their demonstrated fidelity in both receipt and enactment, opens up promising avenues for future farm safety interventions. Farmers who have completed the intervention have showcased their ability to not only grasp safety knowledge but also practically apply it, particularly through home demonstrations. Their positive experience in conducting these demonstrations, as well as their expressed intent to repeat them with family members and students in the future, suggest the potential for a "train-the-trainer" model. This may enable farmers who have undergone the BeSafe program to become safety ambassadors within their communities, spreading safety knowledge and practices. This is a crucial aspect, as one of the major drawbacks of voluntary safety education often lies in the overrepresentation of safety-conscious participants.[51] The results to date indicate that BeSafe has the potential to bridge this gap by equipping safety-conscious farmers with the knowledge and practical skills to reach out to more reluctant members of the farming community and farm family members who are not typically the primary focus of community safety initiatives. This approach reinforces that safety is a collective effort, emphasising the communal or multi-actor nature of farm safety promotion and skills development.

It is also important to note that effective train-the-trainer sessions may require a knowledgeable facilitator to ensure that the intervention skills are effectively communicated between peers. These facilitators can not only guide the participants in the practical aspects of the demonstration but also provide support when participants have specific questions or concerns related to their farm settings, equipment models, or other contextual factors. In the current study, safety researchers and advisors served as facilitators, delivering the intervention. Hence, the fidelity of training intervention providers was not evaluated. Future research could delve deeper into facilitator training to better understand the role of knowledgeable facilitators in optimising the learning experiences within farm safety interventions and may consider the development of facilitator guides to ensure consistent and effective program delivery.

Findings also emphasised the potential of integrating individual intervention components, particularly the peer-to-peer demonstration, combined with the demonstration kit and facilitated discussion, to existing farm programs to raise awareness about different safety topics. This integrated approach could extend beyond dedicated safety events to include livestock markets, farm walks, and other non-safety-related farm activities. For national or large-scale rollout, incorporating the intervention and its components into existing farm programs and events, such as farm discussion groups, livestock markets, farm walks, and agricultural events, may be beneficial.

Strengths and Limitations

The study has several strengths and limitations. Strengths include the detailed insights into sustained interest and acceptability acquired by comparing surveys and post-intervention interviews. The inclusion of participants from different age groups enriched understanding and facilitated an intervention tailored to the safety needs of older and younger farmers. The published protocol paper[52] ensured the replicability and transparency of study procedures. Novel contributions include the use of the TFA and fidelity checklist for assessing the acceptability and fidelity of a farm intervention, respectively.

The study also has some limitations. The post-intervention interviews were conducted by the same person who delivered the intervention, which may have introduced social desirability bias, impacting participants' expressing dissenting opinions or viewpoints. The study relied on self-reported data, which may also be subject to biases such as social desirability bias and recall errors. As participation was voluntary, it is likely that participants were already safety-conscious and motivated to improve their safety practices prior to their involvement, limiting the generalizability of the findings. In addition, participants' familiarity with the recruitment team influenced the recruitment.

Furthermore, gift vouchers were provided as tokens of appreciation for participation; however, their specific impact on participant retention was not assessed. Future research should assess the potential influence of incentives on engagement and retention. Furthermore, no female farmers participated in this intervention, and female farmers may have different perceptions of the intervention and its acceptability. To enhance the intervention's reach, future strategies should aim to target a broader farming audience through diverse avenues such as farming events, agricultural shows, discussion groups, farm walks, and agricultural programs.

Conclusion

In summary, the BeSafe intervention, with its farmer-focused approach and adaptability, holds promise for enhancing farm safety. Its potential to create safety advocates and integrate seamlessly with existing initiatives suggests broader applicability. The train-the-trainer aspect further enhances its potential impact. Findings also provide essential guidance for future behaviour change interventions aimed at promoting safer agricultural practices, contributing to safer and more sustainable farming communities. Further research is required to demonstrate the long-term effectiveness on health and safety outcomes.

References

1. Surendran A. BeSafe: A safety programme to increase machine-related safety on farms. doi:10.1186/ISRCTN22219089
2. Health, Authority S. *A Review of Work-Related Fatalities in Agriculture in Ireland 2011-2020*. Health and Safety Authority; 2021. https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/a_review_of_work-related_fatalities_in_agriculture_in_ireland_2011-2020.pdf.
3. Health and Safety Authority. *Farm Safety Action Plan 2021 - 2024*. Health and Safety Authority; 2021. https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/farm-safety-action-plan-2021-2024.pdf.
4. McNamara J, Griffin P, Phelan J, Field WE, Kinsella J. Farm health and safety adoption through engineering and behaviour change. 2019:226.6Kb. doi:10.15159/AR.19.151
5. Irwin A, Caruso L, Tone I. Thinking Ahead of the Tractor: Driver Safety and Situation Awareness. *Journal of Agromedicine*. 2019;24(3):288-297. doi:10.1080/1059924X.2019.1604279
6. Miller J, Fragar LJ, Rural Industries Research and Development Corporation (Australia). *Farm Machinery Injury: Injury Involving Tractor Run-over: A Report for the Rural Industries Research and Development Corporation*. Rural Industries Research and Development Corporation; 2006. https://aghealth.sydney.edu.au/wp-content/uploads/2019/05/farm_machinery_injury_tractor_runover.pdf.
7. Irwin A, Mihulkova J, Berkeley S. 'No-one else wears one:'Exploring farmer attitudes towards All-Terrain Vehicle helmets using the COM-B model. *Journal of safety research*. 2022;81:123-133. doi:10.1016/j.jsr.2022.02.004

8. Rautiainen R, Lehtola MM, Day LM, et al. Interventions for preventing injuries in the agricultural industry. *Cochrane database of systematic reviews*. 2008;(1):CD006398. doi:10.1002/14651858.CD006398.pub2
9. Surendran A, Mc Sharry J, Di Domenico R, Meredith D, O'Hora D. *Enhancing Machine-Related Safety on Farms: A Systematic Review*. Open Science Framework; 2023. doi:10.31219/osf.io/rp9cj
10. Gunderson P, Gerberich S, Gibson R, et al. Injury surveillance in agriculture. *American journal of industrial medicine*. 1990;18(2):169-178.
11. Stave C, Törner M, Eklöf M. An intervention method for occupational safety in farming — evaluation of the effect and process. *Applied Ergonomics*. 2007;38(3):357-368. doi:10.1016/j.apergo.2006.04.025
12. Murphy M, O'Connell K. Systemic Behaviour Change: Irish Farm Deaths and Injuries. In: Dept. of Management & Enterprise Conference Material. Society of Macromarketing; 2018. https://sword.cit.ie/dptmecp/4. Accessed September 27, 2023.
13. Shortall S, McKee A, Sutherland LA. Why do farm accidents persist? Normalising danger on the farm within the farm family. *Sociology of Health & Illness*. 2019;41(3):470-483. doi:10.1111/1467-9566.12824
14. Michie S, Richardson M, Johnston M, et al. The behaviour change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behaviour change interventions. *Annals of behavioural medicine*. 2013;46(1):81-95. doi:10.1007/s12160-013-9486-6
15. French SD, Green SE, O'Connor DA, et al. Developing theory-informed behaviour change interventions to implement evidence into practice: a systematic approach using the Theoretical Domains Framework. *Implementation Science*. 2012;7(1):1-8. doi:10.1186/1748-5908-7-38
16. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*. 2011;6(1):42. doi:10.1186/1748-5908-6-42
17. Surendran A, McSharry J, Meade O, et al. Increasing Machine-Related Safety on Farms: Development of an Intervention Using the Behaviour Change Wheel Approach. *International Journal of Environmental Research and Public Health*. 2023;20(7):5394.
18. Skivington K, Matthews L, Simpson SA, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. *BMJ*. 2021;374. doi:10.1136/bmj.n2061
19. Lancaster GA, Thabane L. Guidelines for reporting non-randomised pilot and feasibility studies. *Pilot and Feasibility Studies*. 2019;5(1):1-6. doi:10.1186/s40814-019-0499-1
20. Arain M, Campbell MJ, Cooper CL, Lancaster GA. What is a pilot or feasibility study? A review of current practice and editorial policy. *BMC medical research methodology*. 2010;10(1):1-7. doi:10.1186/1471-2288-10-67
21. Borrelli B, Sepinwall D, Ernst D, et al. A new tool to assess treatment fidelity and evaluation of treatment fidelity across 10 years of health behaviour research. *Journal of consulting and clinical psychology*. 2005;73(5):852. doi:10.1037/0022-006X.73.5.852
22. Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. *BMC health services research*. 2017;17(1):1-13. doi:10.1186/s12913-017-2031-8
23. Surendran A, McSharry J, Meredith D, et al. Assessing the feasibility, fidelity and acceptability of a behaviour change intervention to improve tractor safety on farms: protocol for the BeSafe tractor safety feasibility study. *Pilot Feasibility Stud*. 2023;9(1):114. doi:10.1186/s40814-023-01319-w
24. O'cathain A, Murphy E, Nicholl J. The Quality of Mixed Methods Studies in Health Services Research. *Journal of Health Services Research & Policy*. September 2017. doi:10.1258/jhsrp.2007.007074
25. Hoffmann TC, Glasziou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *Bmj*. 2014;348. doi:10.1136/bmj.g1687

26. Fetters MD, Curry LA, Creswell JW. Achieving Integration in Mixed Methods Designs—Principles and Practices. *Health Services Research*. 2013;48(6pt2):2134-2156. doi:10.1111/1475-6773.12117
27. Toomey E, Matthews J, Hurley DA. Using mixed methods to assess fidelity of delivery and its influencing factors in a complex self-management intervention for people with osteoarthritis and low back pain. *BMJ Open*. 2017;7(8):e015452. doi:10.1136/bmjopen-2016-015452
28. Mehra S, Helder J van den, Visser B, Engelbert RHH, Weijs PJM, Kröse BJA. Evaluation of a Blended Physical Activity Intervention for Older Adults: Mixed Methods Study. *Journal of Medical Internet Research*. 2020;22(7):e16380. doi:10.2196/16380
29. Markle-Reid M, Ploeg J, Fisher K, et al. The Aging, Community and Health Research Unit—Community Partnership Program for older adults with type 2 diabetes and multiple chronic conditions: a feasibility study. *Pilot Feasibility Stud*. 2016;2(1):24. doi:10.1186/s40814-016-0063-1
30. Kennedy BL, Thornberg R. Deduction, induction, and abduction. *The SAGE handbook of qualitative data collection*. 2018:49-64.
31. Elo S, Kääriäinen M, Kanste O, Pölkki T, Utriainen K, Kyngäs H. Qualitative Content Analysis. *SAGE Open*. February 2014. doi:10.1177/2158244014522633
32. Verbi S. MAXQDA. 2019. https://www.maxqda.com/new-maxqda-2020.
33. DeRoo LA, Rautiainen RH. A systematic review of farm safety interventions. *American journal of preventive medicine*. 2000;18(4):51-62. doi:10.1016/S0749-3797(00)00141-0
34. Coman, Marcu, Chereches, Leppälä, Van Den Broucke. Educational Interventions to Improve Safety and Health Literacy Among Agricultural Workers: A Systematic Review. *IJERPH*. 2020;17(3):1114. doi:10.3390/ijerph17031114
35. Horsburgh S, Langley JD. Recruitment and retention of farm owners and workers for a six-month prospective injury study in New Zealand: a feasibility study. *Journal of Occupational Medicine and Toxicology*. 2011;6(1):1-10.
36. Narasimhan GR, Peng Y, Crowe TG, Hagel L, Dosman J, Pickett W. Operational safety practices as determinants of machinery-related injury on Saskatchewan farms. *Accident Analysis & Prevention*. 2010;42(4):1226-1231. doi:10.1016/j.aap.2010.01.016
37. Russell-Green S, Cotton J, Brumby S. Research Engagement Changes Attitudes and Behaviours towards Agrichemical Safety in Australian Farmers. *Safety*. 2020;6(1):16. doi:10.3390/safety6010016
38. Volkmer K, Lucas Molitor W. Interventions Addressing Injury among Agricultural Workers: A Systematic Review. *Journal of Agromedicine*. 2019;24(1):26-34. doi:10.1080/1059924X.2018.1536573
39. Nilsson K. Interventions to reduce injuries among older workers in agriculture: A review of evaluated intervention projects. *WOR*. 2016;55(2):471-480. doi:10.3233/WOR-162407
40. Prager K, Creaney R. Achieving on-farm practice change through facilitated group learning: Evaluating the effectiveness of monitor farms and discussion groups. *Journal of Rural Studies*. 2017;56:1-11. doi:10.1016/j.jrurstud.2017.09.002
41. Brennan C. *Exploring the Impact of a Farm Safety Intervention Programme in Ireland Examining Farmer's Behaviour towards Farm Safety-A Study of the Farm Safety Mentor Programme*.; 2015.
42. Murphy M, O'Connell K. The Use of Mentoring To Effect Cultural Change: Irish Farm Deaths And Injuries. 2018. https://sword.cit.ie/cgi/viewcontent.cgi?article=1002&context=dptmecp.
43. Sutherland LA, Marchand F. On-farm demonstration: enabling peer-to-peer learning. *The Journal of Agricultural Education and Extension*. 2021;27(5):573-590. doi:10.1080/1389224X.2021.1959716
44. Biesheuvel MM, Santman-Berends IMGA, Barkema HW, et al. Understanding Farmers' Behaviour and Their Decision-Making Process in the Context of Cattle Diseases: A Review of Theories and Approaches. *Frontiers in Veterinary Science*. 2021;8. doi:10.3389/fvets.2021.687699

45. Mullen J. Investigating factors that influence individual safety behaviour at work. *Journal of safety research*. 2004;35(3):275-285.
46. Hansen BG. Financial extension that challenges farmers' thinking in discussion clubs helps farmers improve their problem solving abilities. *Agricultural Systems*. 2015;132:85-92. doi:10.1016/j.agsy.2014.09.009
47. Parry J, Lindsey R, Taylor R. Farmers, farm workers and work-related stress. 2005.
48. Franklin RC, McBain-Rigg KE, King JC, Lower T. Exploring the barriers and facilitators to adoption of improved work practices for safety in the primary industries. *Barton ACT: Australian Government, RIRDC*. 2015.
49. Sundberg JO. *Conserving Biodiversity on South Africa's Privately-Owned Grasslands: Farmer Experiences with Protected Areas*. Lincoln Institute of Land Policy.; 2020.
50. Mwachofi A. Building trust and collaboration with rural minorities: Experiences with minority farmers in the Mississippi Delta. *Journal of Health Disparities Research and Practice*. 2012;5(2):6.
51. Robson LS. Guide to evaluating the effectiveness of strategies for preventing work injuries: how to show whether a safety invervention really works. 2001. https://stacks.cdc.gov/view/cdc/11272.
52. Surendran A, McSharry J, Bligh F, McNamara J, Meredith D, O'Hora D. Assessing the feasibility, fidelity and acceptability of a behaviour change intervention to improve tractor safety on farms: Protocol for the BeSafe tractor safety feasibility study. 2022. https://doi.org/10.21203/rs.3.rs-2113603/v1.

Chapter 8 Discussion

This discussion chapter serves as the capstone of an extensive research journey aimed at enhancing machinery-related safety on farms through a behaviour change intervention. It synthesises and contextualises the findings of the thesis's four main objectives, shedding light on the impact and implications of this research.

This doctoral research was motivated by a pressing concern – the need to enhance machinery-related safety on farms, with a specific focus on Irish farmers. Agriculture is one of the most hazardous industries globally, characterised by a multitude of risks, with machinery-related incidents being a significant contributor to injuries and fatalities. Recognising this critical issue, the central purpose of this work was to develop and test behaviour change-based intervention tailored to mitigate these risks and to promote a safer working environment for Irish farmers.

The development of the complex behaviour change intervention as part of this thesis was done in accordance with the MRC framework for the design and evaluation of complex interventions (Skivington et al., 2021). Development of the behaviour change intervention was theoretically driven by the use of the BCW (Michie et al., 2005) and has been structured around four main objectives:

Objective 1: Evaluate existing machinery-related farm safety interventions, including an examination of the behavioural change techniques employed, to assess their effectiveness and limitations
Objective 2: Investigate farmer attitudes and the barriers and facilitators influencing the adoption of safer farm machinery practices on farms.
Objective 3: Develop and refine a behaviour change intervention targeting farm machinery safety through co-design workshops.
Objective 4: Explore the feasibility, fidelity, and acceptability of the developed behaviour change intervention to assess its practicality and alignment with acceptability and fidelity principles

To address these multifaceted objectives, a comprehensive mixed-methods approach was adopted. A series of interconnected studies were conducted, comprising a systematic review, focus group discussions with older farmers and co-design workshops involving a diverse range of stakeholders and experts. These collective activities contributed to the creation of a stakeholder-informed, evidence-based intervention.

The result of these collaborative efforts materialised in the form of a behaviour change intervention that was methodically developed to target and mitigate safety issues related to blind spots around tractors. Subsequently, this newly devised intervention underwent a rigorous feasibility-testing phase involving the participation of nineteen farmers. This final phase assessed the feasibility, fidelity, and acceptability of the overall intervention as well as the various intervention strategies employed within the intervention.

The findings from these studies were presented as five separate research papers (Chapters 3-7). These individual research papers have collectively contributed to this thesis, offering a comprehensive insight into behaviour change interventions for farm safety. The findings of

each of these studies have been presented in detail within their respective chapters, and key insights derived from these studies will be thoughtfully highlighted in the subsequent section.

Summary of Key Findings

Objective 1:

The foundation for this objective was established through a rigorous systematic review, which served as the foundation of this PhD research. The comprehensive Cochrane review of farm safety interventions (2008) categorised interventions into three primary domains: education, regulation, and engineering. However, given the ultimate goal of this research - to inform the development of behaviour change-based interventions for enhancing machine-related safety - it became apparent that a more in-depth analysis of the BCTs within the farm machine safety interventions was essential. Consequently, the Behaviour Change Wheel (BCW) framework and the Behaviour Change Technique (BCT) taxonomy were employed to delve into the nuances of the BCTs employed in these interventions (Michie et al., 2013, 2014). The systematic review chapter in this thesis aimed to shed light on machine-related farm safety interventions. Specifically, it sought to answer three crucial questions: What interventions and components are utilised to enhance farm machine safety? What behaviour change techniques (BCTs) are employed within these interventions? And finally, what are the outcomes of machine-related farm safety interventions? This review provides essential insights into the landscape of machine safety interventions, identifying trends, complexities, and areas where further research is needed.

The systematic review, as detailed in Chapter 3 of this thesis, yielded several key findings that have significantly informed the trajectory of this PhD research:

Demographic Factors: Demographic factors, encompassing variables like gender, age, location, and farm type, were repeatedly identified as significant determinants of farm injury and fatality rates (Colémont & Van den Broucke, 2008; McNamara et al., 2021; Mohammadrezaei et al., 2022). However, these factors are often overlooked during the intervention development. The review strongly emphasised the necessity of addressing age-related safety concerns, with a particular focus on the vulnerability of children and older adults to fatal incidents in farm settings.

