



Provided by the author(s) and University of Galway in accordance with publisher policies. Please cite the published version when available.

Title	Stimulus Over-selectivity: An Investigation of Extinction Effects and Correlates across Populations
Author(s)	Kelly, Michelle Patricia
Publication Date	2012-09-19
Item record	<a href="http://hdl.handle.net/10379/3282">http://hdl.handle.net/10379/3282</a>

Downloaded 2024-04-25T04:07:39Z

Some rights reserved. For more information, please see the item record link above.



**Stimulus Over-selectivity: An Investigation of Extinction  
Effects and Correlates across Populations**

Michelle P. Kelly

Dissertation submitted in partial fulfilment of the requirements for the  
Degree of Doctor of Philosophy in Applied Behaviour Analysis

Supervisor: Dr. Geraldine Leader  
School of Psychology  
National University of Ireland, Galway  
September, 2012

## Contents

	Declaration and Statements.....	vii
	Summary.....	viii
	Acknowledgements.....	ix
	Dedication.....	x
	Publications and Conference Presentations Resulting from this Thesis...	xi
Chapter 1	Introduction to, and Literature Review of, Stimulus Over-selectivity.....	1
1.0	Autistic Spectrum Conditions.....	2
2.0	Stimulus Over-selectivity.....	3
2.1	Measuring Stimulus Over-selectivity.....	3
2.2	Initial Demonstrations of Over-selectivity.....	5
2.3	Systematic Replications and Extensions.....	7
2.3.1	Visual Over-selectivity.....	7
2.3.2	Auditory Over-selectivity.....	8
2.3.3	Tactile Over-selectivity.....	8
2.3.4	Sensory Preferences and Stimulus Over-selectivity.....	9
2.4	Real World Implications of Stimulus Over-selectivity.....	10
2.4.1	Deficits in Communication Skills.....	10
2.4.2	Deficits in Social Behaviour.....	11
2.4.3	Deficits in Learning.....	12
2.4.3.1	Deficits in Observational Learning.....	12
2.4.3.2	Deficits when Learning with Prompts.....	13
2.4.3.3	Deficits in Learning in Match-to-Sample Tasks.....	15
2.4.4	Deficits in Generalisation Skills.....	15
3.0	Stimulus Over-selectivity Across Populations.....	17
3.1	Typically Developing Individuals.....	18
3.1.1	Typically Developing Children.....	18
3.1.2	Typically Developing Adults.....	20
4.0	Correlates.....	22
4.1	Mental Age.....	23
4.2	Chronological Age.....	23

4.3	IQ.....	24
4.4	Diagnosis.....	25
4.5	Stereotyped Behaviour.....	26
5.0	Theories of Stimulus Over-selectivity.....	27
5.1	Sensory Overload.....	27
5.2	Tunnel Vision.....	28
5.3	Limbic System Hypothesis.....	29
5.4	Increased Cognitive Load.....	31
5.5	Executive Dysfunction.....	33
5.6	Attention Deficit.....	37
5.6.1	Eye Tracking Assessment.....	37
5.6.2	Correlation between Attention and Eye Movement.....	39
5.6.3	Observing versus Attending.....	41
5.6.4	Event Related Potentials.....	43
5.7	Comparator Theory.....	44
5.7.1	Hippocampus as a Comparator.....	44
5.7.2	Comparator System and Behaviour.....	46
5.7.3	Predictions of the Comparator System.....	47
5.7.4	Emergence Effects.....	49
5.7.4.1	Emergence Effects in Animals.....	50
5.7.4.2	Emergence Effects in Individuals with ASC.....	51
5.7.4.3	Emergence Effects in Typically Developing Individuals.....	54
6.0	Remediation of Stimulus Over-selectivity.....	57
6.1	Prompt Fading.....	57
6.2	Multiple-Cue Training and Repeated Probes.....	59
6.3	Pre-training and Over-training.....	59
6.4	Differential Observing Responses.....	60
6.5	Schedules of Reinforcement.....	63
6.6	Mindfulness.....	63
6.7	Vocal Punisher.....	64
6.8	Extinction.....	64

7.0	Summary.....	65
Chapter 2	The Effects of Extinction of Over-selected Stimuli on Under-selected Stimuli in High, Moderate and Low Functioning Children with Autistic Spectrum Conditions .....	67
	Experiment 1A.....	72
	Method.....	72
	Results and Discussion.....	77
	Experiment 1B.....	80
	Method.....	80
	Results and Discussion.....	81
	General Discussion.....	85
Chapter 3	Stimulus Over-selectivity in Children with Autistic Spectrum Conditions: Correlations with Attention, Flexibility, and Stereotyped Behaviour.....	88
	Experiment 2.....	94
	Method.....	95
	Results.....	102
	Discussion.....	110
Chapter 4	Stimulus Over-selectivity in Typically Developing Children: A Developmental Profile.....	116
	Current Experiments.....	120
	Experiment 3.....	121
	Method.....	121
	Results .....	127
	Discussion.....	132
	Experiment 4.....	132
	Method.....	132
	Results.....	133
	Discussion.....	136
	Experiment 5.....	137
	Method.....	137
	Results.....	137

	Discussion.....	141
	Experiment 6.....	141
	Method.....	141
	Results.....	142
	Discussion.....	145
	Experiment 7.....	145
	Method.....	146
	Results.....	146
	Discussion.....	150
	Developmental Trend Analysis.....	150
	General Discussion.....	156
Chapter 5	Emergence of Under-selected Stimuli following Extinction of Over-selected Stimuli in Elderly Individuals.....	161
	Experiment 8.....	164
	Method.....	165
	Results.....	171
	Discussion.....	178
Chapter 6	General Discussion.....	182
1.0	Overview of the Aims.....	183
2.0	Summary of Thesis Findings.....	186
3.0	Theoretical Implications of Thesis Findings.....	192
3.1	Comparator Theory of Over-selectivity.....	192
3.2	Attention Deficit Theory of Over-selectivity.....	195
4.0	Implications for the Remediation of Over-selectivity.....	197
5.0	Implications for Future Work.....	203
5.1	Extinction.....	204
5.2	Predicting Recovery from Over-selectivity in ASC.....	204
5.3	Over-selectivity and Attention.....	204
5.4	Over-selectivity and Flexible Behaviour.....	205
5.5	Over-selectivity and Stereotyped Behaviour.....	206
6.0	Limitations of the Current Thesis.....	207

6.1	Participants and Matched Controls.....	207
6.2	Power.....	208
6.3	Non-automated Procedures.....	208
6.4	Generalisations of Results.....	209
7.0	Conclusions.....	211
	References.....	213

## Declarations and Statements

This work has not been previously been accepted in substance for any degree, and is not being concurrently submitted in candidature for any degree.

Signed..... (candidate)

Date.....

### STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed..... (candidate)

Date.....

### STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed..... (candidate)

Date.....

## Summary

This thesis examined stimulus over-selectivity, a phenomenon where only a limited subset of the total number of stimuli present during discrimination learning controls behaviour. Stimulus over-selectivity is a widely acknowledged problem for an individual's functioning because it limits learning in situations consisting of multiple and complex cues. This research experimentally demonstrated over-selectivity in both clinical and non-clinical populations, using a discrete trial discrimination paradigm. It investigated the remediating effects of stimulus over-selectivity by manipulating post-learning behaviour by extinguishing the over-selected stimuli. This research examined the correlation between stimulus over-selectivity and several variables, including: attention, cognitive flexibility, behavioural flexibility, stereotyped behaviour, IQ, mental age, chronological age, and severity of autism diagnosis.

Chapters 2 and 3 investigated stimulus over-selectivity in children and adolescents with Autistic Spectrum Conditions (ASC). Chapter 2 examined the effects of level of functioning on degree of over-selective responding. Extinction was investigated as a potential remediation strategy for stimulus over-selectivity. Chapter 3 explored the correlation between stimulus over-selectivity and inflexibility, attention, and stereotyped behaviour to extend the theoretical framework of the concept.

Chapter 4 examined stimulus over-selectivity in typically developing children aged three to seven years. An extinction procedure was employed to test the effects on the previously over-selected and under-selected stimuli, and to evaluate its potential to act as an effective remediation strategy. Chapter 4 also investigated correlations between cognitive flexibility and selective attention with over-selectivity in this non-clinical population. In Chapter 5, extinction was employed to demonstrate its effects on post-test levels of over-selectivity in three age groups of typically developing elderly individuals. This chapter also analysed chronological age, cognitive flexibility and attention levels as correlates of over-selectivity.

The results from the current thesis are discussed in terms of theoretical perspectives of stimulus over-selectivity, and implications for potential remediation strategies.

## Acknowledgements

Funding was received for this thesis from the *Galway Doctoral Research Fellowship Scheme* and the *Write-Up Bursary* of the College of Arts, Social Sciences, & Celtic Studies, National University of Ireland, Galway.

First and foremost, I am very grateful for the support and guidance provided by my supervisor, Dr. Geraldine Leader over the past four years. Thanks to Professor Phil Reed for his advice and contributions made throughout this thesis. Thank you to both Dr. Jennifer Holloway and Dr. Olive Healy whose enthusiasm for behaviour analysis, and expert knowledge in this area have been such a massive inspiration to me. Huge thanks also to Declan Coogan for his patience and technical assistance throughout this process. Special thanks to all of my friends and especially Clodagh Murray for being there from start to the eventual finish. We have gone through so much together and I know I definitely couldn't have done it without you. You have been such an amazing and supportive friend and colleague. Thanks also to my parents Pat and Dolores, and my younger sister Debs for your generosity, encouragement and never-ending faith in me. Finally, I would like to extend my deepest gratitude to each and every one of my 211 participants and their families for providing consent for all my research. Without you all, this thesis would certainly not have been possible.

## **Dedication**

For my sister Lorraine.

To the world you were one, but to us you were the world.

## **Publications and Conference Presentations Resulting from this Thesis**

A review of the literature on stimulus over-selectivity, based upon the research in Chapter 1, was presented at the 39<sup>th</sup> Annual Conference of the Psychological Society of Ireland in Wexford, 2009. The data from Chapter 2 was presented at the 5th Conference for the Association for Behavior Analysis International (ABAI) in Oslo, 2009. Chapter 2 data was also presented in poster format at the 1st International Conference on Behavior Analysis and Developmental Disorders: Experimental and Applied Prospects in France, 2009. A selection of data from Chapter 4 was presented at the 6th Annual Conference for the Division of Behaviour Analysis in Trinity College Dublin, 2012. The data from Chapter 5 was presented at the 36<sup>th</sup> Annual Convention for the ABAI in Texas, 2010 and the 4th Conference for the Division of Behaviour Analysis in the National University of Ireland, Galway, 2010.

The research reported in several of the chapters of this thesis is being prepared for publication in a number of journals.

- Chapter 1: Kelly, M.P., & Leader, G. Stimulus Over-selectivity in Autistic Spectrum Conditions: A Review of Remediation Strategies.
- Chapter 1: Kelly, M.P., & Leader, G. Theories of Stimulus Over-selectivity: A Critical Review.
- Chapter 2: Kelly, M.P., Leader, G. & Reed, P. The Effects of Extinction of Over-selected Stimuli on Under-selected Stimuli in High, Moderate and Low Functioning Children with Autistic Spectrum Conditions.
- Chapter 3: Kelly, M.P., Leader, G., & Reed, P. Stimulus Over-selectivity in Children with Autistic Spectrum Conditions: Correlations with Attention, Flexibility and Stereotyped Behaviour.
- Chapter 4: Kelly, M.P., & Leader, G. Stimulus Over-selectivity in Typically Developing Children: A Developmental Profile.
- Chapter 5: Kelly, M.P., & Leader, G. Emergence of Under-selected Stimuli following Extinction of Over-selected Stimuli in Elderly Individuals.

## Chapter 1:

Introduction to, and Literature Review of,

Stimulus Over-selectivity

## **1.0 Autistic Spectrum Conditions**

Autistic Spectrum Condition (ASC) includes a range of diagnoses: Autistic Disorder, Rett's Disorder, Childhood Disintegrative Disorder, Asperger's Disorder, and Pervasive Developmental Disorder Not Otherwise Specified (American Psychiatric Association [DSM-IV-TR], 2000). The prevalence rate of ASC in Ireland is currently unknown. However, the Center for Disease Control and Prevention (2008) estimate that 1 in 88 children have been diagnosed with an ASC in the USA.

ASC is characterized by a triad of impairments which includes social-interaction difficulties, communication challenges and a tendency to engage in repetitive behaviours (Wing & Gould, 1979). However, symptoms and their severity vary widely across these three core areas. Taken together, they may result in relatively mild challenges for someone on the high functioning end of the autism spectrum. For others, symptoms may be more severe, as when lack of spoken language interferes with everyday life (Autism Speaks, 2012).

In 2000, the American Psychiatric Association released the diagnostic and statistical manual (DSM IV-TR), which refined diagnostic criteria for ASC. The symptoms marking impairments in social interaction include: deficits in the use of multiple non-verbal behaviours such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction; failure to develop peer relationships appropriate to developmental level; a lack of spontaneous seeking to share enjoyment, interests, or achievements with other people; and a lack of social or emotional reciprocity.