Focus on Specific machine operation-related behaviours: Many existing interventions primarily focus on general safety measures, overlooking specific behaviours and practices associated with high-risk injury areas related to farm machinery. Even within studies that address machine safety, there is a common tendency to narrow their focus solely on the adoption of rollover protective structures (ROPS), neglecting a broader spectrum of farm machine-related hazards and safety practices.

Intervention Components and Complexity: Education emerged as a prevalent approach in existing interventions despite literature suggesting the effectiveness of engineering and enforcement measures. A significant revelation was the intricate nature of education-based interventions, often characterised by the simultaneous use of multiple components. These multifaceted approaches included safety campaigns, demonstrations, social marketing, and farm audits, presenting a challenge in isolating the effectiveness of individual strategies. Additionally, the review echoed the persistent challenge of limited high-quality studies in the realm of farm safety interventions. This limitation is especially pronounced concerning rigorous evaluation and the identification of active intervention elements.

Behaviour Change Techniques (BCTs): Within these interventions, the review identified a range of behaviour change techniques (BCTs) commonly used. These included providing information about health consequences, vicarious consequences, and demonstrations of the behaviour. However, despite many of the studies employing a multifaceted approach, often incorporating diverse educational strategies within the interventions, they typically provided limited descriptions of these individual intervention components. This lack of specificity made it challenging to pinpoint the exact behaviour change techniques that were applied within these multifaceted approaches.

Overall, this systematic review provides a comprehensive overview of the complex landscape of machine-related farm safety interventions. It highlights the need for tailored strategies, consideration of demographic factors, and more rigorous research in this critical field. Therefore, in addition to the systematic review, complementary secondary research was undertaken, specifically focusing on the Irish farm context. This examination drew upon authoritative sources, including Teagasc and HSA, which provided farm fatality reports, farm surveys, and farm reports. The findings from this work further enriched the understanding of the Irish farming landscape and its unique safety challenges:

Role of Tractors and Quad Bikes: The reports revealed that tractors and quad bikes played a significant role in the majority of farm accidents in Ireland (Dillon et al., 2017.; *Farmers over 65 Years - Health and Safety Authority*, 2021.; Watson et al., 2017). This highlighted the critical need to address safety concerns associated with these specific machines.

Vulnerable Demographics: Reports from the HSA (*2018 - Alarming Rise in Farm Accidents – Teagasc Survey - Teagasc | Agriculture and Food Development Authority*, 2019.; Health & Authority, 2021) indicated that older farmers and children were among the most vulnerable populations to farm injuries and fatalities in Ireland. These findings underscored the importance of tailoring interventions to address the needs and risks associated with these specific demographic groups.

Lack of Attention to Older Farmers: An additional insight was the limited attention given to older farmers in existing safety initiatives. These older farmers were not adequately addressed, and they were more likely to disengage from safety initiatives (McCallum et al., 2022; Nilsson, 2016). This highlighted a significant gap in existing interventions.

In summary, this first objective provided a comprehensive assessment of machinery-related farm safety interventions, their BCTs, and the associated research gaps. It also incorporated critical insights from secondary research, focusing on the Irish farm context, which laid the groundwork for the subsequent objectives.

Objective 2:

The second objective was to understand the perspectives and experiences of older Irish farmers concerning farm machinery safety, specifically focusing on tractors and quad bikes. This qualitative study utilised the COM-B framework (Michie et al., 2008) to explore the barriers and facilitators influencing the adoption of safe practices linked to machinery operation. The study involved focus group discussions with older Irish farmers from four major farm systems, capturing a wide range of experiences and perspectives within the farming community.

The participants were asked about their capabilities, opportunities, and motivations related to adopting safe machine-related practices, and they discussed various safety practices, barriers, and facilitators. The study also delved into their attitudes toward potential behaviour change techniques (BCTs) identified in the systematic review. The key findings were:

Capability-Related factors: Farmers discussed issues like a lack of knowledge and the ability to manage the demands of farm work as challenges that hindered their capability to adopt safe practices. However, they also highlighted proactive planning and organisational skills as strengths, which enabled them to mitigate stress, manage task overload, and build safer habits. These capabilities played a significant role in their decision-making processes regarding safety practices, emphasising the need for tailored interventions that harness and enhance these capabilities while addressing knowledge gaps.

Opportunity-Related factors: Farmers highlighted economic pressures, time constraints, and weather conditions as barriers that often hindered their ability to opt for safer practices over makeshift risky practices. On the flip side, the presence of supportive family members and knowledgeable farm advisors emerged as facilitators, enhancing farmers' opportunities to engage in safer practices. These social opportunities were pivotal in influencing their capability and motivation to adopt safety measures, underscoring the importance of these relationships in farm safety initiatives.

Motivation-related factors: Farmers' motivation is a delicate balance between perceiving the risks and benefits of their actions. They weigh the rewards of task completion against the perceived risks involved, which significantly influence their choices. Therefore, effective risk communication through education becomes pivotal for encouraging safer decision-making among farmers. Understanding these motivations is essential for developing behaviour change interventions that take into account farmers' beliefs, perceived self-efficacy, and the real-world benefits they seek.

Focusing on Immediate Environment and Situation Awareness: The findings underscored the importance of immediate environment and situational awareness in farm safety. Farmers acknowledged the need to be aware of their surroundings and avoid distractions caused by paperwork, phone calls, and family matters. This awareness was seen as critical in reducing the risk of accidents.

Addressing Stress and Anxiety: Stress and anxiety, often related to production, price, paperwork and weather, contributed to inattentiveness among farmers, leading to injuries. Participants suggested that interventions should address stress and anxiety and help farmers plan and organise their tasks effectively.

Effectiveness of Education Tools: Traditional educational methods like user manuals and safety guides were found to be ineffective in conveying crucial safety information. Farmers often found these resources overwhelming and poorly engaging. Instead, they preferred learning through interactions with peers, family members, and farm advisors.

Advocating for Strict Regulations: Most participants recognised the need for strict regulations and mandatory safety checks. They also acknowledged that these measures might not be popular among farmers. However, they believed that such regulations could encourage safety compliance.

Tailored and locally relevant Interventions: Participants stressed the significance of interventions finely tuned to the unique needs and challenges of Irish farmers. They highlighted the need for farmer-centric design in engineering interventions to ensure that

safety equipment and machinery do not interfere with their work. Policies should be farmer-centric, recognising the diverse resources and conditions of farms. Similarly, educational interventions must be delivered in a way that resonates with farmers. This involves addressing topics that are directly relevant to their works and taking into consideration the heterogeneity and seasonality of farm operations. Such an approach ensures that interventions are not just effective but also well-received by the farming community, enhancing their impact on farm safety practices.

Interest in Safety-Focused Discussion Groups and Peer-to-Peer Learning: Participants not only expressed a keen interest in discussing various safety-related topics but also highlighted the importance of safety-focused discussion groups and community spaces. These platforms are essential for sharing specific risks and solutions, fostering peer-to-peer learning, and encouraging knowledge exchange among farmers. Additionally, the study revealed the influence of different generations on each other's safety practices. Younger farmers, often more aware of modern safety practices, motivated older farmers to adopt safer methods. This intergenerational exchange of knowledge played a vital role in shaping attitudes towards safety, emphasising the power of social opportunities as drivers of behaviour change.

In summary, these findings offer valuable insights into the complex interplay of capability, opportunity, and motivation factors that influence older Irish farmers' safety practices related to machinery. By connecting these insights to established theories and concepts in farm literature and behaviour change, we gain a deeper understanding of how to design effective interventions to promote safer farm practices among this demographic.

When considered alongside the previously mentioned findings, these additional insights provide a comprehensive understanding of the challenges and opportunities associated with promoting farm machinery safety among older Irish farmers. These findings further underscore the importance of tailoring interventions to address the specific needs and preferences of the targeted population, ultimately enhancing the relevance and effectiveness of interventions like BeSafe.

Objective 3:

Objective 3 of this study focused on the development of farm safety interventions tailored to the needs of older Irish farmers. Building upon insights gathered in previous phases, this objective aimed to identify specific target behaviours, assess barriers and enablers relevant to the adoption of these behaviours and design evidence-based farmer-centric interventions using behaviour change techniques. This objective entailed a multifaceted approach, incorporating insights from both the co-design Workshop and the feasibility screening with the Teagasc Advisory Team. This objective sought to address a common critique of educational interventions for farm safety, which often lack comprehensive evaluation and a robust theoretical foundation (Rautiainen et al., 2008). Key findings were:

Identified Target Behaviours: Co-design workshop and focus group participants observed the paramount importance of two target behaviours for enhancing machine safety among older farmers: a) allocating attention to machinery operation and the local environment and b) installing and using appropriate safety devices on machinery. These behaviours served as the focal points for subsequent discussion on selecting the intervention strategies.

Barriers and Enablers: Participants identified various barriers and enablers influencing these target behaviours. Key barriers included financial constraints, voluntary safety

regulations, lack of knowledge, risk habituation, and time constraints. Meanwhile, facilitators included peer support, vicarious learning, and raising awareness among family members and co-workers.

Behaviour Change Techniques (BCTs): The BeSafe intervention strategically incorporated several BCTs, including but not limited to goal setting (behaviour), problem-solving, goal setting (outcome), action planning, behavioural contract, salience of consequences, and identification of self as a role model.

Tailored Approach: The study emphasised the significance of tailoring interventions to cater to different farm types and age groups. Recognising the diversity within the farming community, the specific target behaviour identified for the intervention was universally relevant for all tractor operators to ensure resonance with various demographics. Furthermore, the intervention also acknowledged that different farmers had different types of parking areas and models of tractors. Therefore, the intervention ensured that the intervention skills in focus were applicable to heterogeneous environments and available resources to make them more effective.

Feasibility Screening with Teagasc Advisory Team: The study integrated insights and feedback from the Teagasc Advisory Team during the Feasibility Screening phase. This collaboration ensured that intervention components and strategies aligned with practical considerations and resource constraints, enhancing the real-world applicability of the designed interventions.

Overall, this phase concentrated on the meticulous development of farm safety interventions, with a particular focus on tailoring them to meet the unique needs of older farmers in Ireland. In crafting these interventions, the study adopted a multi-level approach underpinned by the BCW framework, accounting for individual and contextual factors that influence behaviours. This approach not only ensured evidence-based strategies but also upheld context-specific relevance, ultimately enhancing the effectiveness of the interventions. Furthermore, recognising the common critiques of farm safety interventions, the study laid a robust theoretical foundation by systematically mapping barriers, facilitators, and intervention recommendations to the COM-B framework and the BCW framework. This approach is pivotal, facilitating comprehensive evaluations and providing a solid theoretical framework underpinning intervention design and evaluation.

As we move forward to the final stage, the intervention was put to the test. The insights gained during the development phase were applied in real-world scenarios, allowing us to assess their impact in enhancing farm safety practices among older farmers. Through pilot testing and evaluation, we aimed to refine and optimise the interventions further.

Objective 4:

Objective 4 represents the culmination of this study's comprehensive approach to enhancing farm safety among older farmers. In this phase, the BeSafe intervention strategies, systematically developed in Objective 3, were put to the test through a feasibility trial. This final objective assessed the real-world acceptability of the interventions, refined them based on practical insights, and prepared them for wider implementation.

In-depth interviews with participants following the intervention session delved into their understanding of the intervention's skills and their practical application on farms. These interviews also explored participants' perceptions of the intervention components and their impact, both in the short term and after a two-week period. These rich qualitative data

provided valuable insights into the various intervention components and the optimal use of them for maximum impact.

The BeSafe intervention comprised several components, including a peer-to-peer demonstration, facilitated discussion, safety training procedure document, SMS reminder, BeSafe poster and demonstration kit. These components were strategically designed to address blind spot-related risks and promote safety behaviours among participants.

High Retention and Implementation Fidelity: Of the 20 farmers recruited, 19 attended the on-site intervention sessions, and 17 completed the entire trial (i.e., attempted the safety goals at home and attended the follow-up interview). This high level of retention and implementation fidelity is a testament to the success of the intervention. It underscores the value of stakeholder-informed, evidence-based, and theory-driven research conducted during the intervention's design phase.

Effectiveness and Acceptability: Overall, the intervention was well-received by participants immediately after the trial, reflecting its potential to positively influence tractor-related safety behaviours. The hands-on, practical nature of the demonstration component was widely regarded as highly effective and engaging. It aligned well with farmers' preferences for experiential learning.

Differential Acceptability Over Time: While certain components, like the hands-on demonstration, maintained high acceptability throughout, others, such as posters and SMS reminders, exhibited decreasing acceptability over time. This underlines the evolving nature of acceptability and the importance of considering temporal dynamics.

Stakeholder Consultation Enhances Feasibility and Acceptability: Consultation with stakeholders during the design process was instrumental in enhancing the feasibility and acceptability of the intervention. Studies have shown that involving stakeholders in intervention design can improve effectiveness. The success of BeSafe is, in part, attributed to this collaborative approach.

A Theoretical Framework for Evaluation: Many farm safety education interventions lack comprehensive evaluations, hindering comparisons with other studies (Coman et al., 2020; Dyreborg et al., 2022). In contrast, the BeSafe study employed a theoretically driven evaluation guided by existing frameworks of acceptability and fidelity. This ensured a thorough assessment not only of overall acceptability but also of the factors influencing the perceived acceptability of each intervention component.

Potential for Safety Ambassadors: Participants recognised the importance of passing on their newfound knowledge to family members, co-workers, and neighbours. This highlights the potential ripple effect of the BeSafe intervention, with participants becoming advocates for farm safety within their communities. These ambassadors can play a crucial role in disseminating farm safety knowledge and practices among their peers.

Train-the-Trainer Approach: BeSafe's train-the-trainer aspect underscores its potential as a versatile tool for promoting safety education on various topics and behaviour change within the farm industry.

Objective 4 represents the bridge between theory and practice in enhancing machine-related safety for Irish farmers. The BeSafe intervention, guided by stakeholder collaboration, theoretical frameworks, and a comprehensive evaluation approach, has demonstrated its potential to improve tractor safety among a diverse group of farmers. The high retention rate and fidelity of implementation suggest its readiness for broader application. The insights

gained from this study not only enrich our understanding of behaviour change interventions in farm safety but also provide practical guidance for promoting farm safety through peer learning and community engagement.

BeSafe intervention and mechanisms of action

Farm safety education remains one of the most prevalent safety interventions in the farming community (DeRoo & Rautiainen, 2000). However, literature and research consistently highlight the limitations of traditional education-based approaches. Such interventions often struggle with effectiveness due to their failure to engage stakeholders during development and their inability to tailor interventions to local contexts and the specific needs of the target population (Coman et al., 2020; DeRoo & Rautiainen, 2000; Rautiainen et al., 2008). Moreover, the voluntary nature of these educational programs tends to attract individuals who are already safety-conscious, potentially leading to a skewed representation in the participant pool (O'Connor, 2020; Robson, 2001). The knowledge-action gap, also a significant challenge of education-based interventions, is widely recognised in the literature (Franklin et al., 2015; Hakvoort et al., 2021).

Research emphasises the vital role of farmers as both sources of information and conduits for vicarious learning, where fellow farmers play a central role in increasing safety awareness. Therefore, farmers prefer learning from peers and advisors through conversations and visual observation of farming practices (O'Connor et al., 2021; Sutherland & Marchand, 2021a). The peer-to-peer demonstration enables experiential learning and direct communication between peers (Sutherland & Marchand, 2021b). The peer-to-peer demonstration component of the BeSafe intervention– the exercise of inspecting blindspots of the tractors and implements with their peers – resulted in a significant experiential learning outcome. Participants actively engaged in the demonstration, where they sat on the tractor and personally experienced the limitations of visibility, particularly blind spots around the vehicle. This hands-on experience led to a heightened awareness of the potential dangers posed by these blind spots. It facilitated a deeper understanding of farm safety risks associated with operating tractors and machinery. Furthermore, participants' direct involvement in the demonstration encouraged active learning and critical thinking, enhancing their ability to recognise and mitigate safety hazards in real-life farm settings. They could draw from real-life scenarios to discuss specific safety concerns related to different models of tractors, the injuries and near-misses they experienced, and the knowledge they had gained through the intervention. This experiential learning process was a pivotal component of the BeSafe intervention, contributing to participants' increased safety awareness and preparedness to implement safety measures on their farms.

In farm literature, discussion forums have long been recognised as effective platforms for learning, knowledge exchange, and word-of-mouth dissemination (Hansen, 2015; O'Connor et al., 2021; Prager & Creaney, 2017). In the case of the BeSafe intervention, the facilitated discussion component was received by the participant as an effective strategy for raising safety awareness and driving behavioural change among participants. These discussion forums served as fertile ground for leveraging vicarious learning opportunities, providing a dynamic forum for delving deeply into the specific challenges they anticipate with the implementation of intervention skills at their farms, acquiring practical insights, and seeking advice from safety experts who were part of the facilitation team.

The Safety training procedure template, while not directly impacting increased risk awareness, had an effect on consolidating participants' responsibilities and providing clarity on how to implement the intervention skills on their farms. It served as an effective tool for

planning safety tasks, outlining safety goals, and creating a sense of accountability. Participants noted that the goal-setting process, along with specified completion timelines, prompted them to execute safety tasks promptly. This structured approach was particularly beneficial, given the common tendency among farmers to postpone safety obligations (M. Murphy & O'Connell, 2017).

The peer-to-peer agreement, a crucial part of the safety training procedure template, contributed to a heightened sense of accountability among participants. Furthermore, the demonstration kit provided participants with the necessary resources to perform safety tasks at home and share their knowledge with others, making the safety agreement's objectives achievable. These steps supported the translation of the safety agreement's commitments into practical actions by offering tangible tools and materials. Together, these Besafe elements not only heightened awareness of potential hazards on the farm but also equipped farmers with the knowledge, skills, and tools necessary to address these risks effectively.

Participants perceived the BeSafe intervention as uniquely farm-centric, primarily due to its on-field and peer-to-peer learning components. This aspect, coupled with the composition of both older and younger farmers, mirroring the generational dynamics often found on family farms, contributed to participants perceiving the program as one of the most farm-centric safety initiatives they had experienced. The combination of these features allowed them to relate to the program on a personal and practical level.

Participants' consistent and robust engagement in the peer-to-peer demonstration, facilitated discussions, and their commitment to the safety goals demonstrated the program's efficacy. Farmers' positive reception of BeSafe, particularly its concise format and focused demonstration topics, strengthened its potential effectiveness. Furthermore, in contrast to the limitations of traditional farm safety education, the BeSafe intervention demonstrated promising outcomes in promoting safer behaviours within the farming population. Notably, BeSafe appeared to have the potential to empower safety-conscious farmers to become safety ambassadors who can reach out to more reluctant members of the farming community. This approach reinforces the idea that safety is a collective effort, emphasising shared responsibility for farm safety.

The BeSafe intervention's notable success in terms of high fidelity in both the receipt and enactment of intervention skills, combined with farmers' reported confidence in the program's effectiveness in enhancing risk awareness, underscores its potential as a 'train-the-trainer' model for broader dissemination. Building on this success, the BeSafe program could be strategically expanded and adapted to address various farm safety concerns. Overall, The program's potential as a 'train-the-trainer' model, where experienced farmers become safety ambassadors within their communities, holds promise for broader dissemination and long-term sustainable impact.