The symptoms listed as diagnostic criteria in the communication category include: delay in, or total lack of, the development of spoken language; deficits in the

ability to initiate or sustain a conversation with others; stereotyped and repetitive use of language; lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level.

Within the category of restricted repetitive and stereotyped patterns of behaviour, interests, and activities, the following symptoms are listed as potential diagnostic criteria: encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity or focus; apparently inflexible adherence to specific, non-functional routines or rituals; stereotyped and repetitive motor manners; and persistent preoccupation with parts of objects. Although each of the five ASCs has varied specific diagnostic criteria, they are all centrally based upon the triad of impairments.

Specifically, one defining feature of ASC is the inability of the individuals to respond to environmental stimuli (Rimland, 1964). This often leads to some individuals with ASC being wrongly diagnosed with hearing or vision impairments (Reynolds, 2012). However, the underlying cause for this inability to adequately respond to their surroundings may, in fact, be due to stimulus over-selectivity.

## **2.0 Stimulus Over-selectivity**

In 1971, the term stimulus over-selectivity was introduced by Lovaas, Schreibman, Koegel and Rehm. These authors described this phenomenon as a “problem in dealing with stimuli in context, a problem of quantity rather than quality of stimulus control” (Lovaas et al., 1971; p. 219). Stimulus over-selectivity occurs when only a limited subset of the total number of stimuli present during discrimination

learning controls behaviour and thus, it may restrict learning of the range, breadth or number of stimuli, or features of a stimulus (see Lovaas & Schreibman, 1971; Dube & McIlvane, 1999; Ploog, 2010). The stimuli which become over-selected and control responding are not necessarily relevant cues. In fact the over-selected stimuli are often irrelevant or insignificant features of a complex array of stimuli (Reynolds, 2012; Lovaas et al., 1971). Several synonyms for stimulus over-selectivity have since been employed in the literature including: over-selective attention (Wilhelm & Lovaas, 1976); restricted stimulus control (Doughty & Hopkins, 2011; Dube et al., 2010; Litrownik, McInnis, Wetzel-Pritchard & Filipelli, 1978); selective responding (Dube & McIlvane, 1997); an attentional abnormality (Ploog, 2010); and lack of responsiveness to multiple cues (Koegel, Schreibman, Good, Cerniglia, Murphy & Koegel, 1989).

### ***2.1 Measuring Stimulus Over-selectivity***

Procedurally, stimulus over-selectivity is determined by training the individual to discriminate between two complex stimuli, each of which comprises two or more stimulus components or elements (Bickel, Stella & Etzel, 1984). Once the discrimination is acquired (criterion is usually set as a number of correct consecutive responses) then the single elements of the complex stimuli are presented to determine if one, some, or all of the elements control responding. If only one or a small number of the elements from the reinforced stimulus complex (S+) control behaviour, then the inference of stimulus over-selectivity is made (Bickel et al., 1984).

The measurement system used in research on stimulus over-selectivity is based on the proportion of responses (usually calculated as percentages) to all the S + complex

stimulus elements on probe trials. Although there is no paradigm-independent definition of what degree of selectivity actually constitutes stimulus over-selectivity (Ploog, 2010), a review of the literature reveals some of the criteria employed. Bickel et al. (1984) suggest that individuals should be considered over-selective when responses are made to one of two S + components on at least 90% of the trials (when it is compared to an element from the negative complex stimulus, S-), and they respond at near "chance" (range: 25% -75%) levels to the other S + component when the latter is paired with an S- element. An inference can then be made that only one element reliably controls behaviour and the other S + element was not exerting reliable control. Other researchers who have cited a similar criteria include Koegel and Wilhelm (1973; p.449), Bailey (1981; p.242), Schreibman, Koegel, and Craig, (1977; p.431) and Anderson and Rincover (1982; p.222).

## ***2.2 Initial demonstrations of over-selectivity***

In the initial demonstration of over-selectivity, Lovaas et al., (1971) trained three groups of five participants (ASC, developmental delay and typically developing) to press a bar four times in the presence of a multidimensional cue (discriminative stimulus; Sd), and to withhold bar presses in the absence of the cue (S delta; S $\Delta$ ). The complex cue consisted of four components presented simultaneously: (i) a tactile stimulus applied by a blood pressure cuff; (ii) an auditory stimulus emitted from a tape recorder; (iii) a visual stimulus consisting of a red floodlight; and (iv) a temporal component that was inherent in the compound stimulus (i.e., the cue was presented every 20 seconds for a 5 second duration). Criterion was reached in the training phase

when participants completed two consecutive sessions in which at least 90% of their bar presses fell within the Sd period.

The visual, auditory and tactile elements of the compound were then presented in isolation to assess levels of over-selectivity. The results showed that the typically developing participants responded uniformly to all three cues; the participants with ASC responded primarily to only one of the cues; and the participants with a developmental delay responded at a level between these two extremes. Lovaas and colleagues (1971) interpreted these results as being related to “stimulus blocking” in children with ASC. It was assumed that attending to one of the stimulus components in a complex stimulus blocked the learning of the other cues present. In examining the implications of this research for understanding ASC, it was also suggested that, if over-selectivity continued to be a replicable phenomenon, it could help to explain the primary features of ASC.

Lovaas and Schreibman (1971) conducted a second study which simplified the stimulus input, controlling for possible stimulus flooding or sensory overloading effects in the earlier study. The earlier results could have been due to difficulties children with ASC have in processing too much sensory input (cf., Hedbring & Newsom, 1985). The same basic experimental paradigm as described above was used in this second study, but the compound stimulus consisted of only two cues, the same visual and auditory stimuli. Only two groups of participants were tested in this study (ASC and typically developing). The findings of this study were consistent with the previous research; the typically developing children responded to both cues, while seven of the nine children with ASC only responded to one. As in the previous study, there was no evidence that one sense modality was impaired or preferred by children with ASC.

### ***2.3 Systematic replications and extensions***

These two experiments (Lovaas et al., 1971; Lovaas & Schreibman, 1971) showed that stimulus over-selectivity was a replicable phenomenon when the complex compound consisted of stimuli from different sensory modalities. In the first study all five of the children with ASC demonstrated stimulus over-selectivity. Conversely, in the second study over-selectivity was not observed in all of the participants with ASC. Lovaas, Koegel, and Schreibman (1979) suggested that this discrepancy occurred because levels of over-selectivity are increased with a larger quantity of stimulus inputs. Hintgen and Churchill (1971) described how children with ASC may experience difficulties “integrating” information along more than one modality. To test this hypothesis, several studies were conducted to determine whether over-selectivity would occur when complex cues contained elements all within the same sensory modality: visual (Koegel & Schreibman, 1977), auditory (Reynolds, Newsom, & Lovaas, 1974) or tactile (Ploog & Kim, 2007).

***2.3.1 Visual Over-selectivity.*** Koegel and Wilhelm (1973) taught their participants (15 with ASC and 15 typically developing) in a discrete-trial visual discrimination task. The compound stimulus contained two cues (red shapes or black and white drawings) presented on white cards. This study differed from the earlier two studies in the following ways: (i) the elements in the complex cue were both within a single stimulus modality; (ii) it was a simultaneous rather than a successive discrimination; that is, the participants had to point at the correct picture rather than respond under one set of stimulus conditions and not another; and (iii) only responses to

the compound stimulus (and not the component stimuli) were reinforced during test trials.

The results were consistent with the earlier research; 80% of the children with ASC demonstrated stimulus over-selectivity, while only 20% of the typically developing children did. Some children with ASC had difficulty responding to multiple cues even when both cues were in the same modality (Koegel & Wilhelm, 1973). The basic procedures used in this study have become the main means of examining stimulus over-selectivity (Wilhelm & Lovaas, 1976; Broomfield, McHugh & Reed, 2008; Reed, Broomfield, McHugh, McCausland, & Leader, 2009).

**2.3.2 Auditory Over-selectivity.** Reynolds et al. (1974) utilised a successive discrimination task to examine over-selectivity within the auditory modality of children with ASC and typically developing children. The compound S<sub>d</sub> consisted of a continuous high tone plus periodic relay clicks and the S<sub>Δ</sub> consisted of a low tone with periodic bursts of a motor sound. Once the participants' bar pressing was consistently occurring when they heard the S<sub>d</sub> compound only, the individual S<sub>d</sub> components were then tested interspersed with the S<sub>Δ</sub> components. Again, within the auditory stimulus modality, the majority of children with ASC (six out of eight) responded primarily to one cue. Two of the eight typically developing children (the youngest) displayed stimulus over-selectivity.

**2.3.3 Tactile Over-selectivity.** Ploog and Kim (2007) trained six children with ASC and five typically developing children on a simultaneous discrimination task with three tactile compound stimuli. These compounds consisted of four stimuli in total per set: two shapes and two textures (e.g., fleece and wrinkled foil). Responding to S<sub>+</sub> was

reinforced during the training sessions. S+ and S- elements were recombined for Test 1 sessions. It was found that all children (ASC and typically developing) responded exclusively to one test probe. In Test 2, the over-selected stimulus from Test 1 was presented in a discrimination task with the training S+. The typically developing children responded mostly to the training S+ indicating control by both S+ elements. However, the children with ASC responded to both stimuli demonstrating over-selectivity with the reduction of control by the second S+ element.

**2.3.4 Sensory Preference and Stimulus Over-selectivity.** Lovaas and colleagues (1971) failed to show that any one sense modality is impaired in children with ASC or that their participants demonstrated modality preference. Kolko, Anderson, and Campbell (1980) used a successive discrimination task to test whether sensory preference could predict stimulus over-selectivity. Sensory preferences were first identified for five children with ASC and five typically developing children who pressed a bar to gain free access to a visual (slide presentation) or an auditory (music) stimulus. The participants were taught to discriminate between the presence and absence of a red light plus white noise. Standard tests were conducted to determine stimulus control. Results showed that all of the children with ASC who demonstrated some sensory preference did over-select the preferred stimulus modality during testing. None of the typically developing children displayed sensory preference or over-selectivity in this study.

#### **2.4 Real World Implications of Stimulus Over-Selectivity**

The inability to respond to each cue in the environment may be an underlying factor to many of the deficits seen in ASC including deficits in communication skills,

social behaviour skills, learning skills and the ability to generalise material that has already been learned (Lovaas et al., 1979; Dube, 2009).

**2.4.1 Deficits in communication skills.** The stimuli that control our communicative responses are extremely complex and require that an individual must attend to several complex stimuli presented both simultaneously and in succession (Barthold & Egel, 2001; Dunlap, Koegel, & Burke, 1981). “Stimulus over-selectivity may make it difficult for individuals to identify the subtle, complex, and often multiple cues that are critical to social and communicative interaction” (Chiang & Carter, 2008; p. 701). Over-selectivity, to either the visual or auditory components of language, can lead to deficits in communication skills. To understand speech, a number of visual cues must be focused upon including watching facial expressions, lip movements and gestures etcetera.

Reynolds et al. (1974) suggested that the existence of auditory over-selectivity would create a significant deficit for an individual trying to understand a speech signal. These authors discussed the necessity for the successful discrimination between the various speech sounds for speech perception. Liberman, Cooper, Shankweiler, and Studdert-Kennedy (1967) showed that no one single element of an auditory compound stimulus led to recognition of basic segments of speech, such as syllables or phonemes. Instead, as Lovaas et al. (1979) described, “adequate responding necessitates the child’s attention to a number of stimulus dimensions (e.g., voiced vs. voiceless, tense vs. lax, volume vs. pitch)” (p. 1241).

Chiang and Carter (2008) conducted a thorough review of the lack of spontaneity of communication in individuals with ASC and suggested that stimulus over-selectivity

could impact on the development of spontaneous language in three different ways. Firstly, the individual may focus on the most salient available cue and fail to attend to other aspects in the environment that are more subtle and relevant. Secondly, communicative responses at the higher end of the spontaneity continuum contain multi-elements. Chiang and Carter (2008) illustrate this point with the example of an individual with an interoceptive feeling of hunger and the presence of an individual who could potentially respond to their request for food. Individuals with ASC may prefer to respond to single cues that are further down in the spontaneity continuum (e.g., a friend's question) than responding to a complex array of multiple stimuli at the higher end of the continuum. The third suggestion made by Chiang and Carter (2008) is that irrelevant cues may make it more difficult to attend to the relevant feature at the higher end of the spontaneity continuum.

**2.4.2 Deficits in Social Behaviour.** Deficits in social behaviour have been approached as a stimulus control problem in numerous studies (Schrandt, Townsend, & Poulson, 2009; Gena, Krantz, McClannahan & Poulson, 1996; Harris, Handleman, & Alessandri, 1990). Scherf, Behrmann, Minshew, and Luna (2008) compared high functioning children and adults with ASC to typically developing children and adults on their ability to discriminate between faces, "greebles" (computer generated objects that are designed to act as controls for faces), and everyday objects. The high functioning ASC group had greater difficulty recognising and discriminating between individuals, the sex of human faces, and greebles (complex stimuli). However, they did not have difficulty with everyday objects (simpler stimuli). This difficulty in face recognition

may limit an individual's ability to socially interact if they cannot recall their previous conversations or interactions with a particular peer or acquaintance.