Generalisability of findings to other populations and context

The feasibility trial of the BeSafe intervention shed light on the potential generalizability of its components to diverse farm settings and demographics. One notable strength of the trial was the in-depth post-intervention qualitative interviews where participants discussed how they successfully conducted demonstrations at their homes involving various groups such as family members, neighbours, and friends. While this data doesn't establish the generalizability of the entire intervention program, it provides valuable insights into the adaptability of one of its components. This highlights the potential for farm demonstrations as

an awareness-raising strategy and underscores the importance of providing the right resources to enable participants to practice safety measures effectively on their farms.

As farming practices continue to evolve, driven by technology and mechanisation, the concerns regarding blind spots are also expected to grow. As few participants from our trial observed, the installation of new devices on tractors, such as GPS systems, may inadvertently create new blind spots. The BeSafe intervention, with its reported impact in raising concerns about these blind spots among participants and fostering a deeper understanding of associated risks, has opened new avenues. It can empower farmers to proactively investigate whether the new devices they install or the modifications they make can potentially introduce more blind spots into their machinery.

This heightened risk perception, cultivated by BeSafe, extends beyond tractors and has the potential to encompass other farm machinery, such as teleporters and emerging technologies that present similar safety challenges. By instilling this proactive mindset, BeSafe not only addresses current safety concerns but also equips farmers with the skills and awareness needed to adapt to the evolving landscape of farm technology. In doing so, it fosters a culture of continuous safety improvement, ensuring that safety remains a top priority as farming practices and machinery continue to advance. Future effectiveness trial should take on appropriate methods to monitor whether the skills and awareness extends beyond tractors.

The BeSafe intervention, designed around the specific needs and suggestions of Irish farmers, offers evidence and behaviour change theory-supported components that can be applied to other farm initiatives focusing on education and behaviour change. The feasibility trial indicated that intervention, in its current format, has the potential to address a wide range of farm safety concerns beyond its initial scope. Based on the requirement, the active ingredients of the intervention, especially the peer-to-peer demonstration with the demonstration kit, facilitated discussion, and safety training procedure template, can be integrated as a package or individual components into existing farm initiatives. This adaptability allows for the development of comprehensive safety programs that tackle multiple aspects of farm safety within a single framework.

There is also a potential for BeSafe to be repackaged as a train-the-trainer approach, as noted previously. Family farms often operate in isolated spaces with blurred distinctions between family workspaces, making the farmers and their families more susceptible to injuries (Europäische Kommission, 2004; Lee et al., 2017; McNamara et al., 2022). Participants recognised the importance of not only making safety-conscious decisions for themselves but also actively sharing this knowledge within their farming community, emphasising a collective responsibility for safety. The study's findings align with recent literature showcasing the potential of mentoring and education within family farming structures (Helitzer et al., 2014; Mohammadrezaei et al., 2023; M. Murphy & O'Connell, 2018). This approach can effectively transfer safety knowledge and practices from one generation to another, fostering a culture of safety. However, the large-scale implementation should continue to focus on addressing one safety topic at a time within diverse age groups since these aspects were highlighted as contributing factors for the high acceptability among participants.

However, some limitations to generalizability must be considered. The study's participants were all male, and although these participants worked with female family members during home demonstrations without reported issues, further evaluation with women farmers is necessary for conclusive evidence. Additionally, while mentoring-based initiatives exist in different countries, this study leveraged the prevalent family farming setting in Ireland and

addressed factors specific to Irish farmers. The underlying safety problems can also differ significantly among various populations, necessitating tailored interventions. In such cases, the evidence-based theory intervention development methodology presented in this thesis can serve as a valuable guide when evidence on the unique factors influencing different farming populations is limited.

Contribution to knowledge

This body of work made novel and substantial contributions to knowledge in several areas of health and safety research. Firstly, it establishes a solid foundation for the application of the behaviour change wheel framework in the specialised domain of farm machine safety. This innovative approach offers the promise of bridging the knowledge-action gap by furnishing evidence-based, cost-effective strategies that are deeply embedded in the unique context of farm safety (Chapter 3). Secondly, it provides a nuanced understanding of the intricate determinants influencing the adoption of safer farming practices among older farmers within the unique context of Irish farms. This comprehension is pivotal in crafting targeted interventions that effectively account for the multifaceted factors guiding farmers' safety decision-making processes (Chapter 4). Thirdly, Chapter 5 introduces a novel methodology for developing theory-driven, evidence-based, stakeholder-informed behaviour change interventions. Chapters 6 and 7 provide a comprehensive template for conducting feasibility evaluations, enhancing the rigour and replicability of future research in this domain. This thesis has clearly demonstrated how concepts from health behaviour change research can be consistently applied and adapted to the specific context of farm safety. This adaptation not only enhances our understanding of farm safety but also advances the broader field of health behaviour change research. Lastly, this work contributes to behaviour change literature by identifying potential Behaviour Change Techniques (BCTs) and their delivery methods through systematic reviews, focus groups, and co-design workshops. This aids in developing evidence-based interventions for behaviour change among farmers.

While the primary objective of this PhD work was developing behaviour change interventions for farm safety, it was considerably bolstered by two key aspects: active stakeholder engagement and commitment to transparent reporting. Stakeholder involvement ensured interventions were tailored to real-world needs, while adherence to reporting guidelines enhanced research transparency. Therefore, these three pillars—our theory-driven approach, stakeholder engagement, and commitment to transparent reporting—represent not only our comprehensive strategy to improve farm safety and drive behaviour change but also our foundational strengths and substantial contributions to the knowledge in this field.

Advancing Farm Safety Through a Theory-Driven Approach

This PhD research makes a significant contribution to the field of farm machine safety by conducting a novel feasibility study. It assesses not only the feasibility of the proposed intervention but also the fidelity and acceptability of its core components and the overall approach. During the intervention period, participants displayed a strong grasp of the intervention's skills and reported positive outcomes in terms of adopting safety measures, particularly those aimed at reducing risks related to tractor blind spots. This achievement is grounded in a unique approach, as it marks the first instance where the Behaviour Change Wheel (BCW) and COM-B model were employed to design an intervention targeting behaviour change in farm machinery safety.

Drawing from the systematic review described in Chapter 3, it becomes evident that previous interventions in farm machinery safety have produced mixed results. They often suffer from a lack of detailed reporting on their various components, making it challenging to identify and assess the effectiveness of the active ingredients of the intervention. In contrast, the current

feasibility trial has provided valuable insights into the commendable acceptability and perceived effectiveness of each intervention strategy crafted using the BCW framework and stakeholder insight. Recognising the difference between "theory-inspired" and "theory-based" interventions, as highlighted in existing health behaviour change research, reveals that theory-inspired interventions often fall short in specifying the links between theory and intervention strategies (Michie et al., 2016; Prestwich et al., 2014; Timlin, 2021). The BCW framework effectively bridges this gap by aligning theoretical constructs with Behaviour Change Techniques (BCTs) likely to induce change in farm safety practices (Michie et al., 2016).

Our feasibility trial outcomes affirm the BCW as an acceptable framework for designing and delivering effective interventions that enhance capability, opportunity, and motivation to adopt safer practices in farming. Consequently, the results from the feasibility trial discussed in Chapter 7 represent a major effort in evaluating the feasibility, fidelity, and acceptability of a theory-driven behaviour change intervention intended to promote farm machinery safety.

Traditionally, education has been the primary tool used by stakeholders in Ireland to influence work safety behaviour (McCallum et al., 2022). Nevertheless, these approaches have not been immune to criticism from occupational safety experts, who have questioned their overall efficiency and effectiveness in achieving tangible improvements in work safety and farmers' behaviour change (Narasimhan et al., 2010; Svennefelt, 2019). Existing studies have, for the most part, demonstrated a weak or nonexistent correlation between educational work safety interventions and actual changes in work safety practices. In response to these concerns, some have advocated for a shift in intervention strategies, focusing on Haddon's other E-principles, such as increased legislation and engineering solutions like Rollover Protective Structures (ROPS) (Svennefelt, 2019). These alternatives have shown promise in select studies, suggesting their potential effectiveness in reducing injuries. However, it is important to recognise that even if engineering solutions may be effective in reducing injuries, their success ultimately hinges on farmers' consistent adoption and consistent use (Alwall Svennefelt, 2019; Jakob et al., 2021; Lower & Temperley, 2018; Pickett et al., 2022; Sorensen et al., 2017). Furthermore, with family farms often lacking oversight to ensure compliance with safety regulations and guidelines, the role of educating farmers becomes even more critical for achieving long-term behaviour change.

Furthermore, education remains the most common intervention due to its broad support (Lundqvist & Svennefelt, 2012), necessitating a deeper exploration of education-based interventions and the underlying mechanisms influencing their implementation. These interventions are universally applicable and contribute to their potential for widespread impact. They can be systematically designed to cater to the diverse demographic and operational spectrum of farmers, ensuring that safety education reaches far and wide across various agricultural contexts (D. J. Murphy, 1992).

The Behaviour Change Wheel (BCW) plays a pivotal role in this context by offering a systematic framework for identifying specific behaviours and thoroughly investigating the multitude of factors that influence these behaviours. It moves beyond the assumption that the mere acquisition of knowledge will inevitably lead to changed behaviours. Instead, the BCW empowers researchers to delve deeply into the intricacies of behaviour change, facilitating the understanding of not only what behaviours need to change but also how and why they change (Davis et al., 2015; Michie et al., 2014). Therefore, by incorporating the BCW framework, we obtained a thorough understanding of behavioural drivers within the context of farm machine safety behaviour. This theoretical framework guided us to create intervention strategies that were finely tuned to address the specific challenges and facilitators

encountered by farmers. Therefore, this alignment ensured that each component of the BeSafe intervention not only adhered to sound theoretical principles but also could bring about the desired behavioural changes.

In our interviews with farmers, we found that they were generally aware of common threats in their environment and the need for safer farming practices. However, safety considerations sometimes took a backseat to productivity concerns, with farmers often weighing the risks against the benefits of safety measures. Interestingly, farmers appeared to be more concerned about safety threats related to family members and employees than personal safety, highlighting a strong sense of responsibility towards others. Our intervention effectively heightened awareness and urgency regarding the targeted safety measures, motivating farmers to improve safety awareness among their family members.

Moreover, through a theory-driven examination of the feasibility, fidelity and acceptability of our intervention, we gain valuable insights into whether it can be effectively delivered and sustained on a larger scale. This multifaceted evaluation does not merely encompass the intervention as a whole but also examines the acceptability of its components at two distinctive time points. This approach provides a nuanced assessment of the intervention components and their contributions to overall acceptability, shedding light on the evolving nature of participant perceptions. Our study notably pioneers the integration of an acceptability and fidelity framework into feasibility assessments for farm machine safety interventions. This enriches our understanding of farmers' attitudes toward such interventions and offers valuable guidance for selecting suitable interventions based on its acceptability and relevance.

However, while our study demonstrated the intervention's ability to motivate farmers to engage in injury prevention activities in the short term, it did not assess its effectiveness in reducing occupational injuries. Hence, we propose a future large-scale effectiveness trial to evaluate the impact of this innovative intervention comprehensively.

In conclusion, our study advocates for a significant shift in farm safety practices underpinned by a theory-driven approach. Instead of solely relying on engineering or policy solutions, we emphasise the pivotal role of education. Our journey through the intricacies of farm safety underscores the need for evidence-based educational interventions. Evidence-based educational interventions, informed by robust theories of behaviour change, can shape safer practices among farmers. This approach addresses a critical gap in previous interventions and provides a structured and evidence-based framework for designing and delivering effective interventions. The study advocates for a practical, theory-driven educational approach to farm safety that is rooted in sound behavioural theories and can drive meaningful change in how farmers perceive and practice safety on their farms.

Stakeholder Involvement: The Foundation of Acceptability

Our research prioritises stakeholder involvement as a fundamental pillar of our intervention's success. We recognised the pivotal role that farmers play in shaping the effectiveness and acceptability of farm safety interventions. To ensure our intervention was not only evidence-based but also contextually relevant, we actively engaged with farmers through focus groups, co-design workshops and in-depth interviews. This stakeholder-focused approach ensured that the BeSafe intervention was locally relevant, addressing the specific needs and concerns of the target population. As a result, participants consistently reported that our intervention was one of the most farmer-centric safety programs they had encountered.

Farming, a diverse and multifaceted industry, presents unique challenges across different farming systems. Recognising that different farming systems come with their distinct

challenges and considerations, we deliberately incorporated this diversity into our research. We ensured the participation of farmers from each of the four major farm systems, Beef, Dairy, Sheep and Tillage, in focus group discussions and feasibility trials. This approach ensured that BeSafe intervention is capable of addressing the unique demands of each farming system.

Moreover, our study made significant strides in addressing a critical gap in farm safety interventions by emphasising older farmers, a demographic often sidelined in such endeavours (McCallum et al., 2022; Nilsson, 2016). These older farmers, despite their heightened vulnerability to farm-related injuries, have historically received limited attention in safety interventions. The focus group discussions exclusively focused on the older farm population, aimed at understanding their unique needs and challenges. This initial engagement informed our subsequent feasibility trials, where approximately half of the participants were older farmers. The remaining participants represented various younger age groups. This conscious effort to include farmers from different age groups enabled us to thoroughly examine the acceptability and suitability of each intervention strategy across different age groups. Moreover, historically, retaining older farmers in safety initiatives has been challenging (McCallum et al., 2022), but the high retention rate of older farmers in the current trial marks a critical step towards ensuring their safety and well-being.

In this PhD research, we also acknowledged the lone-working nature of family farms, a significant concern repeatedly highlighted in the farming literature (Etienne et al., 2023; M. Murphy & O'Connell, 2018; Wheeler et al., 2022). However, through stakeholder involvement, we identified the facilitators of safer farm practices on family farms, such as the mentoring and modelling safe behaviour among different generations. Understanding this aspect allowed us to leverage and replicate these intergenerational dynamics in the BeSafe intervention, making it highly relatable, engaging and practical for participants.

BeSafe's approach to farm safety intervention empowers farmers with knowledge about practices capable of mitigating physical hazards and offers insights into the risk implications of their existing practices. However, we recognise that the successful implementation of these practices hinges on local contexts, given the diverse nature of farming and the prevalence of small, often sole-operator farm operations. In this regard, socio-psychological factors such as individual characteristics, social support, and external pressures significantly influence farmers' safety behaviour and the sustained adoption of safe work practices. Stakeholder engagement played a pivotal role in addressing these challenges. By involving stakeholders in each phase of our study, we gained a nuanced understanding of the specific needs and dynamics within various farming contexts. This insight enabled us to tailor our interventions, ensuring they were relevant and personalised to their needs. Based on this understanding, the intervention provided essential resources and support (safety document and demonstration kit) for the local implementation of safety practices. This not only increased engagement and acceptability of the intervention but also encouraged the enactment of intervention skills on the ground. The collaborative and stakeholder-focused approach, therefore, contributed significantly to the effectiveness and real-world impact of our farm safety intervention.

In summary, this PhD research highlights the pivotal role of stakeholder involvement in driving the acceptability and effectiveness of farm machinery safety interventions. By prioritising the preferences and needs of farmers, especially older ones, we have created an inclusive and locally relevant intervention that stands as a testament to the power of engaging the community in shaping its safety practices.

As a result of this stakeholder-focused approach, we achieved a high retention rate among participants, indicating their strong engagement and acceptability. Farmers' active involvement in shaping the intervention not only enhanced its acceptability but also established a sense of ownership within the farming community. This participatory process ensured that our intervention was not a top-down imposition but a collaborative effort, making it more likely to be embraced and sustained by farmers.

Transparency and Accountability in Reporting

Transparent reporting is not just a requisite in academic research; it is a fundamental element of responsible and impactful research in the realm of farm safety, behaviour change and intervention research. Our systematic review of existing literature identified several issues that guided the initial stages of this research study. Replication research faced multiple barriers, including a lack of clear intervention descriptions. Many interventions comprised a mix of different strategies, and an inadequate understanding of the composition of the interventions risked ineffective evaluations. As a result of these findings, we opted to conduct a feasibility study, which has yielded crucial insights into participant retention, group composition for the peer-to-peer learning group, implementation fidelity, and the acceptability and evolving nature of the participant's perception of intervention strategies. This pragmatic approach ensures that our research is theoretically rigorous and practically effective.

Furthermore, the study protocol for the feasibility trials provided a detailed description of the BCTs present in the intervention and their intended effects on the capability, opportunity, and motivation of farmers. This level of detail offers valuable guidance to not only researchers but also practitioners and policymakers, enabling them to understand the mechanics of our intervention thoroughly.

Moreover, our PhD work followed relevant standard reporting guidelines, such as the TIDieR checklist (Hoffmann et al., 2014), ensuring that the present research adheres to recognised standards for transparent and comprehensive reporting. The systematic review protocol was registered with PROSPERO, and the feasibility trial with the ISRCTN registry in advance. The study protocol of the feasibility trial for publication was submitted before the data collection began. This pre-registration ensured that our research plans and intentions were documented before data collection, reducing the risk of selective reporting or outcome switching.

As detailed in chapters 6 and 7, to ensure treatment fidelity, a critical component of this work, the National Institutes of Health Behaviour Change Consortium guidelines were followed (Bellg et al., 2004). The published intervention checklist, an integral part of the feasibility trial protocol, served as a guide for implementation. Adherence to the intervention was methodically examined by comparing the actual implementation to the checklist and assessing the percentage of key components that were successfully executed. High treatment fidelity, defined as having more than 80% adherence to the intervention checklist, was reported for the BeSafe feasibility trial.

Additionally, progression criteria were established a priori, as outlined in the protocol (chapter 6), to evaluate the success of the trial. These criteria were designed to assess the feasibility of implementing the intervention, the extent to which participants received the intended intervention, and the acceptability of the intervention among participants. If some of these criteria were not met, we were prepared to investigate the potential causes of these issues and consider necessary changes to the intervention components and delivery methods.

This iterative approach ensured that we could make informed decisions about recommending the development of a future larger trial to test the effectiveness of the intervention.

Moreover, current work has embraced principles of open science to further enhance transparency and accountability. This includes making pre-prints of manuscripts available, publishing through open-access platforms, and providing comprehensive supplementary files. These supplementary materials along with the additional data provided in the Open Science Framework (OSF), support the replication of the studies and increase the transparency of the findings. By sharing the work in an open and accessible manner, we contribute to reducing the "reinvention of the wheel" in farm safety and behaviour change research. Researchers and practitioners can access the research outputs, understand the methodologies, and even build upon these findings rather than duplicating efforts or starting from scratch.

In conclusion, this integrated summary highlights the multidimensional approach this PhD research has undertaken to advance farm safety. Adopting a theory-driven intervention strategy laid the groundwork for evidence-based, effective interventions. The stakeholder engagement has ensured that the focus of this work remains firmly rooted in the perceptions and needs of farmers, leading to widespread acceptance and engagement. Finally, the commitment to transparent reporting upholds the integrity of the present work, promoting accessibility and accountability.

Implications for research, practice and policy

The findings from this comprehensive body of work have significant implications for future research, practical application, and policy development. Moreover, it is important to note that implications and recommendations specific to the scope of each study are elaborated upon in the corresponding chapters (Chapters 3,4,5,6 & 7).