Schrandt et al. (2009) examined empathy skills as another example of social behaviour. These authors posited that failures in empathy may not reflect a deficit of necessary responses but instead may occur due to the individual's inability to differentiate the stimuli in the presence of which specific responses would be deemed socially appropriate.

Gena et al. (1996) examined affective behaviour as an example of a social behaviour that may be limited due to stimulus over-selectivity. Affective behaviours include those that act as Sd for the use of modifiers such as happy, sad and angry and include observable facial, verbal, postural, and gestural response repertoires. Since these affective behaviours act as Sd for social interaction, deficits in displaying appropriate affect may create problems with overall social development and reduce the probability of successful interactions (Gena et al., 1996; Feldman, Philippot, & Custrini, 1991; Walters, Barrett, & Feinstein, 1990).

**2.4.3 Deficits in Learning.** Stimulus over-selectivity has been documented to contribute to difficulties in learning also. The specific problems focussed upon here include learning via observation, prompts and match-to-sample tasks.

**2.4.3.1 Deficits in observational learning.** Bandura (1969) described how typically developing children learn a lot of their behaviours by watching social interactions in their environment. Children who do not naturally learn by observing a model's behaviour can be very restricted in their behavioural development (Lovaas et al., 1979). Varni, Lovaas, Koegel, and Everett (1979) demonstrated how stimulus over-

selectivity can limit observational learning. In this study, the participants with ASC sat across from an adult model and a teacher. After the model followed a single-word vocal prompt from the teacher to complete an action (e.g., “phone”), the participant was tested to see if they had learned to complete the novel task just by observing the model.

Although each child received up to 1000 trials watching the model select the correct stimulus on cue, results showed that the participants usually only learned a part of the response they observed, that is, they over-selected one element of the complex cue presented by the model. For example, a child touched the phone rather than pick it up like the model. In some cases, the children did complete the task correctly, but the response was not contingent upon the teacher’s vocal command. Remediating stimulus over-selectivity would allow people with ASC to learn more effectively through observation alone.

**2.4.3.2 Deficits when learning with prompts.** Stimulus over-selectivity can also limit learning where a prompt is used to “facilitate” instruction. A prompt is used to increase the likelihood that a person will engage in the correct behaviour at the correct time (Miltenberger, 2001). Examples include the use of gestural prompts when asked to discriminate a word and using pictures of a word when teaching a child to textually respond. The aim is to fade and eventually remove these prompts until the child can complete the task independently. This process is referred to as a shift in stimulus control from the prompt stimulus (e.g., gesture or picture) to the training stimulus (e.g., text).

If a child over-selects, these additional prompt stimuli might prevent the child from learning by creating multiple cues in the instructional episode. Koegel and

Rincover (1976) examined the problem of using extra cues in their study. The experimental (ASC) and control (typically developing) groups were both taught to discriminate between two auditory stimuli (low-pitch and high-pitch tones) using two colours as extra-stimulus prompts (red with the low tone and green with the high tone). The prompts were faded gradually until only the auditory stimuli were presented. The control group successfully discriminated the tones independently. However, the experimental group were unable to transfer the stimulus control from the prompt to the test stimulus. Interestingly, the experimental group acquired the discrimination between the test stimuli when no colour cue was used in the training session.

Schreibman (1975) found similar results. Children with ASC over-selected the prompt cue as long as it was available and then reverted back to chance performance when the prompt was faded completely. Furthermore, this effect is more frequent the more difficult the discrimination is (Lovaas et al., 1979). An example of a more difficult discrimination is between the internal cue of a full bladder and the available external cues in toilet training. LeBlanc, Carr, Crossett, Bennett, and Detweiler (2005) described how all extraneous prompting should be removed when trying to decrease primary urinary incontinence in children with ASC.

**2.4.3.3 Deficits in learning in Match-to-Sample tasks.** Match-to-Sample (MTS) tasks are commonly used in special education classrooms to teach “stimulus-stimulus relations among spoken and printed words, objects, pictures, and sometimes symbols used in augmentative and alternative communication systems” (Dube & McIlvane, 1999; p. 25). Stimulus over-selectivity may lead to problems when learning with this

procedure. Birnie-Selwyn and Guerin (1997) showed that selective stimulus control led to the problem of consonant cluster errors in six typically developing children's spelling.

Walpole, Roscoe and Dube (2007) completed a study with a 16-year-old girl with ASC, who demonstrated over-selectivity towards the first two letters when textually responding to three-letter words. For example she could discriminate the sample *cat* from the comparison stimuli *cat*, *bug* and *dog* (non-overlapping trials); but could not discriminate the sample *cat* from the comparison sample *cat*, *can*, and *car* (overlapping trials).

**2.4.4 Deficits in Generalisation Skills.** Baer, Wolf and Risley (1987) discussed the importance of generality when they described the seven defining characteristics of Applied Behaviour Analysis (ABA). These authors claimed a behaviour change had generality if it lasted over time, if it appeared in a different environment to the one in which it was learned and if it had spread across to other behaviours not directly treated. If a child is restricted in how many cues they can respond to, it follows that they will have a problem with transferring a learned behaviour from one environment onto another. The fewer the number of stimuli that had become functional in the original environment, the fewer stimulus elements would control the behaviour in the new environment (Lovaas et al., 1979; Brown & Bebkko, 2012). Thus, the probability of generalisation occurring is reduced.

Rincover and Koegel (1975) demonstrated how stimulus over-selectivity could directly limit generalisation. In this study, one teacher gave a one-step demand (e.g., touch your nose) to ten children with ASC. Once each child had learned to follow this direction, they were immediately brought into a different classroom with a new teacher

who gave the same vocal antecedent. Results showed that four of the ten children did not generalise this new simple behaviour in the novel environment. The behaviour of these four participants was analysed and it was found that they had over-selected an irrelevant cue (e.g., therapist hand movements or the presence of tables and chairs) during the original training session in the first classroom with the original teacher. They did not respond on the basis of the relevant cue, that is, the vocal instruction.

Falcomata, Roane and Pabico (2007) replicated the results from the Rincover and Koegel (1975) study. In this experiment, stimulus control procedures were examined during the treatment of pica behaviour exhibited by a 12-year-old boy with ASC. These researchers used an inhibitory treatment package first. They then paired a neutral stimulus (a wristband) with the treatment package to establish stimulus control. Results showed however, that the boy demonstrated stimulus over-selectivity and was unable to generalise the new behaviour. Stimulus control was inadvertently achieved with an alternative stimulus (the presence of the therapist) in the learning environment rather than the intended stimuli (the wristband and treatment package).

Another study demonstrating the limiting effects of stimulus over-selectivity on generalisation was completed by Schreibman and Lovaas (1973). These authors tested the ability of children with ASC to generalise social stimuli. Two groups of children (ASC and typically developing) were taught to discriminate between lifelike male and female dolls. A boy - girl discrimination was trained and then stimulus control was tested by varying the components of the figures during probe trials. Six of the seven children with ASC in the study responded in a way that was considered over-selective, whereby they responded to minor, unreliable and “peculiar” cues such as the doll’s

shoes. They did not respond to the reliable cues such as the doll's head like the typically developing participants did. It was suggested that "since the human face is a very complex stimulus... it may become non functional for [children with ASC] on the basis of its complexity" (Schreibman & Lovaas, 1973, p. 167). Lovaas and colleagues (1979) described how this explains why some children with ASC don't recognize their own parents when they remove their glasses or cut their hair etcetera.

### **3.0 Stimulus Over-selectivity across Populations**

The majority of studies demonstrating stimulus over-selectivity has been with individuals with ASC (e.g. Anderson & Rincover, 1982; Chiang & Carter, 2008; Dube & McIlvane, 1997, 1999; Frankel, Simmons, Fichter & Freeman, 1984; Hedbring & Newsom, 1985; Koegel & Wilhelm, 1973; Kolko, Anderson, & Campbell, 1980, Lovaas & Schreibman, 1971; Matthews, Shute & Rees, 2001). However, it should be noted that the phenomenon is not only found in this population and has been demonstrated in other clinical populations including individuals with an intellectual disability (Smeets, Hoogeveen, Striefel & Lancioni, 1985); individuals with a learning disability (Bailey, 1981; Dube & McIlvane, 1999; Lovaas & Schriebman, 1971; Gersten, 1983; Litrownik et al., 1978); females with Rett's Disorder (Fabio, Giannatiempo, Antonietti & Budden, 2009); individuals with an acquired brain injury (Wayland & Taplin, 1982) and individuals with schizophrenia (Feeny, 1972).

Broomfield (2007) posited that if over-selectivity is modelled in typically developing individuals the phenomenon can be further explored in a population which is not as vulnerable as those with disabilities (with the attendant ethical advantages) before

being applied to a clinical population. Furthermore, McHugh and Reed (2007) warned that if over-selective responding is only demonstrated in clinical populations that this may raise questions about the generality of this phenomenon.

### ***3.1 Typically Developing Individuals***

Since the first study on over-selectivity, typically developing individuals have regularly been employed as control groups (e.g., Koegel & Wilhelm, 1973). However there have been only a few studies examining typically developing individuals as the main study sample.

***3.1.1 Typically Developing Children.*** Bickel et al. (1984) examined auditory over-selectivity in 27 typically developing preschoolers. Training stimuli included auditory sounds emitted from a tape recorder, sounds similar to those used by Reynolds et al. (1974) who examined auditory over-selectivity in children with ASC. There were two complex stimuli, each with two components comprising of different pitches and temporal characteristics. During training, two complexes were presented and each participant was instructed to find the correct “sound”.

Test results showed that the participants could be divided into three groups. The “complete” group included eight participants who responded to both elements of the S+ complex at least 80% of the time with little or no stimulus control exerted by the two elements of the S-. The “partial” group comprised of 13 participants. The percentage of responses to one of the two elements of the S+ was at least 80%, but the percentage of responses to the other S+ element ranged from 50-80%. Six participants made up the “weak” group. For this group, the percentage of responses to one of the S+ elements

was less than 50%. The authors noted that the participants in both the weak and partial groups would typically be interpreted as being over-selective.

Eimas (1969) also examined over-selectivity in typically developing children. He trained 270 kindergarten, second and fourth grade children on a simultaneous discrimination task with two, three, or four relevant and redundant visual complex cues. The stimuli employed were colour-form patterns. The original presentation consisted of two relevant cues, for example a green triangle. The three component cues were colour, form, and size (large green triangle). Test trials consisted of presenting the single elements of the complex cue to measure levels of over-selectivity. All 270 participants were tested individually and then received twenty-five trials per day until they correctly discriminated twenty out of twenty-five trials or until 100 trials had been administered.

Nine students from kindergarten, eight from second grade and two from fourth grade failed to learn the original discrimination. Furthermore, the mean number of errors made by the kindergarten children (15) was greater than that made by the second graders (10.5) and the fourth graders (7.4). In addition, all participants (with the exception of one training condition), acquired two, often three, and in some individual cases all four cues. The number of cues learned about increased with both chronological and mental age.

Hale and Morgan (1973) tested their 100 4 and 8-year old typically developing participants to see if they responded to a single feature of a complex stimulus. The stimuli used included coloured shapes on black cards, white shapes on black cards, and coloured cards. Two sets of five stimuli were employed that differed in the colour chosen to be associated with each shape as well as in the particular group they were in.

The five cards were displayed with the shape facing away from the participant and with instruction to match the cue card to one of the five display cards. Findings showed that the younger group responded primarily to a single component (shape) during the acquisition of the discrimination and that the 8 year-olds displayed over-selectivity to a lesser degree than the 4 year olds.

**3.1.2 Typically Developing Adults.** Reed and Gibson (2005) completed a study to examine over-selectivity in typically developing adults in four different experiments. The aims of this study were to examine if over-selectivity could be induced in a non-clinical population and in what conditions this phenomenon could be induced. And specifically, the researchers wanted to investigate if the presentation of a concurrent task load was one of the conditions in which stimulus over-selectivity could be generated. Results showed that increasing the task complexity could induce over-selective responding.

McHugh and Reed (2007) extended the findings of Reed and Gibson (2005) by categorizing their 48 typically developing participants into three groups according to their chronological age. The aims of Experiment 1 were to investigate if over-selectivity increased with a distractor task, if over-selectivity increased with age and if there was an interaction effect between age and the distractor task. Results showed that there was a clear trend of over-selectivity increasing with chronological age and with the use of the distractor memory task. The effect of the distractor also increased with age.

Broomfield, McHugh and Reed (2008) conducted two experiments to investigate the emergence of under-selected stimuli to control behaviour after extinction in an automated MTS paradigm in typically developing adult students. Broomfield, McHugh

and Reed (2010) conducted a study with 107 typically developing university students using a table-top visual discrimination task. In both studies, results showed a large degree of stimulus over-selectivity in the participants, induced by the use of the concurrent task load.