Implications for research

This PhD work has demonstrated the significance of employing comprehensive behaviour change frameworks like the Behaviour Change Wheel (BCW) and the COM-B model in designing tractor safety interventions. Future research in this domain should explore the utility of these frameworks to various farm safety contexts and assess their effectiveness in promoting safety behaviours. Building upon the work on systematic selection and tailoring of intervention strategies, future research should adapt and refine these strategies to diverse study contexts. Studies in different settings and regions can benefit from these methods to identify contextually relevant delivery strategies effectively.

Investigating the long-term impact of farm safety interventions is essential. While our feasibility trials showed promising short-term results, future research should assess whether these interventions lead to sustained behaviour change and reduced farm-related injuries over time. Longitudinal studies can provide insights into the durability of intervention effects and guide the development of strategies for long-term engagement and effectiveness.
Incentives are often included in interventions, whether as financial support for the adoption of engineering solutions or for recruitment and retention purposes. In the current work, vouchers were given to the focus group and feasibility trial participants as an appreciation for their participation. Previous research (Day et al., 2004; Hallman, 2005) has investigated the ideal rebate rate for the maximum ROPS adoption. However, the impact of incentives as a tool for intervention participation and engagement has limited evidence. Future research should delve into the impact of these financial incentives and explore the potential use of social incentives to generate interest and enhance engagement in farm safety interventions.

The success of the stakeholder-focused approach suggests that involving farmers and key stakeholders in intervention development is pivotal. Future research endeavours should delve deeper into stakeholder engagement strategies, seeking to identify best practices for including diverse perspectives. Studies should investigate the specific needs and concerns of older farmers, recognising them as a unique demographic within farm safety interventions. Furthermore, research should explore the intergenerational dynamics and knowledge transfer within family farms, as findings suggest this can be a strong facilitator for behaviour change.

Detailed descriptions of intervention components, their intended effects, and evaluation methods should be consistently provided to support the adoption of evidence-based practices. Researchers should also consider adhering to standard reporting guidelines like TIDieR, enhancing the clarity and replicability of research.

Recognising that farm safety is a complex and multifaceted challenge, future research should emphasise interdisciplinary collaboration. Engaging experts from fields such as agriculture, psychology, policy, engineering, and public health can provide a holistic understanding of farm safety challenges and the development of effective interventions.

Implications for practice

The peer-to-peer demonstration and facilitated discussion approach have demonstrated the potential to improve farmers' safety behaviours. However, it is crucial to recognise that these strategies may not be universally effective for raising awareness about all safety topics. Therefore, safety interventions should be tailored to specific safety concerns and behaviours. Additionally, when the interventions targeting farmers' behaviour change are designed and implemented that focus on raising awareness (psychological capability) and motivation, it is important to ensure that farmers have the physical capability and right opportunities, including access to resources for performing these behaviours. Assessments of the target population's capabilities, opportunities, and motivation are, therefore, essential for designing effective interventions.

The role of safety advisors in disseminating information and facilitating discussions during the design and feasibility trials cannot be understated. They serve as reliable and authentic sources of information regarding safe practices and can provide guidance on relevant schemes and opportunities available to farmers for sustaining target behaviours. The support of safety advisors should be integrated into education-based intervention efforts as valuable resources for farmers.

The list of specific target behaviours related to improving safety on farms, their barriers and facilitators, and behavioural change strategies for addressing these factors developed in this research holds significant implications for behaviour change among farmers. These evidence-based strategies provide a foundation for researchers and practitioners to develop farm safety interventions. Whether implementing engineering-based or policy-based interventions, a holistic approach should be considered for maximum impact. These farmer-centric strategies can complement primary interventions (e.g. ROPS) to increase engagement and awareness. They can also serve as follow-up interventions to sustain behaviour change in the long term. The target behaviours, their facilitators and barriers and proposed BCTs relevant to tractor safety is available in chapter 4 and 5. A comprehensive list of findings from these studies will be uploaded onto the Open Science Framework in the future.

Farmers have expressed a clear interest in participating in safety discussions on various topics. Safety advisors and inspectors can explore the feasibility of adding safety as a regular topic for regular discussion group sessions and other venues where farmers congregate, eg. Farm marts. Providing platforms for farmers to seek advice and share experiences related to safety can contribute to increased awareness and knowledge dissemination.

Farmers and family members closely linked to the farm and exposed to risks are crucial stakeholders in safety interventions. Their perspectives on intervention strategies, design preferences, delivery methods, and facilitation should be actively sought to ensure the their interests are met.

Safety practitioners should identify ensure the representation of vulnerable groups for farm events and initiatives. The deliberate inclusion of underrepresented groups, such as older farmers, can offer unique insights into their safety challenges and contribute to the development of more inclusive and effective interventions.

Implications for policy

Farm machinery safety policies should be tailored to address specific safety concerns and behaviours identified among Irish farmers. Recognising that one-size-fits-all approaches may not be effective, policies should be context-specific and adaptable to various farm types and practices. Recognising the unique challenges faced by various farmer demographics, including older farmers, policies should aim to address the specific safety needs of these groups. Inclusive policies will contribute to safer farming practices across the board.

Policy development should consider the call for stricter safety regulations and punitive measures, as voiced by participants. This can serve as a deterrent to non-compliance and enhance overall safety culture. However, as noted in Chapter 4, though farmers agreed on the need for strict rules, there were also worries that these may bring additional paperwork for them, further increasing their workload. Therefore, policymakers need to conduct a detailed investigation into the impact of these regulations to ensure farmer-friendly implementation.

Regulators should prioritise the development of more stringent compliance monitoring mechanisms, with a particular focus on equipment manufacturers, importers, and suppliers. Ensuring strict adherence to safety standards is paramount for injury prevention. This includes user-centred equipment design and engineering solutions to rectify potential flaws that may put farmers at greater risk. More safety-focused schemes should be made available to facilitate the transition to safer equipment models as they become available in the market. This can involve incentivising farmers to upgrade to safer machinery and providing information about the benefits of such transitions.

Incentive-based programs, such as subsidies for safety equipment and reductions in insurance premiums for safety-conscious farmers, should be explored to encourage safety compliance. Furthermore, the potential effectiveness of social incentives, like recognition or awards for exemplary safety practices, cannot be overlooked. These social incentives can foster a sense of pride and belonging within the farming community, further encouraging a culture of safety.

Farm safety policies should integrate evidence-based behavioural change strategies identified in this research. The strategies identified in this research can serve as a foundation for designing interventions that influence safe practices. These policies should promote the

adoption of farmer-centric approaches and leverage the insights gained from the research. Policy efforts should focus on supporting the development and dissemination of farmer-centric safety education materials as well. These materials should align with farmers' preferences, needs, and capabilities. The intervention strategies outlined in this thesis can serve as a valuable resource for designing such educational materials.

Authorities must address farmers' reported lack of knowledge regarding existing resources, such as schemes for succession (Chapter 4). Efforts should be made to effectively inform farmers about these support mechanisms. This can include the development of clear, accessible resources and outreach programs to ensure that farmers are aware of and can access the support they need. Safety advisors can play a pivotal role in disseminating information about these support measures, acting as intermediaries between policymakers and farmers. Support mechanisms, such as training and resources for safety advisors, can be integrated into policies to strengthen their interaction with farmers.

Safety agencies should address the reported absence of clarity in certain areas of safety, such as machine maintenance and tool handling. Clear guidelines and educational resources should be developed and disseminated to enhance awareness and knowledge in these specific areas. This should include a focus on empowering farmers with knowledge of their rights regarding equipment usage, as mandated by the Safety, Health and Welfare at Work Act 2005 (Shannon, 2005).

Farm research bodies should encourage active stakeholder engagement in the development and implementation of safety interventions. Farmers and their families, as key stakeholders, should have a voice in shaping policy decisions related to farm machinery safety. Similarly, collaboration between researchers, practitioners, and policymakers may also be encouraged. Creating platforms for dialogue and knowledge exchange can facilitate evidence-based policymaking and ensure that research findings are effectively translated into policy and practice.

Funding agencies for farm research should consider implementing transparency and reporting standards for farm safety interventions. This can include requirements for detailed reporting of intervention designs and evaluations, as well as making study protocols and results publicly accessible. Open science principles can guide the development of such standards.

Limitations of the thesis

The research undertaken in this PhD program exhibits several strengths as highlighted in the previous sections (8.3 & 8.4) while also recognising certain limitations that were examined in detail in the preceding chapters. Presented below is a summary of the limitations:

Firstly, the primary data collection for intervention development was cross-sectional. This design, while effective in many ways, may not fully capture the dynamic and evolving nature of farm tasks. Farm work is seasonal and diverse, and understanding how safety practices change over time could provide a more nuanced perspective. Future studies could consider employing a longitudinal qualitative study approach. This would involve repeated data collection over an extended period, allowing researchers to track how safety perceptions and practices evolve with changing seasons, farm tasks, and environmental factors such as weather. Such an approach would provide a more nuanced understanding of the temporal dynamics of safety behaviours on farms.

In the application of the Behaviour Change Technique (BCT) taxonomy, certain challenges arose due to its limited use in the farm safety domain. Operational definitions had to be established based on limited farm literature, potentially impacting the accuracy of BCT coding by introducing an element of subjectivity and uncertainty. This limitation highlights the need for more comprehensive research in this domain to refine and expand the taxonomy.

The recruitment of participants within the Teagasc network and their voluntary participation introduced the possibility of selection bias, potentially favouring farmers who were already interested in farm safety, which could limit the generalizability of the research findings. To enhance the reach and impact of future farm safety research, several strategies can be considered. First, targeting "hard-to-reach" farmers, who may have heavy workloads and limited access to educational resources, should be a priority(Furey et al., 2016). Implementing a "train-the-trainer" model can effectively reach a broader audience, as trainers may have existing relationships within these communities. Offering incentives, such as financial compensation or equipment discounts, to farmers trained through the train-the-trainer approach can encourage them to reach out to these “hard-to-reach” farmers.

Furthermore, the limitation of the underrepresentation of female farmers in this PhD research is noteworthy. Recognising the unique circumstances that female farmers face is crucial for a more comprehensive understanding of farm safety. In many farming communities, women are often cast in roles as assistants to their male counterparts, even though they significantly contribute to farm production. They may lack financial independence and official recognition in occupational spheres, yet they are not exempt from the risks of farm injuries. While this study successfully engaged one underreported group, older farmers, future effectiveness trials should make a concerted effort to actively involve female farmers(O’Hara, 1998). Therefore, it is imperative to conduct further research using more inclusive sampling techniques to address this gender-related research gap comprehensively.

Finally, the study is also susceptible to response and social desirability biases. Despite efforts to mitigate these biases through audio-based focus group discussions and anonymised evaluation surveys, some responses may have been influenced by what participants believed to be socially acceptable. Future research could consider employing a longitudinal evaluation approach to address these potential biases. This would involve monitoring safety behaviours, near-misses, injuries, and fatalities over an extended period, allowing for a more comprehensive assessment of the intervention's effectiveness. Additionally, utilising independent observers or objective safety measures, such as injury rates, could help reduce social desirability bias.

Conclusion

This thesis represents a novel template for enhancing machine-related safety on farms, with a specific focus on older farmers, through the development of the BeSafe machine safety intervention. Rooted in the Behaviour Change Wheel (BCW) framework, this intervention was systematically developed in collaboration with Irish farmers, safety advisors, experts, and researchers. The central objective of the intervention was to raise awareness about tractor blind spots' risks and promote safety practices through a peer-to-peer learning approach.

To accomplish this, a series of four interlinked studies were conducted, adhering to the MRC framework for complex intervention development and evaluation. This acknowledged the iterative nature of intervention development, highlighting the need for continuous refinement and adaptation. Farm safety, particularly in the context of machine-related hazards, remains a multifaceted challenge. This research investigate the intricate dynamics of safety behaviours

in Irish farming, offering a in-depth understanding of the barriers and facilitators shaping these practices.

This thesis underscores the importance of a holistic approach tailored to farmers' unique perceptions, needs, and capabilities. This farmer-centric strategy acknowledges the complexity of the issue and the necessity of tailored interventions, especially for vulnerable groups like older farmers. By adopting a theory-driven and stakeholder-informed approach, the intervention strategies created were theoretically sound, contextually relevant and highly acceptable among the targeted population.

Notably, this research successfully tested a novel behaviour change intervention with a select group of Irish farmers, showcasing its feasibility. Looking ahead, key areas for future research have been identified, ensuring the continued refinement and optimisation of behaviour change interventions to enhance safety among farmers. In sum, this work advances our understanding of farm safety and provides a promising foundation for future endeavours in this critical field.

Availability of data and materials[12]

The dataset supporting the conclusions of this article is included within the article. Additional data supporting the project is available in the OSF repository.

Author contribution statement

Conceptualisation and formal analysis: A.S., J.M. (Jennifer McSharry) and D.O.; Methodology: A.S., D.O., J.M. (Jennifer McSharry), D.M., J.M. (John McNamara) and F.B.; writing—original draft preparation: A.S. and S.M. ; writing—review and editing: A.S., S.M., J.M. (Jennifer McSharry), O.M., D.O, D.M, and J.M. (John McNamara); Validation: D.O., J.M. (Jennifer McSharry), D.M., J.M. (John McNamara) and F.B.; Project Administration—D.O., D.M., J.M. (John McNamara) and F.B.; Funding acquisition: D.O.; Supervision: D.O., J.M. (Jennifer McSharry), D.M. and O.M.

References

2018—Alarming Rise in Farm Accidents – Teagasc Survey—Teagasc | Agriculture and Food Development Authority. (2019). Retrieved 23 January 2023, from https://www.teagasc.ie/news--events/news/2018/rise-in-farm-accidents.php

Alwall Svennefelt, C. (2019). Occupational injuries and communications in Swedish agriculture safety interventions. *Acta Universitatis Agriculturae Sueciae, 2019: 50.*

Bellg, A. J., Borrelli, B., Resnick, B., Hecht, J., Minicucci, D. S., Ory, M., Ogedegbe, G., Orwig, D., Ernst, D., & Czajkowski, S. (2004). Enhancing treatment fidelity in health behavior change studies: Best practices and recommendations from the NIH Behavior Change Consortium. *Health Psychology*, *23*(5), 443. https://doi.org/10.1037/0278-6133.23.5.443

Colémont, A., & Van den Broucke, S. (2008). Measuring determinants of occupational health related behavior in Flemish farmers: An application of the theory of planned behavior. *Journal of Safety Research*, *39*(1), 55–64.

Coman, M. A., Marcu, A., Chereches, R. M., Leppälä, J., & Van Den Broucke, S. (2020). Educational Interventions to Improve Safety and Health Literacy Among Agricultural Workers: A Systematic Review. *International Journal of Environmental Research and Public Health*, *17*(3), Article 3. https://doi.org/10.3390/ijerph17031114

[12] In the appendix, we have included most of the supplementary files published along with the journal. However, a few supplementary files that are not included here can be accessed on our Open Science Framework (OSF) profile or on the respective publisher websites.

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: A scoping review. *Health Psychology Review*, *9*(3), 323–344.

Day, L., Rechnitzer, G., & Lough, J. (2004). An Australian experience with tractor rollover protective structure rebate programs: Process, impact and outcome evaluation. *Accident Analysis & Prevention*, *36*(5), 861–867. https://doi.org/10.1016/j.aap.2003.09.001

DeRoo, L. A., & Rautiainen, R. H. (2000). A systematic review of farm safety interventions. *American Journal of Preventive Medicine*, *18*(4), 51–62.

Dillon, E., Donnellan, T., Moran, B., & Lennon, J. (2017.). *Teagasc National Farm Survey 2021 Final Results*.

Dyreborg, J., Lipscomb, H. J., Nielsen, K., Törner, M., Rasmussen, K., Frydendall, K. B., Bay, H., Gensby, U., Bengtsen, E., Guldenmund, F., & Kines, P. (2022). Safety interventions for the prevention of accidents at work: A systematic review. *Campbell Systematic Reviews*, *18*(2), e1234. https://doi.org/10.1002/cl2.1234

Etienne, A. J., Field, W. E., & Haslett, N. J. (2023). A Summary of Lone Agricultural Worker Injuries and Fatalities. *Journal of Agricultural Safety and Health*, *29*(3), 185–201. https://doi.org/10.13031/jash.15523

Europäische Kommission (Ed.). (2004). *The magnitude spectrum of farm injuries in the European Union countries*. European Communities.

Farmers over 65 Years—Health and Safety Authority. (2021). Retrieved 7 September 2023, from https://www.hsa.ie/eng/your_industry/agriculture_forestry/young_elderly_on_farms/farmers_over_65_years/

Franklin, R. C., McBain-Rigg, K. E., King, J. C., & Lower, T. (2015). Exploring the barriers and facilitators to adoption of improved work practices for safety in the primary industries. *Barton ACT: Australian Government, RIRDC*. https://agrifutures.com.au/wp-content/uploads/publications/15-068.pdf

Furey, E. M., O'Hora, D., McNamara, J., Kinsella, S., & Noone, C. (2016). The Roles of Financial Threat, Social Support, Work Stress, and Mental Distress in Dairy Farmers' Expectations of Injury. *Frontiers in Public Health*, *4*. https://doi.org/10.3389/fpubh.2016.00126

Hakvoort, L., Dikken, J., Van Der Wel, M., Derks, C., & Schuurmans, M. (2021). Minimizing the knowledge-to-action gap; identification of interventions to change nurses' behavior regarding fall prevention, a mixed method study. *BMC Nursing*, *20*(1), 80. https://doi.org/10.1186/s12912-021-00598-z

Hallman, E. M. (2005). ROPS retrofitting: Measuring effectiveness of incentives and uncovering inherent barriers to success. *Journal of Agricultural Safety and Health*, *11*(1), 75–84. https://doi.org/10.13031/2013.17898

Hansen, B. G. (2015). Financial extension that challenges farmers' thinking in discussion clubs helps farmers improve their problem solving abilities. *Agricultural Systems*, *132*, 85–92. https://doi.org/10.1016/j.agsy.2014.09.009

Health, & Authority, S. (2021). *A Review of Work-Related Fatalities in Agriculture in Ireland 2011-2020*. Health and Safety Authority. https://www.hsa.ie/eng/publications_and_forms/publications/agriculture_and_forestry/a_review_of_work-related_fatalities_in_agriculture_in_ireland_2011-2020.pdf

Helitzer, D. L., Hathorn, G., Benally, J., & Ortega, C. (2014). Culturally relevant model program to prevent and reduce agricultural injuries. *Journal of Agricultural Safety and Health*, *20*(3), 175–198.

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D. G., Barbour, V., Macdonald, H., & Johnston, M. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *Bmj*, *348*. https://doi.org/10.1136/bmj.g1687

Jakob, M., Santa, D., Holte, K., Sikkeland, I., Hilt, B., & Lundqvist, P. (2021). Occupational health and safety in agriculture – a brief report on organization, legislation and support in selected European countries. *Annals of Agricultural and Environmental Medicine*, *28*(3), 452–457. https://doi.org/10.26444/aaem/140197

Lee, M. J., Cawley, D. T., Ng, J. P., & Kaar, K. (2017). *Trends in the Fractures and Fatalities of Farmyard Injuries in Ireland: A 10 year analysis*.