Gemma Reynolds and colleagues have recently conducted a series of studies examining stimulus over-selectivity in non-clinical adults (Reynolds, Watts & Reed, 2012; Reynolds & Reed, 2011a; Reynolds & Reed, 2011b). Reynolds and Reed (2011a) explored the effects of partial and continuous reinforcement schedules on levels of stimulus over-selectivity in a series of 4 experiments with typically developing adults (see Section 6.5 for more details.) Reynolds et al. (2012) offered further evidence that stimulus over-selectivity can be induced in a non-clinical adult population when a distractor task is introduced. Experiment 1 examined the effects of extinction on previously most and least selected stimuli in 16 typically developing adults and explored the type of learning that accrues to the under-selected stimulus in Experiments 2 and 3.

Reynolds and Reed (2011b) conducted three experiments to explore the strength and generality of over-selectivity in non-clinical adults. In a given discrimination trial, an individual may approach an element (previously reinforced element) as well as avoid a previously punished stimulus. Results from Experiment 1 showed that stimulus over-selectivity is not just a function of avoidance. Experiment 2 investigated if the use of a novel stimulus as the test stimulus would lead to the induction of over-selective responding in typically developing adults. Results showed that participants actively avoided the novel stimulus which may have occurred due to the additional distractor task. Experiment 3 further explored over-selectivity by employing a third alternative

test condition that utilised associatively neutral stimuli with no conditioning history in typically developing adults. The over-selectivity effect was also seen in this experiment showing that stimulus over-selectivity “is a highly robust phenomenon” (Reynolds & Reed, 2011b; p. 121).

#### **4.0 Correlating Variables**

Stimulus over-selectivity plays an important role in many of the communication, social and learning deficits in individuals with ASC as evident in Section 2.4.

Therefore, over-selectivity is a phenomenon that may be viewed as having a general negative impact on overall quality of life in individuals with ASC. As a result of this and the fact that over-selectivity is evident in several other populations (see Section 3), it is essential that stimulus over-selectivity is comprehensively investigated (Schreibman, Koegel & Craig, 1977). The current thesis examines the theories explaining why over-selectivity exists and the effectiveness of potential remediation strategies. First, an analysis of the possible independent variables that correlate with stimulus over-selectivity is necessary to further develop a comprehensive theoretical framework of the effect.

#### **4.1 Mental Age**

Mental age is defined by the American Psychological Association (APA) as “the age at which a child is performing intellectually, expressed in terms of the average age at which normal children achieve a particular score” (Gerrig & Zimbardo, 2002). Bailey (1981) found that as mental age increased, over-selectivity decreased in 16 young children with an intellectual disability. Schover and Newsom (1976) examined over-

selectivity and mental age in children with ASC and typically developing children and high correlations were reported between mental age estimates and number of cues correctly matched. Schover and Newsom concluded that over-selectivity "may be part of a general developmental lag rather than being a specific deficit" (p. 297). Further research supporting the correlation between mental age and stimulus over-selectivity include: Eimas (1969); Wilhelm and Lovaas (1976); Dirlich-Wilhelm and Muller (1982); Katoh and Kobayashi (1985); Rincover and Ducharme (1987); and Leader, Loughnane, McMoreland and Reed (2009).

Conversely, Ploog and Kim (2007) and Ploog, Banerjee, and Brooks (2009) showed that mental age may not be the best predictor of stimulus over-selectivity. Both studies found abnormal attention patterns in their participants with ASC. The results showed that the lowest and highest mental age did not correspond, however, with the most and least degree of attentional abnormalities (Ploog, 2010).

#### ***4.2 Chronological Age***

Some research suggests links between stimulus over-selectivity and chronological age. Eimas (1969) found that the number of cues learned about in his simultaneous visual discrimination task increased with both chronological (and mental) age in the 270 typically developing participants (kindergarten up to fourth grade). By the chronological age of six years, typically developing children can selectively respond to multiple-component visual stimuli.

Hale and Morgan (1973) examined component selection (i.e., stimulus over-selectivity) in 100 4 and 8-year old typically developing participants. Results showed

that the younger group responded primarily to a single element during the acquisition of the discrimination and that the 8 year-olds displayed over-selectivity to a lesser degree than the 4 year olds. Hale and Morgan posit that their results showed a “developmentally increasing ability to distinguish between conditions in which attending to redundant stimulus information can and cannot be useful” (1973; p. 302). The authors examined this trend further in Experiment 2 with 96 participants but found that their three tasks produced similar developmental trends in performance in 8 and 12 year olds.

McHugh and Reed (2007) also found an age trend in over-selectivity. Their study had three groups of typically developing participants aged 18-22 years, 47-55 years, and 70-80 years. The results revealed a clear trend of stimulus over-selectivity increasing with chronological age.

### ***4.3 IQ***

Wilhelm and Lovaas (1976) reported the first study in which the relationship between stimulus over-selectivity and cognitive development was investigated. Participants in this study included three groups of children who differed in levels of IQ (mean IQs = 39.2, 65.7 and typically developing children assumed to be of average or greater intelligence). Each group was taught to respond to a complex cue containing three elements. After reaching training criterion and 50 trials on an intermittent reinforcement schedule, probes were conducted on the individual elements of the S+ and S- cards by presenting the nine possible combinations in a MTS format. Results showed that the low IQ group responded to an average of 1.6 cues, the higher IQ group to 2.1

cues, and the typically developing children to all 3 cues. Wilhelm and Lovaas (1976) concluded that "stimulus over-selectivity is not an exclusive feature of early infantile ASC but rather of mental retardation generally" (p.30).

Reed et al. (2009) examined stimulus over-selectivity in both high (IQ=77) and low (IQ=29) functioning children and adolescents with ASC. Similar to the results seen in Frankel et al. (1984), both groups displayed a significant degree of over-selectivity, irrespective of their IQ. However, Reed and colleagues (2009) note that caution should be taken with any conclusions made about the non-correlation between IQ and over-selectivity as they did find a numeric difference toward greater over-selectivity in the group with low IQ. The researchers speculated that their results may have been statistically significant if they had employed a larger sample.

#### ***4.4 Diagnosis***

In Section 3, it is shown that although stimulus over-selectivity is a phenomenon common in ASC, it is not restricted to individuals with this diagnosis. Therefore, ASC is not a reliable predictor of stimulus over-selectivity (Ploog, 2010). In his review of the literature, Ploog (2010) highlighted the point that the definition of ASC has changed significantly since the time of Lovaas and colleagues' (1971) study. Furthermore, there are currently several accepted but variable criteria in use (e.g., DSM-IV-TR, American Psychiatric Association, 2000; International Classification of Diseases, ICD-10, World Health Organisation, 1994). Another issue arises when one looks at the prevalence of co-morbidity rates. Lord and Volkmar (2002) estimate that 26-80% of individuals with an ASC have a co-diagnosis of an intellectual disability, depending on how and when the diagnosis was made. Therefore, Ploog (2010) suggests that diagnosis as a

correlating factor with over-selectivity may be co-founded with co-morbidity, functioning level, mental age, and year when the data was collected.

#### ***4.5 Stereotyped Behaviour***

Ploog (2010) speculated that “over-selectivity may also be associated with erratic, emotional, stereotyped, ritualistic, and inflexible behaviors” (p.1340). No experimental investigations have been conducted to date examining stereotyped behaviours as a correlating variable with stimulus over-selectivity. If an individual only responds to a subset of all the cues available to him at one time (e.g., responds to a preferred toy but doesn’t respond to time cues for when he can access the toy), then there is no effective or predictable contingencies to earn access to external reinforcers. However, internal reinforcers, accessed by engaging in repetitive behaviour, can be predictably produced by the individual and thus, come to control the individual’s behaviour.

#### **5.0 Theories of Stimulus Over-selectivity**

After approximately forty years of research in the area of stimulus over-selectivity, the exact mechanisms underlying this phenomenon are still in question (Reynolds, 2012). In the information processing system, there are many points at which a deficit may occur, resulting in stimulus over-selectivity (Reed, 2007). Several theories reported in the literature have been advocated to account for stimulus over-selectivity, including: sensory overload; tunnel vision, the limbic system hypothesis, increased

cognitive load, executive dysfunction, attention deficit theory and finally the comparator hypothesis.

### ***5.1 Sensory Overload***

This theory posits that over-selectivity is caused by a sensory overload which causes sensory information to be only partially processed (cf., Hedbring & Newsom, 1985). Ploog (2010) notes the anecdotal evidence that some children with ASC can seemingly overreact to some types of sensory stimulation whilst being completely unresponsive to (by blocking out) other types even if in the same sensory modality. The sensory overload theory suggests that typically developing individuals are less vulnerable to over-selectivity because they can process more information overall or because they “can dampen the overall sensory input evenly across all aspects of the stimulation” (Ploog, 2010; p. 1334). Kolko, Anderson, and Campbell (1980) demonstrated in their study that all of the children with ASC who demonstrated some sensory preference did over-select the preferred stimulus modality during test sessions. In contrast, none of the typically developing children displayed a preference for either of the sensory stimuli (visual versus auditory) and none of them were over-selective.

Evidence that does not offer support to this theory is detailed in Section 2.3. Over-selectivity has been shown when the compound stimulus consists of only two components to discriminate (e.g., auditory and visual; Lovaas & Schreibman, 1971) and also when the two components are from the same modality (e.g., visual only; Reed et al. 2009; auditory only; Reynolds et al., 1974). Ploog (2010) describes these as cases where sensory overload seems unlikely.

### ***5.2 Tunnel Vision***

This theory posits that the only stimuli that become functional for the individual are those that are in their restricted field or “tunnel” vision (Anderson & Rincover, 1982). Anderson and Rincover (1982) suggest that one way to conceptualise tunnel vision is in terms of the relative distance or location between cues. If responding is under the control of one stimulus, then the probability of an individual responding to a second stimulus is partially a function of its distance from the first stimulus. Therefore, using this hypothesis, the number of cues may not be the functional element in stimulus over-selectivity, but rather the relative location of the cues. Anderson and Rincover (1982), state that their results support the tunnel vision of stimulus over-selectivity. The eight children with ASC in their study responded more often to the multi-element stimuli (a circle with dots) when the components (i.e., the dots) were closer together.

### ***5.3 Limbic System Hypothesis***

The limbic system hypothesis (Joseph, 1999) proposes that all stimuli are attended to, and processed. The problem occurs when retrieving the stimuli and focuses on attempting to identify a brain-level mechanism for ASC (Reed, 2007). The limbic system comprises of orbital frontal cortex and the medial temporal lobe which includes the hippocampal formation and the amygdale (Joseph, 1999). In order to examine the validity of this theory of stimulus over-selectivity, one must look at the literature examining memory in individuals with ASC.

Boucher (1981) examined the differences between children with ASC and age and ability matched controls on a test of immediate recall of word lists. Results showed that overall performance was very similar for the experimental and control groups. However, the overall recall scores were achieved differently by the two groups with differences in their primacy and recency scores. The children with ASC showed significantly poorer recall of the first three words in the list (primacy effect) but comparable results for the last three words (recency effect). To recall first three words requires an individual to draw on their episodic memory, whilst the last three words are maintained in the articulatory loop in the working memory system (Volkmar, Paul, Klin, & Cohen, 2005). Boucher (1981) suggested that the pattern of memory performance in individuals with ASC is similar to that of patients with medial temporal lobe amnesic disorder and that ASC may be regarded as a “developmental form of the amnesic syndrome” (Boucher & Warrington, 1976; p.85).

However, this amnesic theory of ASC, a theory suggesting a relationship between temporal lobe amnesia and ASC, is not supported in the literature. Minshew and Goldstein (1993) and Minshew, Goldstein, and Siegal (1997) found no significant deficits in recognition of a list of words or delayed recall. Ameli, Courchesne, Lincoln, Kaufman, and Grillon (1988) found similar results in their study on delayed recognition of visual stimuli in ASC.

In their study Bennetto, Pennington and Rogers (1996) examined if individuals with high functioning ASC and individuals with a learning disability displayed a pattern of deficits similar to patients with frontal lesions. The authors administered measures of temporal order memory, source memory and working memory. Upon comparison

between the two groups, it was seen that the group with ASC were significantly impaired on all the tasks. Bennetto and colleagues (1996) suggested that the children with ASC displayed a similar pattern of memory function as patients with frontal lesions and the authors interpreted their findings in terms of a general deficit in working memory.

In summary, the available literature does not support the amnesic theory of ASC. Reed (2007) noted that the memory deficits that have been identified in individuals with ASC appear to be of an executive nature, with weak organisational strategies to encode and recall information. However, Joseph (1999) suggests that the limbic system and its associated functions are important in the development of ASC (Bauman & Kemper, 1994; Dawson, Meltzoff, Osterling & Rinaldi, 1998) and that future research does need to be conducted to test the limbic system hypothesis.

#### ***5.4 Increased Cognitive Load***

Stimulus over-selectivity may reflect the demand level, particularly the memory load, of a task (Reed & Gibson, 2005). Increased pressure on a person's information processing capacity may limit the number of cues that control behaviour. Reed and Gibson (2005) completed a study to examine if over-selectivity could be induced in a non-clinical population and under what conditions this phenomenon could be induced. In the training phase of Experiment 1, all participants were presented with a simultaneous discrimination task with two, two-element compound stimuli. The control group learned to discriminate the predetermined Sr+ ten times consecutively. The experimental group completed the same training but were also given an extra concurrent

task, a second set of compound stimuli to learn to discriminate. The experimental group basically had twice the task load as the first group (Reed & Gibson, 2005). Test results showed that the control group did not demonstrate stimulus over-selectivity. However, the experimental group did, showing that increasing the task complexity can induce over-selective responding.

In Experiment 2, further analysis was conducted on the effects of increasing the memory load on generating stimulus over-selectivity. In Experiment 2A, all participants were given only one set of cards. Half of the participants were also provided with a concurrent visual memory task, where they were instructed to memorize the position of four shapes in a 16-box grid and then reproduce it at the end of the experiment. Reed and Gibson (2005) chose the concurrent task in the same visual modality as the experimental discrimination task as research has shown that memory tasks in one modality do not interfere with the memory of tasks in another modality (Baddeley, 1992). Results showed that increased memory load induced higher levels of over-selective responding.

Experiment 2B analysed whether the generated over-selectivity scores were produced by an increase in the specific memory load or a general increase in cognitive load. Two groups completed a concurrent task, one group had the memory load increased (as above), the other group had an increased cognitive load that did not contain a memory component (provided with memory grid as above but were only required to copy the shapes onto a blank grid). Results showed that the individuals, who were given the concurrent memory task, were more over-selective than the individuals with the increased general cognitive load.

McHugh and Reed (2007) also utilised the 4x4 memory grid employed by Reed and Gibson (2005) to examine the effects of a distractor task on levels of stimulus over-selectivity in typically developing adults. Results showed that it took each of the groups longer to reach criterion in the training phase when the task was used. There was a clear trend of over-selectivity increasing with the use of the distractor memory task. The effect of the distractor memory grid also increased with age.

Broomfield, McHugh and Reed (2010) conducted a study with typically developing university students. The same procedure was used as above in Reed and Gibson's (2005) study where the participants had to make a series of discriminations between two simple or complex stimuli consisting of black pictures. A concurrent task was also employed in this study. For this particular task, participants were given a 5-digit number (e.g., 23,765) and were instructed to continue to subtract seven from the number out loud throughout the experiment (a task also employed by Reed, Savile, & Truzoli, 2012; Reynolds, Watts & Reed, 2012; Reynolds & Reed, 2011a, 2011b). The experimenters vocally prompted the participants to continue to make the calculations aloud if the participants went quiet. Results showed a large degree of stimulus over-selectivity in the participants (67% of participants demonstrated some degree of over-selective responding in the pre-treatment phase) induced by the use of the concurrent task load.

### ***5.5 Executive Dysfunction***

Assuming that the stimuli are processed, stimulus over-selectivity may be produced by deficits that occur later in the information processing channel (Reed, 2007).

“‘Executive function’ is an overarching term for the mental operations which enable an individual to disengage from the immediate context in order to guide behaviour by reference to mental models or future goals” (Hughes, Russell, & Robbins, 1994; p. 477). These functions have been linked to the frontal structures of the brain, particularly the prefrontal cortex (Hill, 2004) and include planning, working memory, initiation and monitoring of action, impulse control, inhibition, and cognitive flexibility or set shifting (Rabbitt, 1997; Roberts, Robbins, & Weiskrantz, 1998; Stuss & Knight, 2002).

The theory of executive dysfunction in ASC makes an explicit link to frontal lobe failure in neuropsychological patients who have impaired executive functions (Hill, 2004). However, most researchers caution that findings of executive dysfunction in developmental disabilities should not be assumed to reflect specific damage to the frontal regions, as it may arise from damage to interconnected cortical and sub-cortical brain structures or from more diffuse damage to the brain (Joseph, 1999; Duncan, 1986; Robbins, 1996; Pennington & Ozonoff, 1996).

Hill (2004) noted that executive dysfunction underlies many of the key characteristics of ASC including problem behaviour such as rigidity and perseveration. These problems can be explained by a deficit in the initiation of non-routine actions and the tendency to get “stuck” in a particular task set. The ability to conduct routine actions can be excellent and may manifest as repetitive behaviours. The first study to explicitly investigate executive function in ASC was conducted by Rumsey (1985). The author administered the Wisconsin Card Sort Test (WCST; Grant & Berg, 1948) to 9 individuals (aged 18-39 years) with high-functioning ASC and 10 control participants, matched for age, sex, education and IQ, as well as with published norms for various

groups of patients with brain damage. Similar to the findings in Ozonoff, Pennington, and Rogers (1991), Rumsey (1985) found that the experimental group showed significant deficits in the formulation of rules and perseverative tendencies and were significantly impaired relative to the control group on all key dependent variables.

Rumsey (1985) related the deficits found in the WCST to the social deficits observed in individuals with ASC. The WCST requires “integration and weighing of multiple contextual variables, selective attention to relevant aspects of the environment, and inductive logic” (Rumsey, 1985; p.34). Therefore, deficits in executive function could explain the inflexibility and rigidity seen in individuals with ASC, as well as their impaired ability to engage in social interactions where selection of appropriate responses to multiple cues is required.

Research has also focussed upon determining why individuals with ASC demonstrate poor performances on the WCST. To examine this issue, Hughes et al. (1994) conducted a study using the Intra-Extra Dimensional Set Shift (IED; Cambridge Cognition, 2011) with 35 individuals with ASC (aged 7 to 18 years), 38 individuals with a mild learning difficulty (aged 6 to 17 years), and 47 typically developing children (aged 5 to 10 years). Unlike the WCST, the IED task can identify the exact source of the deficit by requiring the participants to complete a hierarchy of increasingly difficult set shifting task demands. No deficits in the experimental group were found in the initial stages of the IED, including discrimination between two single cues and discrimination between two compound cues. The authors also found no impairment in the experimental group’s ability to respond to the previously incorrect pattern when the reinforcement patterns were reversed. These results ruled out specific deficits with

discrimination learning, establishing and maintaining a response set, attention to all available stimuli, and rule reversal (Joseph, 1999).

The final two stages in the IED involve an extra-dimensional shift, whereby the participants are required to shift their response set. Relative to the two control groups, the individuals with ASC were unable to identify the relevant response dimension and generalise it to a new set of exemplars. They could not shift out of that cognitive set and adopt a new perspective on the task. These findings suggest that the deficits were of a higher-level or executive nature involving set perseveration (Hughes et al., 1994).

Corbett, Constantine, Hendren, Rocke and Ozonoff (2009) examined executive function in three groups (aged 7 to 12 years) which consisted of 18 children with high functioning ASC, 18 children with ADHD and 18 typically developing children. The researchers conducted a comprehensive battery of measures assessing executive function, including response inhibition, working memory, cognitive flexibility (set shifting), planning, fluency and vigilance. Results showed that the children with ASC demonstrated pervasive impairment across a broad range of tasks measuring executive function. They showed poor performance relative to the typically developing controls in inhibition, working memory, flexibility (set shifting) and vigilance. Compared to the ADHD group, the ASC group performed more poorly in tasks measuring inhibition, working memory, and flexibility. Although there were significant differences across the groups for switching there were no significant differences found on measures of planning, fluency or in the IED tasks across the groups.

The results from Corbett and colleagues' (2009) study supported previous findings that children with ASC demonstrate generalised and profound impairment in

executive functions (Geurts, Verte, Oosterlaan, Roeyers & Sergeant, 2005). The results were also consistent with studies in ASC that reported working memory deficits (Goldberg et al., 2005; Landa & Goldberg, 2005, Pennington & Ozonoff, 1996), as well as set-shifting deficits (Hughes et al., 1994; Ozonoff et al., 2004; Ozonoff & Strayer, 1997). The finding that children with ASC performed more poorly than children with ADHD on measures of set shifting has also been previously reported (Geurts et al, 2005).

It should be noted that there are some inconsistent results in the literature investigating executive dysfunction in individuals with ASC (Reed, 2007). McEvoy, Rogers, and Pennington (1993) noted difficulty in cognitive flexibility in younger children with ASC, but Wehner and Rogers (1994) found no impairment on the spatial reversal task. Turner (1997) replicated the extra-dimensional shifting deficit, as found in Hughes et al. (1994), in individuals with ASC with an ID, but found no deficits in their participants with ASC and no ID relative to outpatient psychiatric controls. Similarly, Ozonoff, South and Miller (2000) found no extra-dimensional problems in individuals with high-functioning ASC relative to typically developing individuals, matched on IQ. Therefore, executive dysfunction may be more prominent in individuals with both ASC and an ID, than in those with ASC in the mean range of intelligence. This is an area of research that requires further analysis.

### ***5.6 Attention Deficit***

Lovaas et al. (1979) concluded, from their experiments, that stimulus over-selectivity occurs due to an inability to attend to all available cues provided by

component elements of a stimulus. Stimuli that are not attended to cannot be processed or learned about. This limits the range, breadth, or number of stimuli or stimulus features that can control behaviour (Reed, 2007).

**5.6.1 Eye Tracking Assessment.** When individuals with ASC are faced with complex cues, eye tracking apparatus can be used to analyse their eye movements and gaze. Dube, Lombard, Farren, Flusser, Balsamo, and Fowler (1999) aimed to examine the relationship between over-selectivity and observing behaviour. They used a head-mounted eye tracking device which tracks eye movements using a corneal reflection system to display the reflected image of the eye on the inside of the mirror.

This head-mounted system was useful as it did not require mechanical head restraint and therefore did not force participants to perform tasks in a different manner to which they usually perform. Creedon (1999) found that children with ASC had a tendency to move their head and their eyes together when fixating on changing target locations. In Dube and colleagues' (1999) brief report, the authors examined the results of DTM, a 12-year old boy with a moderate ID and LCN, a nonclinical adult. Both participants completed 36 two-sample DMTS trials using black abstract forms on a white background of a touch screen computer. Results showed that there was substantial variation in DTM's responding, and that his observing patterns were more irregular than LCN's. In 12 of the 36 trials, DTM only observed one of the two sample stimuli. This showed that "stimulus over-selectivity may be accompanied by a failure to observe all of the relevant stimuli" (Dube et al., 1999; p.13).

Further support for the attention deficit theory was provided by Anderson, Colombo, and Shaddy (2006). These authors used eye tracking apparatus to examine

visual scanning and pupillary responses to face and non-face stimuli in 9 children with ASC, 6 mental age matched children, and 9 chronological age matched children.

Results showed that the participants with ASC had a significant decrease in visual scanning to landscapes. The ASC group also showed pupillary constriction to faces, while both control groups showed pupillary dilation to the same face stimuli.

Studies that don't offer support for the attention deficit theory of over-selectivity include Van der Geest, Kemner, Camfferman, Verbaten and van Engeland (2002) and Kemner and van Engeland (2006). Van der Geest and colleagues (2002) compared the looking behaviour of 16 children with high-functioning ASC and 14 typically developing children. In this study, all the participants sat in a dentist chair with their head held steady using a vacuum cushion. The stimuli depicting a full-coloured, cartoon-like image with neutral objects and a human figure were displayed on a computer screen held one metre in front of the participants' faces. An eye tracking device was used to record fixations and scan-paths. Results showed that all of the children looked longer and more often at the human figures than to the neutral objects such as a car. Furthermore, the children with ASC spent the same amount of time inspecting the pictures, had the same total number of fixations, and had a similar average and total scan-path length as the control group.

Kemner and van Engeland (2006) examined perceptual processing, the activation of modality-specific brain areas after stimulus presentation, in their review. More specifically, the authors looked at eye gaze and event related brain potentials (ERPs) to study perceptual and attentional processing in individuals with ASC. ERPs provide information about the timing and localization of these processes. Results showed that

eye movement research and “ERP studies of the ability to focus attention on a specific channel of information have failed to find consistent evidence of abnormal attentional processing in subjects” with ASC (Kemner, & van Engeland, 2006; p.51).

**5.6.2 Correlation between Visual Attention and Eye Movement.** Is there a correlation between visual attention and eye movement? This issue has been systematically investigated in the cognitive psychology literature since the late seventies (e.g., Klein, 1980; Remington, 1980; Schneider & Deubel, 1995). When an object suddenly appears in the visual field, the line of sight makes an orienting shift toward its location, termed a saccade (Goffart, 2008). It has been noted by some researchers (e.g., Kemner & van-Engeland, 2006; Reed, 2007) that analysis of saccadic eye movements is only imperfectly correlated with attention. However, there are a number of studies offering evidence for the correlation. Hoffman and Subramaniam (1995) examined the role of visual attention in saccadic eye movement and concluded that “attention and saccades are not independent” (p.787). Findlay and Walker (1999) also concluded from their study that there is a “tight relationship between attentional orienting and saccade programming” (p.95).