Lower, T., & Temperley, J. (2018). Farm safety—Time to act. *Health Promotion Journal of Australia*, *29*(2), 167–172.

Lundqvist, P., & Svennefelt, C. A. (2012). Health and safety strategy in Swedish agriculture. *Work*, *41*(Supplement 1), 5304–5307.

McCallum, D. M., Reed, D. B., Claunch, D. T., Davis, C. M., & Conaway, M. B. (2022). Farm Dinner Theater: Testing an innovative health and safety intervention among older farmers and their families. *The Journal of Rural Health*, *38*(2), 433–441.

McNamara, J., Kinsella, A., Osborne, A., Blake, C., Meredith, D., & Kinsella, J. (2021). Identifying farmer workplace injury risk factors in Ireland using farm accounts data. *Journal of Agromedicine*, *26*(4), 411–419.

McNamara, J., Mohammadrezaei, M., & Griffin, P. (2022). Promoting childhood farm safety in Ireland. *Frontiers in Public Health*, *10*, 1055082.

Michie, S., Atkins, L., & West, R. (2014). *The behaviour change wheel: A guide to designing interventions*. Silverback Publishing. http://www.behaviourchangewheel.com/

Michie, S., Carey, R., Johnston, M., Rothman, A. J., Kelly, M., Davidson, K., & de Bruin, M. (2016). From theory-inspired to theory-based interventions: Linking behaviour change techniques to their mechanisms of action. *Eur Health Psychol*, *18*, 395.

Michie, S., Johnston, M., Francis, J., Hardeman, W., & Eccles, M. (2008). From theory to intervention: Mapping theoretically derived behavioural determinants to behaviour change techniques. *Applied Psychology*, *57*(4), 660–680.

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M. P., Cane, J., & Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine*, *46*(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6

Mohammadrezaei, M., Meredith, D., & McNamara, J. (2022). Beyond Age and Cause: A Multidimensional Characterization of Fatal Farm Injuries in Ireland. *Journal of Agromedicine*. https://www.tandfonline.com/doi/abs/10.1080/1059924X.2022.2116138

Mohammadrezaei, M., Meredith, D., McNamara, J., Kinsella, J., & Flannery, S. (2023). Do social influences, awareness, or experience matter? Toward a better understanding of Farm-related Injury Risk Perception among agricultural science college students in Ireland. *Frontiers in Public Health*, *11*, 1076332.

Murphy, D. J. (1992). *Safety and health for production agriculture.* (Issue Ed. 1). American Society of Agricultural Engineers.

Murphy, M., & O'Connell, K. (2017). *Farm deaths and injuries: Changing Irish farmer attitudes and behaviour on farm safety*.

Murphy, M., & O'Connell, K. (2018). *The Use of Mentoring To Effect Cultural Change: Irish Farm Deaths And Injuries*. https://sword.cit.ie/dptmecp/3

Narasimhan, G. R., Peng, Y., Crowe, T. G., Hagel, L., Dosman, J., & Pickett, W. (2010). Operational safety practices as determinants of machinery-related injury on Saskatchewan farms. *Accident Analysis & Prevention*, *42*(4), 1226–1231. https://doi.org/10.1016/j.aap.2010.01.016

Nilsson, K. (2016). Interventions to reduce injuries among older workers in agriculture: A review of evaluated intervention projects. *Work*, *55*(2), 471–480. https://doi.org/10.3233/WOR-162407

O'Connor, T. (2020). *Evaluating the Influence of Dairy Discussion Groups on Farmer Behaviour: An Assessment of Group Engagement with Occupational Safety and Health*. University College Dublin.

O'Connor, T., Meredith, D., McNamara, J., O'Hora, D., & Kinsella, J. (2021). Farmer discussion groups create space for peer learning about safety and health. *Journal of Agromedicine*, *26*(2), 120–131. https://doi.org/10.1080/1059924X.2020.1720882

O'Hara, P. (1998). *Partners in Production?: Women, Farm, and Family in Ireland*. Berghahn Books.

Pickett, W., Belton, K. L., Lear, A., Anderson, R., & Voaklander, D. C. (2022). International commentary: Child injuries on the farm: A brief commentary from Canada. *Frontiers in Public Health*, *10*, 1050621.

Prager, K., & Creaney, R. (2017). Achieving on-farm practice change through facilitated group learning: Evaluating the effectiveness of monitor farms and discussion groups. *Journal of Rural Studies*, *56*, 1–11. https://doi.org/10.1016/j.jrurstud.2017.09.002

Prestwich, A., Sniehotta, F. F., Whittington, C., Dombrowski, S. U., Rogers, L., & Michie, S. (2014). Does theory influence the effectiveness of health behavior interventions? Meta-analysis. *Health Psychology*, *33*(5), 465.

Rautiainen, R., Lehtola, M. M., Day, L. M., Schonstein, E., Suutarinen, J., Salminen, S., & Verbeek, J. H. (2008). Interventions for preventing injuries in the agricultural industry. *Cochrane Database of Systematic Reviews*. https://doi.org/10.1002/14651858.CD006398.pub2

Robson, L. S. (2001). *Guide to evaluating the effectiveness of strategies for preventing work injuries: How to show whether a safety invervention really works*. https://stacks.cdc.gov/view/cdc/11272

Shannon, G. (2005). The Safety, Health and Welfare at Work Act 2005 Update. *Q. Rev. Tort L.*, *1*, 23.

Skivington, K., Matthews, L., Simpson, S. A., Craig, P., Baird, J., Blazeby, J. M., Boyd, K. A., Craig, N., French, D. P., McIntosh, E., Petticrew, M., Rycroft-Malone, J., White, M., & Moore, L. (2021). A new framework for developing and evaluating complex interventions: Update of Medical Research Council guidance. *BMJ*, *374*. https://doi.org/10.1136/bmj.n2061

Sorensen, J. A., Tinc, P. J., Weil, R., & Droullard, D. (2017). Symbolic Interactionism: A Framework for Understanding Risk-Taking Behaviors in Farm Communities. *Journal of Agromedicine*, *22*(1), 26–35. https://doi.org/10.1080/1059924X.2016.1248306

Sutherland, L.-A., & Marchand, F. (2021a). On-farm demonstration: Enabling peer-to-peer learning. *The Journal of Agricultural Education and Extension*, *27*(5), 573–590. https://doi.org/10.1080/1389224X.2021.1959716

Sutherland, L.-A., & Marchand, F. (2021b). On-farm demonstration: Enabling peer-to-peer learning. *The Journal of Agricultural Education and Extension*, *27*(5), 573–590. https://doi.org/10.1080/1389224X.2021.1959716

Svennefelt, C. A. (2019). *Occupational Injuries and Communications in Swedish Agriculture Safety Interventions*. Alnarp: Swedish University of Agricultural Sciences.

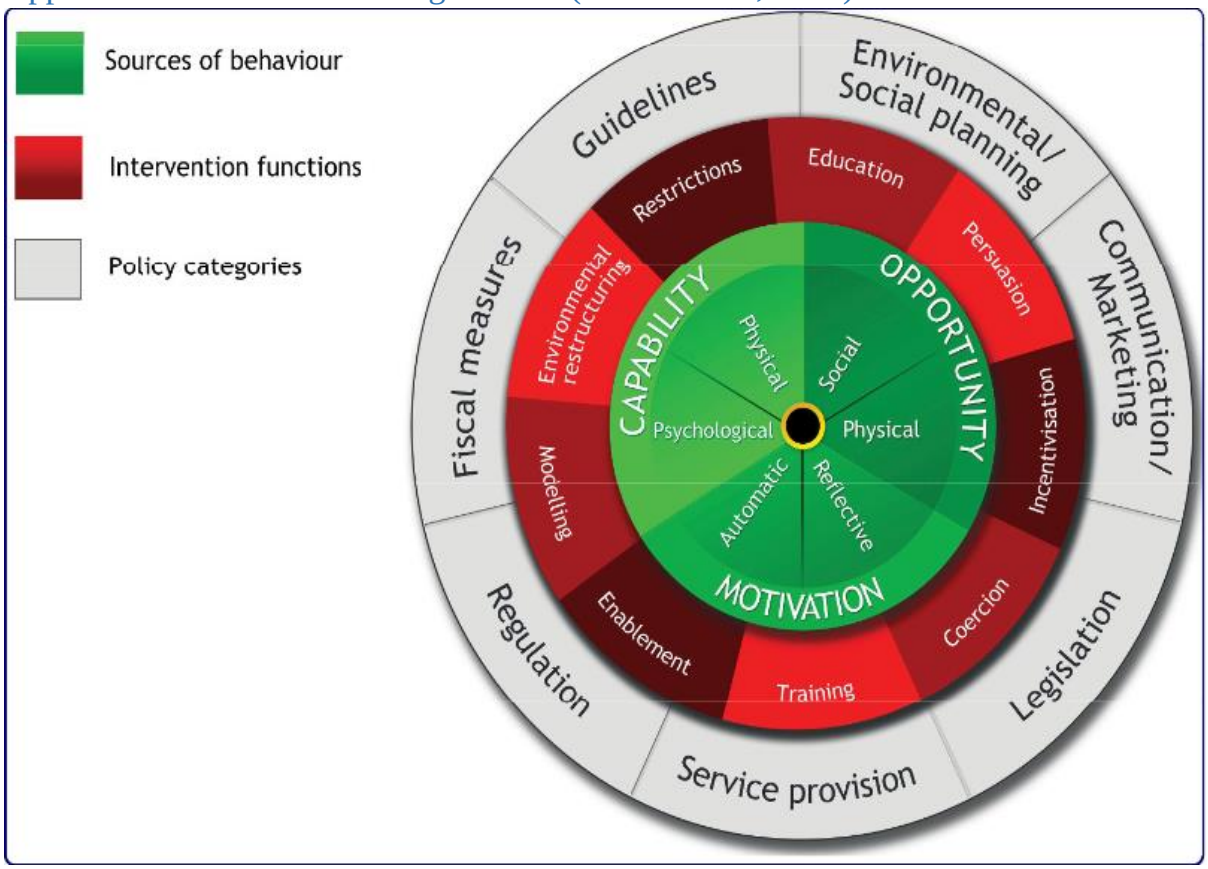
Timlin, D. (2021). *Promoting Uptake of the MIND Diet to Prevent Cognitive Decline in Adults at Midlife: Employing the Behaviour Change Wheel and COM-B Model*. Ulster University.

Watson, D., Kenny, O., Maitre, B., & Russell, H. (2017). *Risk-taking and accidents on Irish farms: An analysis of the 2013 Health and Safety Authority survey*. ESRI.

Wheeler, R., Lobley, M., McCann, J., & Phillimore, A. (2022). 'It's a lonely old world': Developing a multidimensional understanding of loneliness in farming. *Sociologia Ruralis, 63,* 11–36. https://doi.org/10.1111/soru.12399

Appendices

Appendix A1: Behaviour change wheel (Michie et al., 2015)



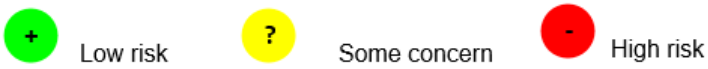
Appendix A2: Search strategy used for the PubMed database

Serial No	Search terms*
1	agricultur*[tw] OR farm[tw] OR farms[tw] OR farmer*[tw] OR farming[tw] OR "farm worker"[tw] OR "farm workers"[tw] OR "farmworker"[tw] OR "farmworkers"[tw] OR "farm work"[tw] OR ranch*[tw] OR dairy*[tw] OR dairies[tw] OR greenhous*[tw] OR "green house"[tw] OR orchard*[tw] OR "crop production"[tw] OR harvesting[tw] OR agronom*[tw] OR "Agriculture"[MeSH]
2	tractor* OR quad OR "quad bike" OR "all terrain vehicle" OR atv OR "all-terrain vehicle" OR "farm machinery" OR "machine*" OR mower OR Rake OR Baler OR Augers OR Trailer OR Loader OR excavator OR Teleporter
3	injur*[tw] OR accident*[tw] OR Accidents[MeSH] OR trauma[tw] OR harm*[tw] OR wound*[tw] OR "fall"[tw] OR OR "falling*"[tw] OR "burn"[tw] OR burning[tw] OR "burns"[tw] OR fatal*[tw] OR suffocat*[tw] OR lacerat*[tw] OR asphyxia[tw] OR asphyxiate*[tw] OR "electric shock"[tw] OR Electrocution[tw] OR "power line"[tw] OR Entanglemen*[tw] OR "injuries"[sh] OR "Accidents, Occupational"[Mesh] OR "Wounds and Injuries"[MeSH] OR roll-over[tw] OR "roll over"[tw] OR "equipments"[tw] OR PTO*[tw] OR "power take off"[tw] OR "power take-off"[tw] OR "scald"[tw] OR scalding[tw] OR scalds[tw] OR "crush" OR "collisions" OR amput* OR mutilate* OR fractur* OR "death"
4	safet*[tw] OR prevent*[tw] OR control*[tw] OR risk*[tiab] OR "risk management"[MeSH] OR "accident prevention"[MeSH] OR Safety[MeSH] OR "Safety Management"[MeSH] OR "prevention and control"[sh] OR risk[MeSH] OR intervention[tw] OR "Accident Prevention"[MeSH] OR "on-farm"[tw] OR intervene*[tw] OR "protective gears" OR mitigation[tw] OR education[tw] OR "roll-over protective structures"[tw] OR ROPS[tw] OR "Personal Protective Equipment"[tw] OR "protective gears"[tw] OR "protective guard"[tw] OR "safety check"[tw] OR "PPE"
5	randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR "clinical trial"[tw] OR ((singl*[tw] OR doubl*[tw] OR trebl*[tw] OR tripl*[tw]) AND (mask*[tw] OR blind*[tw])) OR "latin square"[tw] OR placebos[mh] OR placebo*[tw] OR random*[tw] OR research design[mh:noexp] OR comparative study[tw] OR Evaluation Study[tw] OR comparative study[pt] OR Evaluation Study[pt] OR Follow-Up Studies[mh]OR prospective studies[mh] OR cross-over studies[mh] OR Cohort Studies[mh] OR Longitudinal Studies[mh] OR control*[tw] OR prospectiv*[tw] OR volunteer*[tw] NOT (animal[mh] NOT human[mh]
6	effect* [tw] OR control* [tw] OR evaluation* [tw] OR program* [tw]) NOT (animal[mh] NOT human[mh
7	1&2&3&4
8	5&7
9	6&7
10	8 OR 9 limit 16 to (english language

* Search terms for other studies available in the OSF profile (Aswathi et al., 2022).

Appendix A3: Quality appraisal and Risk of Bias Assessment - Cochrane risk-of-bias tool for randomized trials (RoB 2 v2)

Study	Randomisation process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Gadomski et al., 2006	+	+	+	+	+	+
Pekkarinen et al., 1994	?	+	+	+	+	+
Jinnah et al., 2014	+	+	+	+	+	+
Stoneman et al., 2014	+	+	+	+	+	+
Hallman, 2005	+	+	+	?	+	?
Rasmussen et al., 2003	+	+	+	+	+	+



Appendix A4: Quality appraisal and Risk of Bias Assessment - Cochrane risk-of-bias tool for non-randomised trials (ROBINS-NRCI)

Study	Confounding Bias	Selection Bias	Classification of Interventions	Deviations from intended interventions	Missing outcome data	Measurement of outcomes	Selection of the reported result	Overall
Sorensen et al., 2011	?	+	+	+	+	?	?	+
Morgan et al., 2002	−	+	+	?	−	−	−	−
Day et al., 2004	−	+	+	+	+	+	+	−

Appendix A5: Data extraction table

Authors (year of publication, country)	Name of the study and relevant objective(s)	Study Design	Participants	Intervention(s)	Intervention approaches identified	Quality rating	Theoretical under pinning	Individualised intervention	Participatory research
Pekkarinen et al., 1994 Finland	Accident Prevention in Reindeer Herding To reduce the snow mobile accidents among reindeer farmers	Community-randomised controlled trial Time period: 1985-1987	*Targeted*: Reindeer herders in 53 herding districts *Sample size*: Intervention A : 18 districts (N=1157) Intervention B : 17 districts (N=1 065) *Control Group*: 18 districts	Intervention Group 1 : Information dissemination by theme letters via selected leaders employed by the project Intervention Group 2 : Information dissemination during medical examinations conducted by health personnel Control group: No intervention, had access to information about the study the press *Results*: Herders reported implementing an average of 5.8	Safety education	High	Not Reported	No	No

				safety measures per herder. The number of helmet users doubled to 5%, and eye/face protector usage increased to 10%. Accident rate decreased from 20 to 15 accidents per 1000 working days over two years.					
Morgan et al., 2002 Kentucky, USA	Stories or Statistics? Farmers' Attitudes Toward Messages in an Agricultural Safety Campaign To increase the adoption of ROPS and use of seat belts while driving tractor	Pre-Post study using surveys Time period: Three years	*Targeted*: Farmers in the state of Kentucky, USA *Sample size*: Farmers from two counties of the state of Kentucky *Control group: None*	Phase 1: Incentives for retrofitting Phase 2: Incentive and ROPS Community-based safety capaign *Results*: The number of retrofitted tractors with ROPS increased from 4 to 61 after the implementation of the ROPS promotion campaign.	Safety education	Low	Dual coding theory Narrative theory	No	Yes
Rasmussen et al., 2003	Prevention of farm injuries in Denmark	Randomised controlled trial	*Targeted*: Farms in the county of	*Intervention Group : Injury registration,*	Safety education	High	None	Yes	Yes