Humans explore the visual environment with fixations that last about a quarter of a second. These fixations are interspersed with rapid changes of eye position lasting about 50 milliseconds. Rayner and Pollatsek (1989) noted that these patterns of fixations and saccades are not random but appear to be guided. Various suggestions are made in the literature about what things guide these patterns, such as the goals and interests of the observer (Yarbus, 1967), the word length of text (Rayner, 1975), and the expectations and knowledge of the perceiver (Just & Carpenter, 1987).

Hoffman and Subramaniam (1995) suggest that the spatial attention system is a “mechanism that can operate within a fixation to selectively process information from different locations” (p.787) and choose the destination of each subsequent saccade. This can occur because shifts of attention can happen much quicker than saccades (changes in eye position), allowing time for it to choose the location for the next fixation (Hoffman, 1975). Spatial attending allows for faster and more accurate processing of available information (e.g., form and luminance) in an area surrounding that location (Bashinski & Bacharach, 1980; Downing, 1988).

Hoffman and Scubramaniam (1995) examined whether making a saccade to a location is preceded by a shift of attention to that location. Seven typically developing undergraduate students participated in this study. They placed their heads in a chinrest and viewed a slideshow on a computer screen. Eye movements were analysed using a camera-based eye tracking system. Results confirmed that attention and saccades do not reflect independent processes. Results showed that visual attention precedes saccadic eye movements and that by making a saccade to a location, the ability to detect information in that location is improved.

Hoffman and Scubramaniam (1995) also aimed to establish optimal conditions for allowing the participants to separate attentional allocation from saccadic eye movements. Results supported the findings of Shepherd, Findlay and Hockey (1986) that individuals first attend to a location before they move their eyes to it. Participants had difficulty attending to one location whilst moving their eyes to another location, even when they were instructed by the experimenters to do so. “The link between attention and saccades is obligatory” (Hoffman & Subramaniam, 1995; p.793)

**5.6.3 Observing versus Attending.** Dinsmoor (1985) completed a review on the role of observing and attention in the establishment of stimulus control. The strength of stimulus control depends on how much contact is made by the individual to the stimuli. The type of contact is two-fold. Firstly, the impingement of the stimulus energy on the receptor cells of the sensory apparatus which requires behaviour called observing (e.g., looking at and focusing on the stimuli). Secondly, analogous processes called attending occur in the neural tissue. Although attentional processes are not as readily accessible to observation and can only be assessed indirectly, Dinsmoor (1985) suggested that observing and attending obey similar principles.

Dinsmoor (1985) noted that the more accurate the observing and the greater the proportion of time that the individual engages in a stimulus, the greater the degree of stimulus control. However, Dinsmoor (1985) also posited that purely peripheral adjustments cannot account for all the data, and that the process of attention needs to be considered. In fact, he concludes: “The issue is necessarily somewhat speculative, but I suspect that in general the two processes go hand in hand: If the subject observes a stimulus for the sort of reason we customarily set up in the animal laboratory, I assume that it also attends to that stimulus” (p.371).

Dinsmoor (1985) suggested the observing response, originally developed by Wyckoff (1969), as a promising candidate to account for the focusing of the effects of discrimination training on the appropriate stimuli. Dube and colleagues (2010) examined this issue further. When presented with visual stimuli, effective observing behaviour includes head movements and eye orientation that cause light reflected by the stimulus to fall on the retina (Dube et al., 2010). There are two possibilities about the

role of observing in stimulus over-selectivity. Firstly, if the individual has observed all of the relevant stimuli, then the deficiency is related to attention. However if the individual did not observe all of the relevant stimuli, then this inadequate contact with the stimuli could account for stimulus over-selectivity. Before any analysis of attention could occur, the inadequate observing behaviour would have to be corrected.

Dube and colleagues (2010) employed 4 typically developing adults and 10 individuals with an ID in their study that used head-mounted eye tracking apparatus. The task was a two-sample DMTS procedure with black abstract forms displayed on a white background. Analyses of eye movements showed that stimulus over-selectivity was accompanied by a failure to observe all of the relevant stimuli and a tendency to observe the stimuli for shorter durations than participants who did not demonstrate stimulus over-selectivity. Dube and colleagues concluded: “As the duration of observing behaviour increases (as measured by eye orientation toward stimuli) the probability of attending behaviour increases (as measured by stimulus control by those stimuli)” (p.311). It was noted that there are other factors involved in attention, as all of the participants made errors on a few trials in which the observing duration was within the upper half of the distribution for trials with correct responses.

The interventions used to increase observing behaviour in five participants with intermediate accuracy baseline scores were differential reinforcement, extra-stimulus prompt and within-stimulus prompts (Dube et al., 2010). Additional combinations of these contingencies were utilised if the observing frequency, observing duration or accuracy did not increase in any participant. The prompting contingencies immediately eliminated observing failures and produced observing durations that exceeded those of

participants with high accuracy scores at baseline. In four of the five participants, these prompting procedures also improved the accuracy scores substantially above baseline levels and to levels indicating reliable stimulus control. Therefore, the changes made to their observing behaviour, also led to more effective attending. Dube and colleagues (2010) concluded their paper by stating that “interventions that control observing behaviour seem necessary but may not always be sufficient for the remediation of restricted stimulus control in ID populations” (p.312).

**5.6.4 Event related potential (ERP).** As previously mentioned, Kemner and van Engeland (2006) examined ERPs to study perceptual and attentional processing in individuals with ASC. Reed, Savile and Truzoli (2012) recently extended this research to monitor brain wave activity during an over-selectivity task in typically developing adults, as there have been few, if any, studies of the neurological correlates of over-selectivity. The attention-based account of over-selectivity would predict that the under-selected stimulus, having received less attention during the training phase, would be treated as less probable during the testing phase and would therefore elicit a P300a wave. This prediction is based on the results of oddball tasks (Debener, Makeig, Delorme & Engel, 2005; Katayama & Polich, 1996) which have been used with individuals with ASC (Sokhadze et al., 2009). The findings revealed that, in fact, there was a greater wave for the over-selected stimulus relative to the under-selected stimuli, a result that could not be entirely accommodated by the attention deficit theory of over-selectivity.

## **5.7 Comparator Theory**

The final theory, reviewed by Reed (2007, 2010), ascribes stimulus over-selectivity to a performance deficit, rather than an encoding problem, which is attributable to an oversensitive comparator mechanism. Reed (2007) suggested that there is no impairment in learning and that the problem actually occurs post-learning, at the retrieval level of the information processing system, when selecting stimuli to control subsequent behaviour.

**5.7.1 Hippocampus as a Comparator.** The idea of a comparator system as essential for adaptive functioning has been hypothesised on numerous occasions, especially in the context of clinical or neurophysiological research (Reed, 2007), where it is said to be located in the hippocampal formation (Gray, 1995). Vinogradova (2001) noted that the hippocampus acts as a comparator and determines if information should be stored or ignored when attempting discrimination problems. More specifically, upon presentation of novel stimuli, CA3 cells in the hippocampus become active and cause arousal and an orienting response. Support for this supposition can be seen in studies where lesions to this brain region produce a lack of orienting (Honey, Watt & Good, 1998). Gray and McNaughton (2000) accepted Vinogradova's postulation in their psychologically defined comparator system.

Bachevalier (1994) created a model of ASC in rhesus monkeys by removing their entire medial temporal lobe, including the amygdala, entorhinal and perirhinal cortex, parahippocampal gyrus and the hippocampus. The deficits found were the type observed in individuals with ASC. Relative to typically developing controls, no differences in hippocampal size have been recorded (Reed, 2007). However, Raymond,

Bauman, and Kemper (1996) found that CA4 neurons were smaller and dendritic branching of CA1 and CA4 cells were less developed, in individuals with ASC.

From this research, Reed (2007) suggests that it appears that comparator system deficits would result in reduced orienting responses in individuals with ASC. However, this is not always the case. There are studies that show individuals with ASC with an enhanced ability to learn about stimuli (O’Riordan, Plaisted, Driver, & Baron-Cohen, 2001), and increased orienting responses (Kemner & van Engeland, 2006) and individuals who can display hypersensitivity to some stimuli. Reed (2007) therefore hypothesises that the comparator is not damaged but rather it is oversensitive when comparing the differences in the importance of the stimuli that have been learned already.

**5.7.2 Comparator System and Behaviour.** Reed (2007) suggested that the comparator system may determine the extent to which behaviour is controlled by stimuli previously learned. This comparator mechanism can react to novel stimuli by orientating and learning, but it can also compare the strengths of learned stimuli to decide which one will control future behaviour. Miller and Schachtman (1985) suggested that the strength of a response to a stimulus is reliant on a number of variables including its novelty, the salience of the stimulus, and the strength of learning about the stimulus. However, it also depends upon the comparison of the strength of learning about that particular stimulus with the strengths of all other stimuli that have been previously paired with that target stimulus in the presence of its associated consequence.

Therefore, the comparator mechanism works at the retrieval level of the information processing system by making comparisons between the possible strengths

of available cues to predict the appropriate outcome (Reed, 2007). Cues with relatively weaker strengths are inhibited, whilst cues with the greatest predictive values for outcomes are chosen or selected to control behaviour. In our environment, there are a huge number of stimuli that can potentially form the basis upon which we act, and this comparator system simply chooses which stimuli are the most important.

Reed (2007) postulated that there may be a comparator problem in individuals with ASC, whereby their comparator mechanism is oversensitive. Thus, when presented with an array of stimuli to discriminate, slight differences between the available stimuli are noted by the oversensitive comparator system in individuals with ASC and only a subset of those stimuli come to control behaviour. In individuals with a typically functioning comparator mechanism, the slight differences would not provoke inhibition or selection, and instead each stimulus controls behaviour equally.

**5.7.3 Predictions of the Comparator System.** Reed (2007), states that three predictions can be made based upon the oversensitive comparator mechanism. Firstly, when presented with stimuli with a differing salience, individuals with ASC will be more likely to over-select than those without ASC. Although this prediction is not unique to the comparator hypothesis, it is necessary to aid validation of the theory. Over-selective responding within auditory, visual and tactile modalities has been described in the literature (Reynolds et al. 1974; Koegel & Wilhelm, 1973; Ploog & Kim, 2007). Reed (2007) suggests that this fact makes it likely that differences in salience within modality may play a part in accounting for stimulus over-selectivity, whereby the slight differences trigger selective performance in individuals with ASC but not in individuals with typically functional comparator mechanisms.

Leader, Loughnane, McMoreland and Reed (2009) examined the influence of stimulus salience on levels of over-selectivity in individuals with ASC. In the first experiment, two groups of 16 children participated, one group with ASC and one typically developing mental age matched group. Participants were presented with two complex cues containing two colours of equal or unequal salience. Following training and test sessions, the results showed that the participants with ASC demonstrated a higher degree of over-selectivity, which increased in the unequal stimulus salience condition. The difference in salience was not enough to trigger over-selectivity in the mental age matched control group.

In the second experiment an older sample of 15 individuals with ASC and 15 mental age matched controls were employed to investigate the generality of the effect. Similar results were found where the control group displayed little over-selectivity but the participants in the experimental group displayed over-selectivity in both the equal and unequal salience conditions. The amount of stimulus over-selectivity was, once again, greater in the unequal salience condition. The findings from Leader et al. (2009) are consistent with the first prediction of the comparator theory of over-selectivity, that when presented with stimuli with a differing salience or stimuli of different strengths, individuals with ASC will be more likely to over-select than those without ASC.

The second prediction made by the comparator hypothesis is that greater stimulus over-selectivity is observed when learning is weak, rather than strong (Reed, 2007). Two studies from the animal literature offer support for this prediction. Both Mackintosh (1976) and Stout, Arcediano, Escobar, and Miller (2003) showed that levels of over-selectivity was greater after fewer trials of learning, where learning was

expected to be weaker. Reed (2007) noted, however, that examining these studies as evidence for this prediction makes the assumption that fewer trials equates to less learning.

Reed (2007) describes a study he conducted with Matteo Cella to offer direct evidence that this second prediction is true, that greater over-selectivity accompanies weaker learning. Participants included 20 undergraduate students who were each shown a series of 32 slides. These slides each contained four symptoms, out of a total of the eight symptoms. Each symptom slide was then followed by a slide with the name of one of two diseases that the symptoms could predict. After viewing four slides, all participants were instructed to rate the probability of each disease in the presence of each individual symptom. In order to induce an over-selectivity effect, the researchers made sure one disease was always predicted by the same two symptoms.

The researchers collected data on the strength of the combined prediction that the disease would occur in the presence of the two symptoms. Results showed that over-selective responding was at its highest over the first three trials when learning was at its weakest. Over successive trials, the strength of judgement about the predictive value of the symptoms increased. Also, the difference between the individual strengths of the symptoms in predicting the disease declined over time. Reed (2007) summarised that when overall learning was weak, there was greater over-selectivity, that is, only one of the two symptoms controlled the diagnosis of the disease. Whereas as learning grew stronger both of the symptoms controlled prediction of the diagnosis.

The comparator model of over-selectivity hypothesises that all multi-element cues present during training are attended to, processed, stored and learned. However, it

is only a subset of these stimuli that come to control behaviour. The third prediction is unique to the comparator hypothesis and states that post-learning manipulations of the over-selected cue should enhance the performance of the under-selected cue (Reed, 2007). It is the investigation of this prediction which is the focus of the current thesis.

**5.7.4 Emergence Effect.** This section clearly differentiates between a comparator and more traditional views of stimulus over-selectivity. Reed (2007) suggests that all stimuli presented during training are attended to, processed, stored, and learned about, but that only a subset of these stimuli control behaviour. When a stimulus is presented on its own, it may exert strong control over behaviour. However, overshadowing (Trabasso & Bower, 1968; Diez-Chanizo, Sterio & Mackintosh, 1985) may occur when control of one stimulus is reduced or eliminated by the presence of a second stimulus. Gibson and Reed (2005) suggested that the concept of “overshadowing” from the animal literature can be used as a model for some aspects of over-selectivity.

**5.7.4.1 Emergence Effects in Animals.** Wilkie and Masson (1976) aimed to examine the attention levels in twelve pigeons. In Phase 1, the pigeons were reinforced with grain on a variable interval schedule for pecking when they responded to a compound stimulus comprising of a key with both colour and shape elements (e.g., white triangle on a red background; S+). Pecking in response to the blank key (S-) or when, for example, the key had a white circle on a green background (S-) was not reinforced. During Phase 2, no grain was available as a positive reinforcer. The stimulus elements were presented in isolation (i.e., red, green, circle, and triangle) and the number of key pecks in response to each component was recorded.

Phase 3 was identical to Phase 1 except that (i) only the two shapes appeared alternately on the key, (ii) key pecks in response to both the circle and the triangle were reinforced with grain on a variable interval schedule of 60 seconds, and (iii) the sessions were shorter. Results from Phase 2 (non-reinforcement test) showed that all of the pigeons pecked nearly exclusively to the colour element (red or green) that was previously reinforced. Relatively few pecks were made in the presence of the shape element (circle or triangle). The colour element was subsequently extinguished, which resulted in a rapid increase in the pecking in the presence of the previously learned but under-selected shape element.

Kaufman and Bolles (1981) replicated these results with 36 rats that were tested in a conditioned fear paradigm to test if fear of noise emerged after the extinction of fear of light. There was less fear of noise if it had been presented in conjunction with the light when paired with an electric shock than if the noise alone had been paired with a shock. However, after the fear conditioned to light was extinguished, a high level of fear of noise emerged. This finding suggests that although the rats had learned about the noise during the training phase, it not gained stimulus control on the rats' behaviour. Kaufman and Bolles (1981) concluded that overshadowing occurred in this study due to the noise not being associated with the electric shock and because the noise–shock association failed to be expressed in their behaviour.

Matzel, Schachtman, and Miller (1985) conducted experiments in which conditioned lick suppression by water-deprived rats was used to assess levels of stimulus over-selectivity. It was found that the rats over-selected a tone (over a light) when the light-tone compound stimulus was paired with a shock to their foot. In one

group of rats, the over-selected stimulus (i.e., tone-shock association) was extinguished. Subsequently, this group demonstrated significantly higher levels of suppression to the light relative to the control group of rats where the tone had not been extinguished. Matzel and colleagues' (1985) results suggest that over-selective responding "does not represent an acquisition failure, but rather the failure of an acquired association to be manifest in behavior" (Matzel et al., 1985; p.398).

**5.7.4.2 Emergence Effects in Individuals with ASC.** Reed et al. (2009)

conducted two experiments which examined extinction as a potential remediation strategy for stimulus over-selectivity in both high and low functioning participants with ASC. The aims of Experiment 1 were to assess levels of over-selectivity using a simple discrimination task and to demonstrate the utility of extinction as a remediating intervention for individuals with ASC. The 14 participants were aged 7-15 years (mean IQ= 87) and were divided into experimental and control groups. There were four phases in Experiment 1: training phase, test phase, extinction phase and re-test phase.

During the training phase, participants were presented with two white cards simultaneously. Each card contained two black stimulus elements AB or CD. Participants were reinforced for pointing at, for example, the complex stimulus AB over the complex stimulus CD. If the participant pointed to the correct card they received positive feedback from the experimenter who said "yes". During the training phase, the reinforced compound 'AB' was always paired with the non-reinforced compound 'CD'. Participants reached criterion in the training phase once they chose the reinforced compound 10 times consecutively.

During the test phase participants were presented with two cards simultaneously, each one comprising of just one element from the compound stimulus. The pictures were paired so that the participants had a choice of a previously reinforced stimulus (e.g., A or B) and a previously non-reinforced stimulus (e.g., C or D). Participants were presented with five unsequenced trials for each combination of previously positively reinforced and non-reinforced components of the compound stimuli giving a total of 20 trials.

In the extinction phase, the over-selected stimulus was determined (i.e., A or B) for the participants in the experimental group and was paired with one of four novel stimuli. Participants in the experimental group were then positively reinforced for choosing the novel stimulus, and not the previously over-selected stimulus. Criterion was reached when the participants chose the novel stimulus ten times consecutively. The over-selected element was not determined for the control group. Instead, during this phase, the control group participants were presented with pairs of the novel stimuli and given feedback of “yes” or “no”, with none of the original compound elements extinguished. Finally, in the fourth phase of Experiment 1, the same procedure was used as the first testing phase, with no feedback provided to the participant.

Results from Experiment 1 revealed that both the experimental and control groups showed a significant degree of over-selectivity. Following the extinction phase for the experimental group, the behavioural control exerted by the over-selected element was reduced and the control exerted by the under-selected element emerged. These results were not seen in the control group showing that “the removal of control by the

more salient cue can facilitate an initially less powerful stimulus element to control behaviour” (Reed et al., 2009; p.293).

In Experiment 2, 9 participants (aged 9-13) with high functioning ASC and 9 participants (aged 7-17) with low functioning ASC completed the same procedure as in Experiment 1. Results showed that both groups demonstrated a significant degree of over-selectivity, irrespective of their IQ. For both groups, there was a reduction in the control exerted by the previously over-selected stimulus. However, the emergence of behavioural control of the previously under-selected stimulus was only seen in the high functioning group. Reed and colleagues (2009) suggested that this limitation to the generality of their findings had face validity. Initial learning is less likely to occur in individuals with severe impairment. Therefore, although the extinction procedure could still be effective in reducing the control of the over-selected stimulus, the lack of initial learning of the under-selected cue may lead to no emergence effect.

Leader et al. (2009) examined the influence of stimulus salience on levels of over-selectivity in participants with ASC and typically developing mental age matched controls. Participants were presented with two cards, each displaying two colours of equal or unequal salience. The training and testing procedure was the same as that used by Reed and colleagues (2009). The results showed that relative to the control participants, the individuals with ASC demonstrated greater over-selectivity, which increased when the stimuli differed in salience. The colour stimulus that was over-selected was then extinguished. Results confirmed the findings of Reed and colleagues (2009) and showed that the control exerted by the previously over-selected colour was reduced and that the previously under-selected colour emerged to control behaviour.

**5.7.4.3 Emergence Effects in Typically Developing Individuals.** Broomfield, McHugh and Reed (2008) conducted two experiments to investigate the emergence of under-selected stimuli to control behaviour after extinction in an automated MTS paradigm. Experiment 1 employed 21 typically developing students aged 18-32 years. Following training and testing sessions, the over-selected stimulus was determined (i.e., A, B, or C) and was extinguished by reinforcing a mouse click in response to a novel stimulus and not reinforcing any response to the previously over-selected stimulus. As a result of the extinction procedure, the previously under-selected stimuli re-emerged to control behaviour. These findings suggest that under-selected cues are learned about during training but the test scores reflect “a performance deficit, rather an initial failure to learn, or attend” (Broomfield et al., 2008; p.508).

An interesting finding from the Broomfield et al. (2008) study was that the over-selected stimuli were not put on extinction in the control condition and still the previously under-selected stimuli were chosen more and the previously over-selected stimuli were chosen less in the retest phase. The authors investigated these results in a MTS computer task with 14 participants in the control and experimental conditions. Over-selective responding was assessed during the initial training and test phases and then the over-selected stimuli were extinguished in the experimental group. Once again, in the experimental group the previously over-selected stimulus was chosen significantly less often after being extinguished and the behavioural control of the previously under-selected stimulus re-emerged. In the control group, although there were mean changes in the same direction as the experimental group they were not statistically significant, reliable and did not have a strong effect (Broomfield et al., 2008).

Reynolds et al. (2012) investigated the effects of extinction in sixteen typically developing adults with a concurrent distractor task. The procedure used was identical to that of Reed et al. (2009) with four experimental phases. Results showed that in the experimental group (where an extinction phase or revaluation training was conducted) the previously most selected stimulus was chosen less often and the previously under-selected stimulus was chosen more often in the re-test phase. Neither of these two effects was seen in the control group (participants who did not receive revaluation training). Therefore extinction allowed emergence of control of the previously under-selected stimulus, despite the fact that it was not directly conditioned. This finding further supports the comparator theory of stimulus over-selectivity that attributes this problem to a retrieval or performance deficit as opposed to an attention-deficit (Reed, 2007).

Employing verbal punishers is another post-learning intervention that has been shown to reduce the strength of the previously over-selected cue and increase the control that the previously under-selected cue exerted on behaviour. McHugh and Reed (2007) conducted two experiments with typically developing individuals aged 18-22 years, 47-55 years, and 70-80 years. In Experiment 2, the authors identified the over-selected elements from Experiment 1 for 24 of the participants. These over-selected elements were then vocally punished by the experimenters who said “no” upon selection of this element, when it was presented with one of four novel elements. The participants were then re-tested to reassess levels of stimulus over-selectivity.

Results from Experiment 2 revealed that the verbal punisher was successful in enhancing the stimulus control by the previously under-selected elements in just the two

younger age groups. This effect was not seen in the 70-80 year old group. McHugh and Reed (2007) suggested that the results from the two younger age categories may provide support for the comparator theory of stimulus over-selectivity (Reed, 2007) but that further research needed to be conducted.

Broomfield, McHugh and Reed (2010) conducted a study with 107 typically developing university students. The procedure employed was similar to that of McHugh and Reed (2007). During the treatment phase, participants were positively reinforced (experimenter said “yes”) when they chose the novel stimuli, and were positively punished (experimenter said “no”) when they chose the previously over-selected stimulus. Results showed that the punishment procedure was successful so that post-intervention the previously over-selected stimulus displayed less control over behaviour than it had previously. Also, the level of behavioural control exerted by the previously under-selected stimulus had increased from the pre-intervention phase.

## **6.0 Remediation of Stimulus Over-selectivity**

The detrimental consequences of demonstrating over-selective responding were documented in Section 2.4. As a result of these pervasive deficits, it is necessary that successful remediation strategies are well-researched and developed. Ross (1976) highlighted the importance of finding an effective remediation procedure for stimulus over-selectivity: "If one could discover techniques to teach these children the skill of attending to all relevant aspects of a stimulus, in a learning situation, one would contribute significantly to their education" (p.54). In this section, a range of procedures including prompt fading, multiple-cue training, pre-training and over-training,

differential observing responses, schedules of reinforcement, mindfulness and punishment are discussed, despite not being tested in the current thesis, due to their prominence in the literature and the evidence they offer to support various theories of over-selectivity. The current thesis does however offer a thorough experimental analysis of extinction as a remediation procedure in both individuals with ASC and typically developing children and adults.

### ***6.1 Prompt fading***

“An important implication of stimulus over-selectivity is its effect when simultaneous cues are presented in an operant paradigm to shift stimulus control, as in prompting procedures” (Schreibman, 1975, p.92). Once correct behaviour has been emitted, the prompt is removed gradually across learning trials until the prompt is no longer needed and the behaviour is independent. Therefore, the control is transferred from the prompt to the Sd.

Lovaas and colleagues (1979) highlighted how our everyday environment frequently presents difficult discriminations such as the letters *b* and *d* and the difference between a smile and a frown. Schreibman (1975) aimed to teach six children with ASC how to discriminate between such similar form stimuli using two different prompting procedures to teach visual (line drawing) and auditory (word) discriminations. In the discrete-trial discrimination learning procedure, the extra-stimulus prompts included pointing for the visual task and a buzzer for the auditory task. The within-stimulus prompts consisted of an exaggeration of the relevant component of the S+ for both tasks.