Ringkoebing, Denmark	To reduce the work-related accidents and injuries	Time period: 1993-1997	Ringkoebing, Denmark *Sample size*: Intervention group: 99 farmers from approximately equal numbers of dairy, swine, crops and mixed farms. *Control group:*102 farmers	*safety checks on farms, 1-day farm safety course and custom safety plans* *Control group: No intervention* *Results*: Farmers reported improvement in the machinery repairs post intervention.					
Day et al., 2004 Victoria, Australia	An Australian experience with tractor rollover protective structure rebate programs: process, impact and outcome evaluation To increase the adoption of ROPS among	Pre-Post study using surveys Time period: 1997-1998	*Targeted*: Full and part-time farmers from the state of Victoria *Sample size*: Not available *Control Group:* None	A regulatory amendment that required all operational tractors to be fitted with ROPS. A rebate program that offered $AUD 150 to farmers for each tractor retrofitted with ROPS. A safety campaign involving television advertising, mailing of application forms	Regulation Safety education	Low	Not Reported	No	No

	farmers with tractor rollover protective structure rebate program			to all Victorian farmers, and information dissemination at farm field days and other public events. *Results*: The proportion of unprotected tractors was reduced from approximately 24%–7% in the state.					
Hallman, 2005 New York, USA	ROPS Retrofitting: Measuring Effectiveness of Incentives and Uncovering Inherent Barriers to Success To increase the adoption of ROPS among farmers	Randomised comparative study Time period: Not available	*Targeted*: Farms in the state of New York, USA *Sample size*: Intervention group: 365 Farms *Control group:* None	Nine different Offer packages varying from 0% to 100% for retrofitting ROPS on tractors Free engineering consultation. *Results*: Out of the 365 farms, 30 farms accepted the subsidy and retrofitted the ROPS. An incentive of 75% to 90% funding attracted the	Safety education	Medium	None	No	No

				greatest number of participants per dollar offered.					
Gadomski et al., 2006 New York, USA	Efficacy of the North American Guidelines for Children's Agricultural Tasks in Reducing Childhood Agricultural Injuries Guidelines to reduce the agricultural injuries among children.	Randomised controlled trial Time period: 2001-2003	*Targeted*: Farm children between 7-16 years old and employed at farms *Sample size*: Intervention group:462 farms *Control group:* 469 farms	Intervention Group: Farm visits, Telephone injury surveillance every 3 months, Customised guidelines and remainder mailers and souvenirs Control group: No intervention *Results*: No difference between the 2 groups in adding a rollover protection structure and adding or repairing a power takeoff. Intervention farms reported fewer violations in recommended minimum age guidelines on using ATVs and tractors, hitching and un-hitching trailed implements	Safety education	High	Child development principles. No further details available	Yes	No

				to tractors, and baling hay than control farms.					
Sorensen et al., 2011 New York, USA	The Social Marketing of Safety Behaviours: A Quasi–Randomized Controlled Trial of Tractor Retrofitting Incentives To increase the adoption of ROPS among farmers	Quasi-Randomised controlled trial Time period: 2006-2007	*Targeted*: Small-scale crop and livestock farms in the state of New York, USA *Sample size*: Intervention 1: 214 participants Intervention 2: 227 participants Intervention 3: 282 participants *Control group*: 383 participants	Intervention Group 1: Rebates and Toll-free hotline assistance Intervention Group 2: Rebates, Toll-free hotline assistance, Social marketing messages and promotion Intervention Group 3: Toll-free hotline assistance, Social marketing messages and promotion Control group: No intervention *Results:* Eighteen(5.1%) of the final 350 respondents who completed the program reported retrofitting a tractor since the start of the intervention. The social marketing region reported the	Safety education	High	Theory of planned behaviour	No	Yes

				greatest increases in readiness to retrofit and intentions to retrofit. Farmers in this region also had higher message recall. Movement from precontemplation to contemplation in farm safety habits was observed in the rebate-only and social marketing regions. In the social marketing region, the mean behavioural intention score increased roughly 4 times the baseline value. Comparisons of changes in subjective norms scores found the most notable increase in the social marketing region, followed by the rebate-only region, the					

				messages and promotion region, and the control region.					
Jinnah et al., 2014 Georgia state, USA	Involving Fathers in Teaching Youth About Farm Tractor Seatbelt Safety: A Randomised Control Study AgTeen, a family-based farm safety intervention to increase the use of seat belts while driving tractors	Randomised controlled trial Time period: 2007 -2012	*Targeted*: Crop farming families with children aged 10-19 and employed at farm *Sample size*: Intervention 1: 47 families , Intervention 2: 53 families *Control group:* 51 families.	Intervention Group 1: AgTeen lessons taught by fathers to the children. Intervention Group 2: AgTeen lessons taught by a peer farmer employed by the project to the children. Control group: No intervention. Data collection forms were provided. Incentives were provided to all the participants. *Results*: 70% of farmers of parent-led group began using seatbelts on ROPS-equipped tractors, compared to 40% in other groups. 77% of fathers of parent-led group required their	Safety education	High	Theory of Cognitive Dissonance Extended Parallel Processing theory	Yes	No

				youth to wear seatbelts on ROPS-eqipped tractors, compared to 47% in other groups. Fathers of parent-led group showed positive change in perception of injury susceptibility for youth. Youth of parent-led group less likely to operate ROPS tractor without seatbelt compared to control group.					
Stoneman et al., 2014 Georgia state, USA	Changing a Dangerous Rural Cultural Tradition: A Randomised Control Study of Youth as Extra Riders on Tractors AgTeen, a family-based farm safety	Randomised controlled trial Time period: 2007 -2012	*Targeted*: Crop farming families with children aged 10-19 and employed at farm *Sample size*: Intervention A: 47 families Intervention B : 53 families	Intervention Group 1: AgTeen lessons taught by fathers to the children. Intervention Group 2: AgTeen lessons taught by a peer farmer employed by the project to the children. Control group: No intervention. Data	Safety education	High	Theory of Cognitive Dissonance & Extended Parallel Processing theory cess Model.	Yes	No

	intervention to reduce the extra riding on the tractors by children in the farming families		*Control group:* 51 families.	collection forms were provided. Incentives were provided to all the participants. *Results*: Fathers from both parent-led and staff-led group were less likely to give youth tractor rides compared to control group. The intervention positively affected the attitudes and injury risk perceptions of both mothers and fathers. Both intervention groups showed a decline in youth giving tractor rides to others post-intervention. After the intervention, parents in the intervention groups demonstrated reduced positive cultural attitudes					

				about extra riding, but many still endorsed its value.					

Appendix A6: Intervention categories and their definition

Intervention	Definition
Engineering	Preventive measures involving engineering or structural changes to minimise or eliminate the risks.
Education	Preventive measures that involve training, knowledge and skill translation that enable workers to understand safety knowledge and develop safe attitudes. Any form of financial assistance.
Enforcement	Introduction of safety rules and ensuring compliance from farmers through legal enforcement.

Appendix A7: Intervention sub-categories and their definition

Intervention	Definition
Farm visits/auditing	A systematic assessment of safety hazards and risks on a farm by farm advisors or safety experts.
Financial assistance programs	Any form of assistance to encourage the adoption of safety practices or equipment.
Safety campaigns	Any form of mass communication campaigns or promotions promote a program or raise awareness
Safety demonstrations	Conducting live demonstrations to showcase safe practices and safety equipment usage on farms.
Social marketing campaigns	Any form of monetary benefits

Appendix A8: Operational definitions for the assessed intervention components (Behaviour change wheel Intervention function)

Intervention Function	Definition (Michie et al., 2011)	Contextual details
Education	Increasing knowledge or understanding.	Providing information on risks associated with farming, safety guidelines, operation of farm machines etc.
Enablement	Increasing means/reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring).	Providing support like hotlines to adopt safety devices like ROPS.
Environmental restructuring	Changing the physical or social context.	Changing the farm layout to reduce the risks. Introducing objects to increase awareness about safety.
Incentivisation	Creating an expectation of incentives for performing desired behaviour.	Provide financial support for participation in the safety programmes, retrofit safety devices etc.
Modelling	Providing an example for people to aspire to or imitate.	Collaborating with family members, peer coaches to educate or demonstrate recommended safety guidelines.
Persuasion	Using communication to induce positive or negative feelings or stimulate action.	Narrating real-life accidents, prompts about own and families' well-being, etc., to increase compliance or participation in the safety initiatives.
Restrictions	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours).	Prohibiting the use of unsafe farm vehicles.
Training	Provide any kind of training to any parties involved in the intervention program.	Providing skill training, risk assessment training etc.

Appendix A9: Operational definitions for the assessed behaviour change techniques (BCT))

BCT	Definition (Michie et al., 2013)	Contextual details
1.1 Goal setting (behaviour)	Set or agree on a goal defined in terms of the behaviour to be achieved.	1. Identifying and agreeing to change selected behaviours.
1.2 Problem solving	Analyse , or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators.	1. Encouraging participants to identify the a) cause of accidents b) Solutions for avoiding accidents
1.4 Action planning	Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity).	1. Creating guidelines and plans on how to perform a specific task .
1.8 Behavioural contract	Create a written specification of the behaviour to be performed, agreed on by the person, and witnessed by another.	1. Create contracts that specifying that they will complete agreed tasks or goals with peers as witness.
2.1 Monitoring of behaviour by others without feedback	Observe or record behaviour with the person's knowledge as part of a behaviour change strategy.	1. Observing the behaviour by the a) program facilitator b) Safety advisor
2.2 Feedback on behaviour	Monitor and provide informative or evaluative feedback on performance of the behaviour.	1. Feedback provided on the behaviour/practices by a) safety advisors b) program facilitators
2.4 Self-monitoring of behaviour	Establish a method for the person to monitor and record the outcome(s) of their behaviour as part of a behaviour change strategy.	1. Reporting own behaviour via a) Survey b) Questionnaire c) Status report

2.5 Monitoring outcome(s) of behaviour by others without feedback	Observe or record outcomes of behaviour with the person's knowledge as part of a behaviour change strategy.	1. Observing the outcome of the adoption of safety behaviours or risky behaviours by the a) program facilitator b) Safety advisor 2. Surveys conducted by the facilitators.
2.7 Feedback on outcome(s) of behaviour	Monitor and provide feedback on the outcome of performance of the behaviour.	1. Observing and providing the feedback on the outcome of the adoption of safety behaviours or the engagement in risky behaviours by a) safety advisors b) program facilitators
3.2 Social support (practical)	Advise on, arrange, or provide practical help for performance of the behaviour	1. Arrange/assist in a) Sourcing machine parts b) repairing the farm machines 2. Technical consultation
4.1 Instruction on how to perform the behaviour	Advise or agree on how to perform the behaviour	1. Information sessions/knowledge transfer/skill building activities on how to use a) PPE b) Ergonomic ways to perform tasks c) Managing yard etc.
5.1 Information about health consequences	Provide information about health consequences of performing the behaviour	1. Provide information on health consequences a) associated with farm accidents
5.2 Salience of consequences	Use methods specifically designed to emphasise the consequences of performing the behaviour with the aim of making them more memorable	1. Effect of farm accidents and specific consequence on a) physical development b) emotional well being
6.1 Demonstration of the behaviour	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate	1. Demonstrate a) How to operate the farm vehicles b) Best practices
7.1 Prompts/cues	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour. The prompt or cue would normally	1. Send the information to the participant's home via a) Mailers b) Put the application form at the participant's home to fill out

	occur at the time or place of performance	2. Add a remainder with safety messages, like calendar/fridge magnets at farm houses. 3. Adding posters with information in farm shops. 4. Adding graphic message with cheques.
9.1 Credible source	Present verbal or visual communication from a credible source in favour of or against the behaviour	1. Dissemination of information via a) Safety advisors b) Medical professionals c) Farm representatives d) Reputed media channels e)Equipment dealers
10.8 Incentive(outcome)	Inform that a reward will be delivered if and only if there has been effort and/or progress in achieving the behavioural outcome	1. Financial incentives a) for retrofitted tractors b) completing intervention related tasks
10.11 Future Punishment	Inform that future punishment or removal of reward will be a consequence of performance of an unwanted behaviour	1. Non-compliance lead to the removal of access or privilege in future to a) operate a vehicle b) Financial support
13.1. Identification of self as a role model	Inform that one's own behaviour may be an example to others.	1. Encourage participants to set a positive example for family members / workers by adopting specific safety behaviours.
13.3 Incompatible beliefs	Draw attention to discrepancies between current or past behaviour and self-image, in order to create discomfort	1. Create situations to draw attention to safety beliefs and risky habits to induce cognitive dissonance
16.3 Vicarious consequences	Prompt observation of the consequences for others when they perform the behaviour	1. Demonstrates the consequence of accidents with others 2. Narrate the accidents happened to others and its impacts 3. Accident survivors sharing their experience

Appendix B1: Topic guide for the focus group discussion

Research team: Ms Aswathi Surendran, Dr Denis O' Hora, Dr Jennifer Mc Sharry. Mr Francis Bligh

Topics to be explored: Below is a list of questions to be discussed in this study. The work will remain flexible to participants' agendas but we will cover the main topics outlined below. It is common in semi-structured work to develop topics and questions as new ideas emerge from early data collection. Therefore, we may add new topics as the interviews progress and data collection continues. However, the focus of the interview will be on the farm machine related accidents and safety measures. This interview will not be looking into non-machine related accidents.

1. **Personal knowledge of farm accidents**

   - ✓ Why do you think tractors and machinery are often involved in accidents?
   - ✓ What are the major impacts of these accidents on farmers, personal and work life
   - ✓ What are the kind of accidents you most frequently see in your community
   - ✓ In your opinion, what type of accidents need immediate attention

2. **Factors contributing to accidents**

   - ✓ A lot of studies and reports from the field says that farmers tend to take more risk than other industries does. Why do you think that is happening?
   - ✓ In your experience, is it possible to reduce the impact or even avoid the accident itself, if precautions are taken?
   - ✓ What do you think of the typical actions that often lead to accidents? Why do you think its getting repeated?
   - ✓ What kind of encouragement and appreciation you get to take up safety measures?
   - ✓ What are the challenges that older farmers face in terms of safety on the farm?
   - ✓ How does making your environment safe influence productivity

3. **Current interventions**

   As experienced farmers, you may have tried and tested different measures to reduce accidents. Therefore, I would like to discuss about that.

   - ✓ Tell me about the safety measures that you are currently taking?

- ✓ I have seen a couple of resources from HSA on recommendations to reduce tractor related fatalities, like safe stop, farm rating etc. What do you think about it? Do they have any influence the safety precautions you take ?
- ✓ Is there any changes in the kind of risks and precautions you take over the years, as you gain more experience
- ✓ What are the challenges you are facing with the existing guidelines and safety measures. Are these guidelines friendly to older farmer population? Is there anything you would like to change?
- ✓ Does the farming community often discuss about safety issues? Do you think community initiatives can create changes?
- ✓ Would you like to share any safety measures you follow that you think will be useful for others?

4. **Suggestions**
   - ✓ Are there any ways that you think we can reduce excess work hours , tiredness and other distractions
   - ✓ Some interventions are not farmers' friendly and you may not be comfortable with implementing it in your farms. So what kind of safety interventions that will encourage farmers to follow it, interventions that you like to see us working on?
   - ✓ Are there any other urgent safety concern that we haven't discussed so far
   - ✓ Any other practices that can improve safety that you would like to share

5. **Summary**
   - ✓ Was there anything I left out?
   - ✓ Anything else you would like to tell me?

Appendix B2: Summary Table of Codes, Sub-themes, and Themes Identified through Reflexive Thematic Analysis

Theme	Sub-theme	Codes (+/-)
Perceived likelihood and cost-benefit analysis in safety decision-making	1.1 Perceived cost and benefits	Previous experiences (+)
		Perceived benefits of SWP (+)
		Perceived long term consequences (+)
		Perceived long term benefits (+)
		Perceived benefit of prioritizing own health (+)
		Perceived practicality/convenience (-)
		High priority for planning and organizing (+)
	1.2 Perceived control and likelihood of risk in safety decision-making	Perceived risks associated with age (+)
		Perceived risks associated with tasks (-)
		Perceived control on safety (-)
	1.3 Non-compulsory nature of guidance	Being your own boss (-)
		Advisory nature of the farm inspections (-)
Characteristics of the farm environment	2.1 Characteristics of the farm environment	Environmental conditions (-)
		Farm type (-)
		Heterogeneity of tasks (-)
Availability and affordability of resources	3.1 Accessibility of services, resources and technology	Poor design of Machines and PPE (-)
		Unavailability of skilled assistance (-)
	3.2 Financial limitations and opportunities	Rising cost of the safety measures (-)
		Financial support (+)
	3.3 Nature of the safety legislations and policies	Administrative burden (-)
		Nature of farm regulations (+/-)
		Nature of safety interventions (+/-)

Prevailing sociocultural opportunities	4.1 Role of familial support and partnerships	Family support (+)
		Perceived influence on young farmers(+)
		Isolation (-)
		Succession plan (+)
	4.2 Peer support and other social factors	Presence of safety discussions (+)
		Influence of safety officers (+/-)
		Influence of media (-)
		Influence of contractors (+)
		Vicarious experiences (-)
Capability to manage competing responsibilities	5.1 Knowledge about safety procedures and support	Lack of Knowledge (-)
	5.2 Situational awareness and competing priorities	Inability to focus on current task (-)
		Ability to be aware of own environment (+)

Appendix C1: Target behaviour categories (survey item)

Target behaviour categories (survey item) identified for the co-design workshops along with the number of reported fatalities associated with it and the percentage of farmers mentioned it in the focus group.

Behaviour	**Fatalities (Total = 62)**	**Focus Group (Total = 19)**
Installing and using appropriate safety devices on machinery	24%	21.05%
Improving planning and timing of machinery tasks	0%	68%
Securing and regularly maintaining the workplace	5%	11%
Scheduling regular machinery maintenance by trained personnel	35%	42%
Wearing appropriate PPE when operating machinery	5%	5%
Starting machinery safely	13%	5%
Allocating attention to machinery operation and the local environment appropriate	32%	63%
Leaving machinery in a safe state when taking a break or finishing a task	24%	58%

Appendix C2: Target behaviours.

Target Behaviour	Who	What	When	Where
Demonstrate blind spots of tractors to family members/co-workers on their farm	Participant farmer	Give an on-field demonstration to a non-participant farmer/family member/neighbours	Within two weeks after the peer-to-peer demo	Home/Farm field
Mark the zone of visibility around their tractor in a parking	Participant farmer	Mark the zone of visibility with a marker around a tractor	Within one week after the peer-to-peer demo	Home/Farm field
Walk around the tractor before moving it from the parking area to ensure that nobody is near the tractor and no obstacles are present near-by	Participant farmer	Do a 360-degree check around the tractor	Everyday; before taking out the tractor from the parking area	Around the tractor

Appendix C3. Summary of BCTs identified at different phases.

BCTs Identified	SR	FFG	EP	Research Team	Selected for Final Intervention
1.1 Goal setting (behaviour)	Y				Y
1.2 Problem solving	Y				Y
1.3 Goal setting (outcome)				Y	Y
1.4 Action planning	Y	Y			Y
1.8 Behavioral contract	Y				Y
1.9 Commitment				Y	Y
2.1 Monitoring of behaviour by others without feedback	Y	Y	Y		
2.2 Feedback on behaviour	Y	Y			
2.4 Self-monitoring of behaviour	Y				
2.5 Monitoring outcome(s) of behaviour by others without feedback	Y				
2.7, Feedback on outcome(s) of behavior		Y	Y		
3.1 Social support (unspecified)		Y	Y		Y
3.2 Social support (practical)	Y	Y	Y		Y
4.1 Instruction on how to perform a behavior	Y	Y	Y		Y
5.1 Information about health consequences	Y	Y	Y		Y
5.2 Salience of consequences	Y	Y	Y		Y
5.5 Anticipated regret		Y	Y		
5.6 Information about emotional consequences		Y	Y		
6.1 Demonstration of the behavior	Y				Y
7.1. Prompts/cues	Y				
8.1 Behavioral practice/rehearsal		Y	Y		Y
8.3 Habit formation				Y	Y
9.1 Credible source	Y				
10.4 Social reward		Y	Y		
10.8 Incentive (outcome)	Y	Y	Y		
10.11 Future Punishment	Y				
12.1 Restructuring the physical environment		Y			Y

12.5 Adding objects to the environment		Y		Y
12.6 Body changes			Y	
13.1 Identification of self as role model		Y	Y	Y
13.2 Framing/reframing			Y	
13.3 Incompatible beliefs	Y			
16.3. Vicarious consequences		Y	Y	

Y indicates “Yes”.

Appendix C4. Evaluation plan.

Objective	Details	Data Collection Method	Measure of Success
Feasibility	Recruitment rate	Report from Teagasc recruiters	Minimum two participant from each of the four farm types: dairy, beef, sheep and tillage. 80% of participants complete 3 phases: baseline data collection, participate in the demo session, complete the safety training procedure and exit survey. Complete follow-up interviews and intervention checklists with 12 participants
	Refusal rates and reason for refusal of participation	Report from Teagasc recruiters	
	Retention and follow-up rates	Audio recording Intervention checklist	
	Time required to recruit target sample size	Report from Teagasc recruiters Baseline data collection	
	Adherence rates to study procedures, intervention engagement, etc.	Field notes Memos	
	Rate of completion of the intervention	SMS Survey	
	Representation of farm population	Report from Teagasc recruiters	
	Barriers and facilitators to set up the in-person event	Report from the recruiter Audio recording Field notes	
	Is the structure of the programme (length of the event, structure and content of the intervention) realistic, clear and reasonable for the participants?	Audio recording Intervention checklist Safety training procedure Exit poll Follow up evaluation	
	The ability of the participants to carry out the target behaviours (safety behaviours) addressed in the study	Safety training procedure Exit poll Follow up evaluation interview	
Fidelity- Intervention Design	1. Provide information about treatment doses in the intervention condition	Intervention checklist	Detailed report on the development of the intervention, content of the intervention and BCTs included in it using TiDier checklist Register the study on ISRCTN registry >80% adherence to the intervention checklist
	a. Length of session		
	b. Number of sessions		
	c. Content of each session		
	d. Duration of contact over time		
	4. Theoretical model upon which the intervention is based is clearly articulated.	Report on development of intervention	
	a. The active ingredients are specified and incorporated into the intervention	Report on development of intervention	
	b. Use of experts or protocol review group to determine whether the	N/A	

	intervention protocol reflects the underlying theoretical model or clinical guidelines		
	c. Plan to ensure that the measures reflect the hypothesised theoretical constructs/mechanisms of action	Report on development of intervention	
	5. Potential confounders that limit the ability to make conclusions at the end of the trial are identified	Follow up evaluation interview	
	6. Plan to address possible setbacks in implementation (i.e., back-up systems or providers)	Risk assessment document	
Fidelity- Treatment providers *	1. Description of how providers will be trained (manual of training procedures))	Intervention manual	Publication of intervention manual
Fidelity- Treatment delivery	1. Method to ensure that the content of the intervention is delivered as specified.	Audio recording Intervention checklist	>80% adherence to the intervention checklist
	2. Method to ensure that the dose of the intervention is delivered as specified.	Audio recording Intervention checklist	
	3. Mechanism to assess if the facilitator actually adhered to the intervention plan.	Audio recording Intervention checklist Field notes	
	4. Assessment of non-specific treatment effects.	Follow up evaluation	
	5. Use of Intervention manual.	Project information sheet	
	6. There is a plan for the assessment of whether or not the active ingredients were delivered.	Audio recording Intervention checklist Field notes	
	7. There is a plan for the assessment of whether or not proscribed components were delivered (e.g., components that are unnecessary or unhelpful).	Audio recording Intervention checklist Field notes	
	8. There is a plan for how will contamination between conditions be prevented.	N/A	
	9. There is an a priori specification of treatment fidelity (e.g, providers adhere to delivering >80% of components).	delivering at least 80% of components	
Fidelity- Receipt of Treatment	1. There is an assessment of the degree to which participants understood the intervention.	Safety training procedure Exit poll Follow up evaluation interview	60% of the participants complete the target behaviour at home.

	2. There are specification of strategies that will be used to improve participant comprehension of the intervention.	Safety training procedure Exit poll Follow up evaluation interview	
	3. The participants' ability to perform the intervention skills will be assessed during the intervention period.	Safety training procedure Exit poll Follow up evaluation interview	
	4. A strategy will be used to improve subject performance of intervention skills during the intervention period.	Peer to peer demo Safety training procedure	
	5. Multicultural factors considered in the development and delivery of the intervention (e.g., provided in native language; protocol is consistent with the values of the target group).	N/A	
Fidelity- Enactment of Treatment Skills	1. Participant performance of the intervention skills will be assessed in settings in which the intervention might be applied.	Post intervention home based tasks (target behaviours)	
	2. A strategy will be used to assess performance of the intervention skills in settings in which the intervention might be applied.	Follow up evaluation interview	
Retrospective acceptability	1. Affective attitude (How did the participant feel about the programme) 2. Burden (What did the participants say about the structure and ease to understand) 3. Ethicality (To what extent the strategy helped in performing the farm tasks) 4. Intervention coherence (How did participant feel in terms of understanding the tasks and performing it by himself) 5. Opportunity costs (What were the benefits the participants perceived) 6. Perceived effectiveness (To what extent did the participant felt that strategy was effective) 7. Self-efficacy (How confident and comfortable was the participant at performing the task)	Safety training procedure Exit survey Follow up evaluation interview	>80% of response to the questions on exit survey rated as "Agree" or "Strongly agree" >80% of response to the questions about confidence on safety training procedure document rated above 7. Evidence for perceived benefits and effectiveness in the follow up interview.

* Treatment is delivered by the research team. Hence no training sessions required.

Appendix C5. Intervention description based on TIDieR checklist.

Name	BeSafe intervention to reduce tractor related accidents on farms
Why? (rationale)	Described above in the background section.
What? (procedure)	TEAGASC will make the primary contact to contact the farmers discussion groups. Once the group indicates their interest, advisors send invitation letters, participant information sheet and consent form to the farmers. On week 1, the participants will receive a call from the primary facilitator (AS) to collect the demography information and detail the project. In the next phase, participants would be invited to participate in the demo session facilitatied by the primary facilitator. Demo would provide participants with strategies to address blind spots on farm and personalized safety training procedure with safety goals to complete at their own homes. Subsequently, a SMS would be send to track the progress in completing their goals. A telephone interview will be set up after 2 weeks of the demo session to collect the feedback of the participants. The breakdown of the tasks along with estimated time and facilitator details are provided in the Appendix section (Intervention and evaluation timeline)
What? (Materials)	Participants will receive: A tailored safety training procedure. Materials to perform the demo and setup the visibility zone in own parking area.
Who provided?	Two researchers (AS, DOH) will deliver the intervention on selected Teagasc campuses. Teagasc farm safety experts will be present on the demo location during the demo session to ensure the safety of the participants.
How?	Face-to-face in a group setting: The intervention consists of peer to peer demo of blind spots of tractors, discussion and demonstration of strategies to address blind spots and investigation of individual barriers to implementing these strategies. The safety training procedure with pre-determined goals will be tailored to suit the participant's farm and barriers discussed in the discussion session. Participants would be encouraged to complete the goals through an SMS survey.
Where?	The intervention will take place on a farm field selected and approved by Teagasc.
When and how much?	The communication will be initiated once the potential participant indicates their interest to Teagasc advisor. The face to face demo session will be approximately 3.5 h. The demo session would be running once a week for 4 weeks. Participants can attend one of these sessions based on their convenience.
Tailoring	The safety training procedure will be tailored to individual needs of the participants, based on their farm setting, resources available and preferences.
How well? (adherence/fidelity)	The facilitators will be audio recording the entire session and making observational notes. Fidelity will be measured using a pre-established checklist created based on the study design, purpose and fidelity framework for behaviour change research by analyzing the recorded data.

Appendix D1 Detailed Intervention breakdown and Evaluation timeline

Target Behaviours

Target Behaviour	Who	What	When	Where
Demonstrate blind spots of tractors to family members/co-workers on their farm	Participant farmer	Give an on-field demonstration to a non-participant farmer/family member/neighbours	Within one week of the peer to peer demo*	Home/Farm field
Mark the zone of visibility around their tractor in a parking	Participant farmer	Mark the zone of visibility with a marker around a tractor	Within one week of the peer to peer demo*	Home/Farm field
Walk around the tractor before moving it from the parking area to ensure that nobody is near the tractor and no obstacles are present near-by	Participant farmer	Do a 360 degree check around the tractor	Everyday; Before taking out the tractor from the parking area	Around the tractor

** tentative time period*

Pre-Intervention interview

Tasks	Estimated time	When	Mode	Facilitators
Pre-Intervention 1-1 online Interview	15-20 minutes	1-7 days before the Demo	Telephone/Skype / Zoom/Team	Aswathi Surendran

Pre Demo activities to be completed by the research team

- ✓ Secure the event site perimeter
- ✓ Make sure the risk assessment and safety checklist is completed
- ✓ Set up an area for the facilitated discussion session next to demo site
- ✓ Test run of the peer to peer demo
- ✓ Test run of the facilitated discussion and completion of safety training procedure

Half-day in-person session

#	Tasks	Subtasks	Time (In minutes)	Primary Facilitator*	Does the activity has evaluation component?
1	Welcome & Introduction		10	Aswathi Surendran	No
2	BeSafe Introduction	Interactive discussion: The prevalence and impact of blind spot related accidents	10	Aswathi Surendran	No

3	Impact of blind spots	Interactive discussion: Estimating the distance travelled by the tractor in 3 sec (in a yard and on regular speed)	10	Aswathi Surendran	No
4	Peer to peer demo	Invite one of the participant(P1) to sit inside the parked tractor	30	Aswathi Surendran	No
		Invite 2 (P2, P3) other participants to perform the demo.			
		Ask P2 to position the kid sized cut-out at different spots around demo tractor.			
		Ask P1 to confirm whether the cut-out is visible or not.			
		P3 mark the areas that was not visible to the P1 using spray paint/chalk			
		Mark the non-visibility area around the tractor using spray paint/chalk			
		Take a picture of the tractor and the marked area			
		Repeat the task on a different tractor with an implement mounted with a different group of participants			
	Break		5		
5	Facilitated discussion	Explore who would be most benefitted in his family when participants demonstrates blind spots at his farm	30	Aswathi Surendran	
		Explore various strategies to conduct the demo that's suitable for each participant, including barriers and facilitators			Yes
		Explore ways to set up the visibility zone in his own designated parking area in his farm based on the type, size and location			
6	Safety training procedure	Complete a tailored document for each participant based on the input from facilitated discussion.	20	Aswathi Surendran	
		Rate their confidence on completing the activity.			Yes
		Participant and a peer who acts as a witness sign the contract			
7	Conclusion	Debriefing session	15	Aswathi Surendran	
		Exit poll			Yes
		Distribute the vouchers and materials to perform the demo and setup the visibility zone in own parking area.			

*Teagasc safety advisor will be present.

Post Demo activities to be completed by the research team

- ✓ Clean up the event site after the demo

Evaluation Phase

SMS Survey

SMS Survey	Estimated time	When	Mode	Facilitators
SMS survey	5 minutes	Based on participant's convenience	Online SMS based survey	Aswathi Surendran

Evaluation session

Tasks	Estimated time	When	Mode	Facilitators
Post-Intervention one-on-one online Interview	45-60 minutes	10-20 days after the event	Telephone/Skype / Zoom	Aswathi Surendran

Appendix D2 Intervention components and BCTs

BCT *	Tasks
1.1 Goal setting (behaviour) *	Safety training procedure: 1.1 Agreement to do a demo of the blind spots and an action plan for setting the demo 1.4 Agreement to park in the designated parking sport daily 1.6 Agreement to walk around the tractor and check perimeter before moving out of the parking area
1.2 Problem solving*	Brainstorming session: 2. Explore various strategies to conduct the demo that's suitable for each participant 3. Explore ways to set up the visibility zone in his own designated parking area in his farm based on the type, size and location
1.3 Goal setting (outcome)*	Safety training procedure: 1.2 Action plan for setting up the visibility zone and agreement to share the picture with research team
1.4 Action planning*	Safety training procedure: 1.2 Action plan for setting up the visibility zone and agreement to share the picture with research team 1.3 Strategies for parking the tractor in the designated area after work 1.5 Strategies to walk around the tractor before starting or moving it from the designated area
1.8 Behavioral contract*	Safety training procedure: 4. Participant and a peer who acted as a witness sign the contract
1.9 Commitment	Safety training procedure: 1.1 Agreement to do a demo of the blind spots and an action plan for setting the demo 1.2 Action plan for setting up the visibility zone and agreement to share the picture with research team 1.4 Agreement to park in the designated parking sport daily 1.6 Agreement to walk around the tractor and check perimeter before moving out of the parking area 4. Participant and a peer who acted as a witness sign the contract
3.1 Social support (unspecified)	Safety training procedure: 4. Participant and a peer who acted as a witness sign the contract

3.2 Social support (practical)	Facilitated discussion: 2. Explore various strategies to conduct the demo that's suitable for each participant 3. Explore ways to set up the visibility zone in his own designated parking area in his farm based on the type, size and location
4.1 Instruction on how to perform a behaviour	Demonstration of the blind spots
5.1 Information about health consequences	Demonstration: 1. One of the farmers sit on a tractor and ask other farmers to stand around 2. Ask that farmer to locate others while sitting on the tractor and later walking around the tractor 3. Repeat this step with non-driver participants standing at various distances from the tractor and with people/cut out of children of different heights. A strong focus on stating that these cut-outs/people represent their family members
5.2 Salience of consequences *	Demonstration: 3. Repeat this step with non-driver participants standing at various distances from the tractor and with people/cut out of children of different heights. A strong focus on stating that these cut-outs/people represent their family members
6.1 Demonstration of the behaviour	Demonstration of the blind spots
8.1 Behavioral practice/rehearsal*	Demonstration of the blind spots
8.3 Habit formation	Safety training procedure
9.3 Comparative imagining of future outcomes*	Demonstration: 3. Repeat this step with non-driver participants standing at various distances from the tractor and with people/cut out of children of different heights. A strong focus on stating that these cut-outs/people represent their family members

12.1 Restructuring the physical environment	Brainstorming session:3. Explore ways to set up the visibility zone in his own designated parking area in his farm based on the type, size and location Safety training procedure
12.5 Adding objects to the environment	1. Provide the marker or similar items to setup the visibility zone 2. Provide materials for demonstration at home
13.1 Identification of self as role model*	Safety training procedure: 1.1 Agreement to do a demo of the blind spots and an action plan for setting the demo

*Identified as active ingredient

Appendix D3 Topic guide for introduction session

Please find below the topic guide for the audio/video-based online introduction session with the participants. The virtual one-on-one session will be scheduled 1-7 days before the intervention based on participant convenience. The objective of this semi structured call is to:

1. To clarify the questions farmers have regarding the project
2. Collect the consent for the program if they haven't already
3. Collect the demographic data
4. Enquire if they have any special needs for the demonstration day (hearing/visual aids, dietary restrictions, etc.)
5. Create a rapport with the participants

Estimated duration: 15-20 minutes

Topic Guide

Briefing:

1) Thank the participant for agreeing to take part.

2) Introduce self.

3) In this study, we will be introduce a safety program that we have developed to a selected few Irish farmers and collect their feedback.

4) If at any time during this call, you do not wish to answer a question that is okay.

5) I would like to record our conversation. The recording will be typed out, but everything you say will be anonymous. Your name and any names or places you mention will be taken out, so that if someone read your interview they would not know who you are.

6) If, at any stage, you wish to stop the audio recorder, please let me know.

7) Do you have any questions?

Topics to be explored: *Below is a list of questions to be discussed in this study. The work will remain flexible with respect to participants' agendas but we will cover the main topics outlined below.*

1. We would like to collect the demograpgic data first. May I know your age?
2. What type of farm do you have?
3. Do you work part time or full time? On an, average how many hours do you work in a day/week?
4. How many tractors do you have? Do you have any implements?
5. How many of those tractors have the following features?
    - ✓ Roll over protective frame
    - ✓ Power take off (PTO) master shield/output guard
    - ✓ Neutral start switch *
    - ✓ Hazard alert symbol or other safety signs
    - ✓ How many have roll back protection
    - ✓ Reverse assistance mirror
    - ✓ Reverse assistance camera
    - ✓ Lights
    - ✓ Horn

- ✓ Reversing beeper

6. Is your family involved in the farm activities? If yes, how do they assist you on the farm?
7. Do you have contractors or other workers to assist you on the farm?
8. Have you or your loved ones ever been in a farm accident involving machine or equipment?
9. We would be providing a light snack and beverage on the in-person event day. Do you have any dietary restrictions that we should know?

Appendix D4: Safety training procedure template

BeSafe-Tractor

Name :……..
Demo #:…….. Date :……

Would you like to take the changes we discussed today to your home and farm?

The plan outlined in this plan will guide and assist you in improving the safety on your farm and raising awareness about the risks among family members and co-workers.

Short term goals:

1. *I will identify a general parking space on my farm and demonstrate blind spots of the tractors and implements to my family/co-workers. Encourage your attendee to estimate the distance covered by tractor in 3 secs.*

When will I likely complete this goal (Preferred date)?

To whom would I like to demonstrate blind spots (Eg: family members/employees /neighours/discussion group members/students)?

How confident am I that I will do this? _____ (on a scale of 0 to 10, with 0 being not at all confident and 10 being completely confident)

2. *I will set up a no-visibility zone to raise the awareness among your audience and document the measurements.*

When will I likely complete this goal (Preferred date)?

How confident am I that I will do this? _____ (on a scale of 0 to 10, with 0 being not at all confident and 10 being completely confident)

Everyday Goals:

3. *Every day, before starting or moving the tractor from the parking area, I will walk around the tractor to ensure that no person or obstacle is present near-by*

How confident am I that I will do this? _____ (on a scale of 0 to 10, with 0 being not at all confident and 10 being completely confident)

List possible obstacles to achieving your safety goals

List possible solution to overcome the obstacles

List possible strategies to perform the safety goals and address blind spots

I, _____
, will ensure that the safety goals are carried out to ensure the safety of my family, co-workers and me.
My friend,_____, who co-signed the sa_____
fety training procedure, witnessed and assisted me in coming up with this plan.

_____
Your Signature

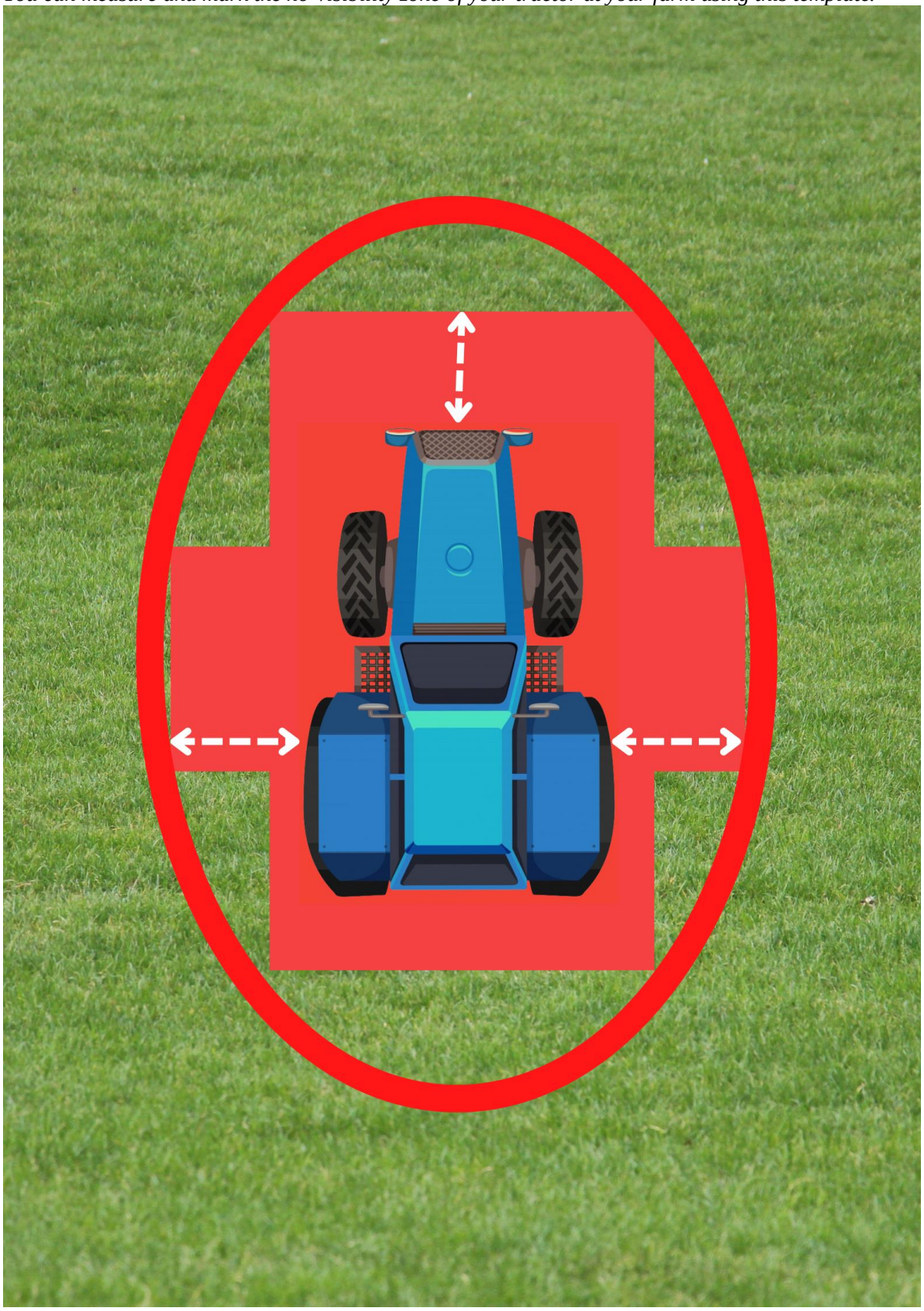
_____
Signature of the peer

Date

I would like to receive an SMS survey to report the progress of the goals on the following date and time:
On ……. at
…….. (Please provide your preferred time to receive the SMS survey)
I would like to participate in the online interview session and share my feedback on the following date and time:
On ……... at
…….. (Please provide your preferred time to schedule the interview)

Thank you for participating in the BeSafe session!

You can measure and mark the no-visibility zone of your tractor at your farm using this template.



Appendix D5: Participant Satisfaction Exit Survey Questionnaire

Demo # Survey # Date :

How do you appreciate various aspects of the program?	Very Useful	Useful	Neutral	Not Useful
Demonstration				
Facilitated discussion				
Safety training procedure				
Poster				

Please indicate your level of agreement or disagreement with each of these statements regarding the program. Place an "X" mark in the box of your answer.

Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The program met my expectations regarding what I wanted to learn.					
I obtained a clearer understanding of the following topic(s) demonstrated: *a. Demonstration of Blind spots*					
b. Setting up visibility zone					
c. Checking the perimeter of the tractor					
I think the day was well structured.					
I will apply what I learned today at home					
I will recommend this program to my friends					

Do you have any other suggestions?

Appendix D6 Topic guide for evaluation interview

Please find below the topic guide for the post-intervention audio/video interview with the participants. The evaluation interview will be scheduled 7-20 days after the intervention based on participant convenience. The objective of this semi-structured interview is to:

1. To assess the acceptability of the program and its delivery among participants
2. To assess the acceptability of each active ingredient and its delivery among participants
3. Assess the fidelity sub-constructs (receipt of treatment & enactment of treatment skills)

Estimated duration: 45-60 minutes

Topic Guide

Briefing:

1) Thank the participant for agreeing to take part.
2) Introduce the objective of this call
4) If at any time during this call, you do not wish to answer a question that is okay.
5) I would like to record our conversation. The recording will be typed out, but everything you say will be anonymous. Your name and any names or places you mention will be taken out, so that if someone read your interview they would not know who you are.
6) If, at any stage, you wish to stop the audio recorder, please let me know.
7) Do you have any questions?

Topics to be explored: *Below is a list of questions to be discussed in this study. The work will remain flexible with respect to participants' agendas but we will cover the main topics outlined below.*

1. Tell me about your experience with the peer to peer demonstration: Was it useful? why?
   - ✓ Do you think now you can teach others about blind spots? If so, will you follow the same style of demonstration? If not, what changes?
   - ✓ Does practising and rehearsing with the peers helped? Yes/No, Why?
   - ✓ Was it difficult to imagine the family members in the blind spot? Why?
   - ✓ Do you think better understanding and setting up the visibility zone improved awareness about immediate environment? Does it help to protect the family members?
   - ✓
2. Do you think elder farmers teaching younger ones in similar demo sessions would encourage them to adopt safer habits as you?
   - ✓ Do you think demonstrating the blind spot helped your family/others to become more aware of blind spots?
   - ✓ Why do you think it was effective/not effective?
   - ✓ Do you think your family members and young farmers look up to the way you work?

3. Tell me about your experience with the brainstorming session:
   - ✓ Does sitting with your peers helped to identify the barriers and find the solutions?
   - ✓ Do you had the feeling that you could share your own knowledge and experience ?

4. Tell me about your experience with creating personalized safety training procedure:
   - ✓ Was it easy to create and understand the protocol?
   - ✓ Was personalizing it made it more beneficial?
   - ✓ Were the goals practical and efficient?

- ✓ Did planning the task step by step and setting up the goals helped you to complete the tasks at home?

5. What do you think about creating a protocol and co-signing it with your peers?
   - ✓ Was it useful?
   - ✓ Were you comfortable co-signing your own protocol and your peer's protocol?

6. Did you complete the following task that we agreed upon in the demo and co-signed with your peer farmer?
   - ✓ Demonstration of the blind spot to family/others
   - ✓ Setting up the visibility zone
   - ✓ Measure the distance (tractor to visibility zone border)
   - ✓ Do you walk around the tractor and check the perimeter before moving it from the parking area?
   - ✓ If not, why?
   - ✓ Did you face any unexpected difficulty while demonstrating blind spots to family/others and setting up the visibility zone?

7. Did you talk to other people about this demonstration? Would you recommend this program to a friend or neighbour?
8. Have you attended another demonstration event during the intervention period?
9. How helpful was the materials distributed during the workshop to complete tasks at home? What other resources were required?
10. We talked about various techniques we had for the workshop. Do you think similar techniques can be used to address other safety concerns? Which techniques would be effective? What safety concerns can be addressed?
11. Have you thought about making/already made any changes in your farm as a result of participation in the peer to peer demonstration? For e.g.: safety devices or reversing assistance devices like mirrors, camera
12. Did the workshop event helped you to gain knowledge or skills? If so,

✓ Which tasks?
✓ What knowledge/skills improved?
✓ Do you think demonstrating the blind spot helped your family/others to become more aware of blind spots?
✓ Is there anything else that you think would be valuable to improve the program?

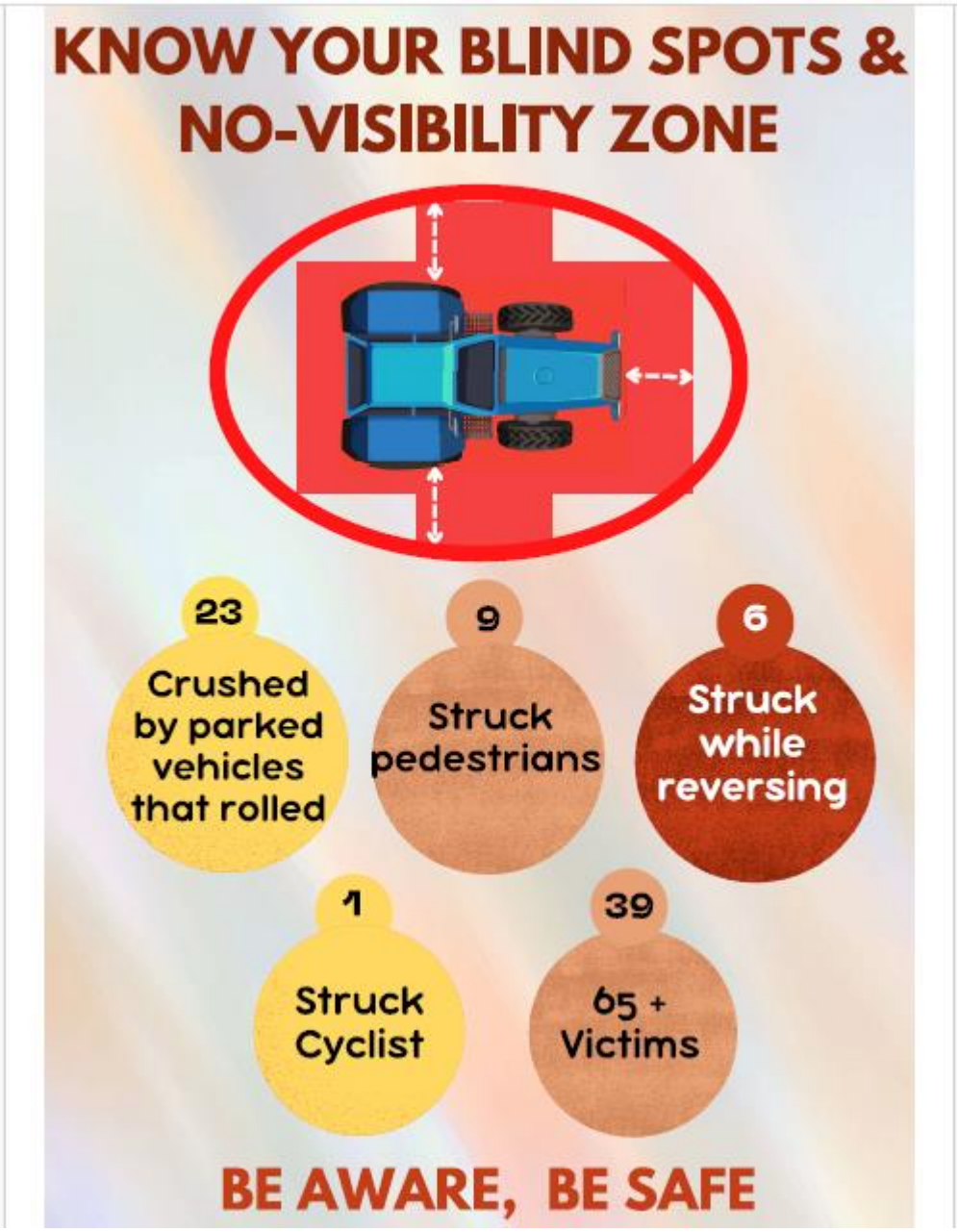
13. What do you think about the posters we have shared? Was it useful?
14. In the discussions we had with farmers, they were telling us that they get too many documents on what to do , how to do, did was there too much paper work with this program
15. As I mentioned in our demo, we had farmers helping us with designing this program throughout. Do you think all future research should consider similar strategies?
16. Suggestions
    - ✓ If you had a chance to give advice to the facilitators of this program, what advice would you give?
    - ✓ Did facilitators failed to address any concerns related this topic?

17. Summary
    - ✓ Was there anything I left out?
    - ✓ Anything else you would like to tell me

Appendix E1: Acceptability and Fidelity Constructs with Definitions Used in Analysis.

Construct	Definition
TFA Construct	
Affective attitude	How did the participant feel about the programme, e.g., how easy it is to perform, were they comfortable to engage or not.
Burden	What did the participants say about the structure and how easy it was to understand.
Ethicality	Commentary about how it fit/ not fit with their value system, health condition, personal choices, working style etc.
Intervention coherence	How did participants feel in terms of understanding the tasks and the benefits they may personally receive from them, e.g., perceived usefulness.
Perceived effectiveness	To what extent did the participant feel that strategy was effective.
Opportunity costs	Commentary on the price paid to engage, e.g., postponing or cancelling appointments, losing working hours.
Self-efficacy	Commentary on how confident and comfortable the participant was at performing the task.
Fidelity Construct	
Receipt of Treatment	Commentary on the comprehension of intervention and performance of the cognitive and behavioural skills taught in the intervention.
Enactment of Treatment Skills	Commentary on the ability to perform and use intervention skills (cognitive and behavioural) in farm settings.

Appendix E2: BeSafe Poster



Appendix E3: Feasibility and fidelity checklist comparison (Progression criteria)

Objective	Indicators, outcome measures and measure of success (as per protocol)	Data collection	Findings
Feasibility checklist			
Feasibility	Recruitment rate and representation criteria: 1. Successfully recruit a minimum two farmers from each of the four farm types: Dairy, Beef, Sheep and tillage. 2. Ensure approximately 50% of the participants are older farmers[#].	Recruitment report by the Teagasc. Baseline data	20 participants were recruited and a minimum of 2 participants from each farm system attended the intervention. 50% of the participants were older farmers(55+ years old)
	Retention, task completion and follow-up rates : 80% of the participants complete the in-person session & a minimum of 12 participants complete follow up interviews.	Audio recording of the in-person sessions Intervention checklist	95% of the participants completed the in-person session (19) & 85% (17) completed follow-up interview.
	Time required to recruit target sample size: 16 participants recruited/time	Recruitment report by the Teagasc	Recruited 20 potential participants within the timeline.
	Barriers & facilitators to set up the in-person event: Factors identified by the facilitators	Recruitment report by the Teagasc Audio recording of the in-person sessions Field notes from the in-person sessions	No barriers reported.
	Is the structure of the programme (length of the event, structure and content of the intervention) realistic, clear and reasonable	Exit survey	100% of the participants reported it as satisfactory or highly satisfactory.

	for the participants? : At least 80% of the participant rate the program structure and content as satisfactory in the exit survey		
	The ability of the participants to carry out the target behaviours (safety behaviours) addressed in the study: Participants' feedback about their experience	Safety training procedure Exit survey Post-intervention interview	Participants responses were positive (Refer table #)
Fidelity- Intervention Design	1 - Provide information about treatment dose in the intervention condition: Detailed information about the intervention is presented in the intervention checklist, such as , a. Length of session b. Number of sessions c. Content of each session d. Duration of contact over time	Intervention checklist Project related publications	Registered the study on ISRCTN registry and uploaded the intervention manual in the OSF. Intervention development and intervention protocol is published [1].

	2 Theoretical model upon which the intervention is based is clearly articulated in the methodology paper and includes following information: a. The active ingredients are specified and incorporated into the intervention b. Use of experts or protocol review group to determine whether the intervention protocol reflects the underlying theoretical model or clinical guidelines		
	c. Plan to ensure that the measures reflect the hypothesized theoretical constructs/mechanisms of action		
	3 Potential confounders that limit the ability to make conclusions at the end of the trial are identified?	Post-intervention interview	No participants attended in other safety programs or reported other confounders that may influence the findings. Described the potential limitations under the section on the strengths and limitations of the trial in the manuscript.
	4 Plan to address possible setbacks in implementation (i.e., back-up systems or providers)	Risk assessment document	Risk assessment document completed as a part of the ethics approval request.
Fidelity- Treatment providers*	1 Description of how providers will be trained (manual of training procedures)	Intervention manual	Intervention was designed and delivered by the authors. Intervention manual for the future trials will be made available in the OSF.
Fidelity- Treatment delivery	1 Method to ensure that the content of the intervention is delivered as specified (content, dose, process):	Audio recording Intervention checklist Field notes	Reported 91% adherence to the intervention checklist

	>80% adherence to the intervention checklist .		
	2 Assessment of non-specific treatment effects: Participants report on the experience of the program vs expected outcome	Post-intervention interview	No participants attended in other safety programs or reported other confounders that may influence the findings. Described the potential limitations under the section on the strengths and limitations of the trial in the manuscript.
	5 Use of Intervention manual	Project information sheet	Intervention manual for the future trials will be made available in the OSF.
	6 There is a plan for the assessment of whether or not the active ingredients were delivered.	Audio recording Intervention checklist Field notes	Reported 91% adherence to the intervention checklist
	7 There is a plan for the assessment of whether or not proscribed components were delivered. (e.g., components that are unnecessary or unhelpful)	Audio recording Intervention checklist Field notes	Reported 91% adherence to the intervention checklist and no unintended tasks were reported.
	9 There is an a priori specification of treatment fidelity (e.g, providers adhere to delivering >80% of components)	Data collection and evaluation plan	Details published in the intervention protocol.
Fidelity- Receipt of Treatment	1 There is an assessment of the degree to which participants understood the intervention: 60% of the participants complete the target behaviour at home.	Safety training procedure Exit poll Post-intervention interview	85% of the recruited participants completed the target behaviours 1& 2 at home. 68% of the recruited participants completed the target behaviour 3 at home.
	2 There are specification of strategies that will be used to improve participant comprehension of the intervention: Completion of tailored plan using the safety training procedure document & participants' feedback	Safety training procedure Exit poll Post-intervention interview	95% of the participants attended the facilitated discussion and completed the safety training procedure document

	3 The participants' ability to perform the intervention skills will be assessed during the intervention period : Self report on the confidence in completing the target behaviours and participants' feedback	Safety training procedure Exit poll Post-intervention interview	
	4 A strategy will be used to improve subject performance of intervention skills during the intervention period: Hands-on practise session on demonstration, Completion of tailored plan using the safety training procedure & participants' feedback	Peer to peer demo Safety training procedure	95% of the participants attended the practise session, facilitated discussion and completed the safety training procedure document
Fidelity- Enactment of Treatment Skills	1 Participant performance of the intervention skills will be assessed in settings in which the intervention might be applied: Participants' self-report on the completion rate of safety goals (target behaviours)	SMS Survey Post-intervention interview	85% of the recruited participants completed the target behaviours 1& 2 at home. 68% of the recruited participants completed the target behaviour 3 at home
	2 A strategy will be used to assess performance of the intervention skills in settings in which the intervention might be applied: Participants' reported experience on completing the safety goals at home	Post-intervention interview	
Acceptability checklist			
Retrospective acceptability	1 Affective attitude (How did the participant feel about the programme) : Average satisfaction score for the program in the exit survey	Safety training procedure Exit survey Follow up evaluation interview	Participants reported high satisfaction and acceptability for the programmer. More details are available in figures 2-4
	2 Burden (What did the participants say about the structure and ease to understand):		

	Average satisfaction score for the program structure in the exit survey and participants feedback		
	3 Ethicality (To what extent the strategy helped in performing the farm tasks) : Average satisfaction score for the program and topics covered in the programme in the exit survey		
	4 Intervention coherence (How did participant feel in terms of understanding the tasks and performing it by himself) : Participants' report on what they learned during the program		
	5 Opportunity costs (What were the benefits the participants perceived) : Participants' feedback		
	6 Perceived effectiveness (To what extent did the participant felt that strategy was effective) : Participants' report on what they learned during the program		
	7.Self-efficacy (How confident and comfortable was the participant at performing the task) : Average confidence score for each the target behaviours in the safety training procedure document		