Results demonstrated that the children always failed to learn when the extra-stimulus prompt was used but usually did learn with the within-stimulus prompt. This showed that within-stimulus prompting combined with a progressive fading procedure could be a useful teaching tool for children with ASC, but that there was a limit to the transfer of stimulus control from the prompt to the training task if extra-stimulus prompting was used. Koegel and Rincover (1976) and Rincover (1978) found similar results. Lovaas and colleagues (1979) highlighted that prompt-fading procedures did not focus on remediating stimulus over-selectivity per se. Instead they “allow the child to remain over-selective, yet learn” (Lovaas et al., 1979; p. 1245).

## ***6.2 Multiple-Cue Training***

Koegel and Schreibman (1977) tested the feasibility of teaching four children with ASC a conditional discrimination requiring response to multiple cues. The participants were required to press a bar to separate auditory (white noise) and visual (red light) cues. Participants were then exposed to the component cues and a complex cue but were only reinforced for responding to the complex cue. The results showed that although the children with ASC appeared to have more difficulty learning and didn't learn in the same way as the typically developing control group (Lovaas et al., 1979), they did learn to respond exclusively to the compound stimulus. Koegel and Schreibman (1977) argued that it may be possible to teach children with ASC a "learning set" so that they are more likely to respond to new discriminations in the future on the basis of multiple cues.

### ***6.3 Pre-training and Over-training***

Meisel (1982) tested the use of pre-training with labels to remediate stimulus over-selectivity in adolescents with severe and profound intellectual disabilities. Pictures containing two components were used as the S+ and S-. The participants were exposed to a pre-training condition followed by three training conditions. They were then tested for stimulus over-selectivity following each of the training conditions. The first condition involved pre-training on both of the relevant cues within the discrimination. In the second condition the individuals were trained on only one of the relevant cues, and the third control condition involved cues that the children could not recognise. Meisel (1982) concluded that labelling had little effect on over-selectivity for children with severe and profound ID. It was found that over-selectivity scores were actually lowest in the untrained condition.

Sutherland and Holgate (1966) demonstrated in their research on infrahuman animals that rats learn more about redundant cues during the process of overtraining, and also that levels of stimulus over-selectivity are reduced. With regards the human literature, Trabasso and Bower (1968) concluded that typically, overtraining is not successful in increased responding to redundant cues. Schreibman, Koegel and Craig (1977) found that simple overtraining (by exposing the children to the stimuli) did not help their participants with ASC to respond to more cues. However, they did find that after prolonged testing with non-reinforced test trials interspersed with reinforced training trials, over-selective responding was eliminated in 13 of the 16 participants. Schover and Newsom (1976) aimed to train their participants (13 participants with ASC, 13 typically developing participants) to broaden their responding to include multiple

cues. They found that the participants “increased their breadth of learning after 50 trials of overtraining” (p. 289).

#### ***6.4 Differential Observing Responses***

In a MTS task, the sample and comparison stimuli are all displayed until the student matches the sample to one of the comparison stimuli and is then reinforced if they matched correctly. In a delayed MTS (DMTS) task the sample is shown, then removed, before the student must match the sample to the appropriate comparison stimuli. Using Differential Observing Responses (DOR) requires the participant to provide a different response for each sample stimulus (Dube & McIlvane, 1999; Cohen, Brady, & Lowry, 1981). “DOR procedures control observing behavior and verify discrimination of critical stimuli or stimulus features” (Walpole, Roscoe, & Dube, 2007; p. 707). There are two types of DOR: vocal and non-vocal.

Previous research has shown that MTS accuracy improved when naming the sample stimulus aloud was required as a DOR (Geren, Stromer, & Mackay, 1997; Gutowski, Geren, Stromer, & Mackay, 1995). Constantine and Sidman (1975) examined the benefits of naming in young men with developmental disabilities. In DMTS tasks, the participants matched pictures to dictation but did not match identical pictures. The accuracy of delayed identity matching then increased when the participants were told to name each sample picture aloud. Without the instructions, accuracy returned to baseline levels. Therefore, the picture naming may have improved delayed picture-picture matching, but participants did not use this method of learning unless they were instructed to by the experimenters.

Broomfield et al. (2008) investigated the effects of a vocal naming DOR procedure to reduce over-selectivity in typically developing university students. In Experiment 1, the aims were to assess the presence of over-selectivity in a DMTS task and to investigate if a DOR procedure could reduce over-selective responses. Results showed that levels of over-selectivity were greater in the 'no naming' group and also in conditions with a time delay. Experiment 2 investigated if the effects of the DOR procedure would last post-intervention in ten students. Results from the DMTS task showed that the introduction of the naming DOR procedure significantly reduced levels of over-selectivity. However the results were consistent with those found by Constantine and Sidman (1975) whereby the effect of the DOR procedure was not maintained after its withdrawal.

Naming may not always be possible as a DOR, for example at times when stimuli are unfamiliar to the student or if the student is not able to produce gestural or spoken names (Dube & McIlvane, 1999). The aim of Experiment 3 in the Broomfield et al. (2008) study was to replicate the results found in Experiments 1 and 2 with an automated MTS task. In this experiment, the DOR procedure involved using a non-vocal pointing observing response using a mouse to click on the stimuli. Results showed the DOR was effective in reducing stimulus over-selectivity but that the effect was not maintained. These results replicated those from Experiments 1 and 2 and show that the type of observing response used does not appear to make a difference to the results (Broomfield et al., 2008).

Dube and McIlvane (1999) examined the use of a non-vocal DOR to reduce stimulus over-selectivity in three teenagers with an ID. The DOR intervention required

participants to match the two-element samples to identical and simultaneously displayed two element comparisons (MTS task) immediately prior to each delayed-matching trial. There were clear and immediate increases on the DMTS scores (and decreased levels of over-selectivity) for two of the participants and modest increases in the third participant after the compound DOR intervention. However, it should be noted that accuracy reverted to baseline intermediate levels when the DOR was no longer required, similar to the results found in Broomfield, McHugh and Reed (2008) and in Constantine and Sidman (1975).

### ***6.5 Schedules of Reinforcement***

Yarczower and Switalski (1969) completed a study using 18 goldfish and found that interspersing reinforcement-stimulus and extinction-stimulus trials resulted in sharper stimulus control and reduced over-selectivity. If non-reinforced trials were not interspersed with reinforced trials, there was no sharpening of stimulus control (i.e., higher levels of over-selectivity). In the human literature, Schriebman, Koegel and Craig (1977) and Koegel, Schriebman, Britten and Laitinen (1979) found that interspersing non-reinforced single stimulus test trials between reinforced compound stimuli reduced levels of over-selectivity.

Reynolds and Reed (2011a) explored the effects of partial reinforcement and CRF in a series of experiments with typically developing adults. Results from Experiment 1 showed that, in contrast to Schriebman et al. (1977) and Koegel et al. (1979), partial reinforcement did not result in a reduction of over-selectivity when compared to CRF. Results from Experiment 2 showed that partial reinforcement had a

tendency to increase over-selectivity when the participants had been exposed to less training. Results from Experiments 3 and 4 revealed that continuing training with the same schedule was more effective as a remediation strategy than changing the schedule from CRF to partial reinforcement or from partial reinforcement to CRF.

### ***6.6 Mindfulness***

McHugh, Simpson and Reed (2010) assigned their 24 elderly typically developing participants (aged 71 to 90 years) to one of two intervention groups. Both interventions involved a ten minute exercise where participants were instructed to focus on the sensations of their breathing (focused attention group) or to let their “mind wander freely without trying to focus on anything in particular” (unfocused attention group; McHugh et al., 2010; p.180). Results showed that participants in the focused attention task group demonstrated lower levels of over-selectivity, when presented with a discrimination- learning paradigm with a concurrent memory load (McHugh et al., 2010; McHugh & Reed, 2007). Research in the area of mindfulness as an effective remediation procedure for over-selectivity, at present, remains limited and further investigation is necessary to examine its long-term benefits.

### ***6.7 Verbal Punisher***

The use of punishers is a post-learning intervention that has been shown to reduce the strength of the previously over-selected cue and increase the control that the previously under-selected cue exerted on behaviour. Both McHugh and Reed (2007) and Broomfield et al. (2010) used mild verbal punishers to obtain these results.

### **6.8 Extinction**

Extinction has been widely explored as a potential remediation strategy for stimulus over-selectivity in the literature with various populations. Extinguishing over-selected stimuli reduced the importance of one stimulus and allowed previously learned but unexpressed associations to emerge and control behaviour in: White and Silver King pigeons (Wilkie & Masson, 1976), rats (Kaufman & Bolles, 1981; Matzel et al., 1985), children with ASC (Reed et al., 2009; Leader et al., 2009) and typically developing adults (Broomfield et al., 2008; Reynolds et al., 2012).

Using all the data from these extinction and punishment studies, Reed (2007), suggested that over-selectivity cannot simply be attributed to an attention deficit, or problems in the acquisition or processing of that cue. Rather than focus on deficits which occur post-attentionally and perhaps, post-executive functioning, Reed (2007) advised researchers to focus on retrieval and comparator processes instead.

### **7.0 Summary**

The above review suggests that there are a number of important theoretical and practical reasons for examining stimulus over-selectivity. There is paucity in the literature of thorough experimental analysis of the many variables that potentially correlate with over-selectivity. Further investigation is also required of the accurateness of the two main theories under review here, namely, the attention deficit theory and the comparator hypothesis.

In particular, it is necessary to establish: firstly, whether the effects of extinction

as a remediation strategy differ for individuals with varying levels of functioning and if IQ and autism severity are effective predictor variables of over-selectivity (Chapter 2); secondly, whether mental age, IQ, attention, flexibility and stereotypy correlate with stimulus over-selectivity in individuals with ASC (Chapter 3); thirdly, whether a concurrent task increases levels of over-selectivity and extinction remediates over-selectivity in typically developing children (Chapter 4); fourthly, whether selective attention, set shifting and chronological age correlate with stimulus over-selectivity in typically developing children (Chapter 4); and finally, whether extinguishing over-selected stimuli results in an emergence effect in typically developing adults and whether chronological age, IQ and cognitive flexibility correlate with over-selectivity in this elderly non-clinical population (Chapter 5).

## Chapter 2:

The Effects of Extinction of Over-selected Stimuli on Under-selected Stimuli in High, Moderate and Low Functioning Children with Autistic Spectrum Conditions

One widespread and well-researched theoretical perspective of stimulus over-selectivity is the attention deficit theory. This theory posits that over-selective responding is caused by an inability to attend to all available cues provided by component elements of a stimulus during initial training. Stimuli that are not attended to cannot be processed or learned about. Therefore only the elements of the stimulus that are attended to, can subsequently control behaviour (e.g., Lovaas et al., 1971; Koegel & Wilhelm, 1973; Dube & McIlvane, 1999; Dube et al., 1999). Research in support of this theory has employed eye-tracking technology and found that over-selectivity is accompanied by a failure to observe all of the relevant stimuli (Dube et al., 1999). However, an imperfect correlation between eye movements and attention has been documented (Shaw, 1978; Remington, 1980). Other inconsistent findings have also been found (van der Geest et al., 2002; Sigman et al., 1986) which contradict this theory.

A recent account of stimulus over-selectivity in the literature is the comparator theory (Reed, 2010). This theory ascribes over-selectivity to a performance deficit, rather than an attentional problem, which is attributable to an over-sensitive comparator mechanism (Miller & Matzel, 1988; Miller & Schachtman, 1985). This comparator mechanism works at the retrieval level of the information processing system by making comparisons between the possible strengths of available cues to predict the appropriate outcome (Reed, 2007).

The comparator theory predicts that when individuals with Autistic Spectrum Conditions (ASC) are presented with multiple pieces of information to discriminate, slight differences between the available stimuli are noted by the over-sensitive comparator system. Thus, only a subset of those stimuli comes to control behaviour (Reed, Broomfield, McHugh, McCausland & Leader, 2009; Leader et al., 2009). In

individuals with a typically functioning and therefore less sensitive comparator mechanism, the slight differences would tend not to provoke inhibition, and instead each stimulus controls subsequent behaviour equally. Unlike the attention deficit theory, the comparator theory suggests that post-learning manipulations of the previously over-selected cue should enable the under-selected cue to emerge to control responding.

Reed et al. (2009) conducted two experiments to examine whether over-selectivity is the product of a post-acquisition performance deficit, rather than an attention problem. In both experiments, children with ASC were presented with a trial-and error discrimination task using two, two-element stimuli and participants over-selected in both studies. After behavioural control by the previously over-selected stimulus was extinguished, the previously under-selected cue emerged to control responding without direct training. This effect was only found in children with higher intellectual functioning, and not with more severely intellectually impaired children.

Reed et al. (2009) concluded from these findings that the children with higher IQ did not respond over-selectively merely because they did not attend to all the stimuli present. Instead the results could be explained in conjunction with the comparator theory. That is, a post-learning manipulation of one stimulus can impact on the behavioural control exerted by the other stimulus in a compound. This suggests that over-selectivity may be the result of a performance deficit, or retrieval failure and not a failure at the time of acquisition.

The individuals with low intellectual functioning did not show the extinction-induced emergence effect found in the individuals with high intellectual functioning. Reed, Savile and Truzoli (2012) suggested that there may in fact be two forms of

stimulus over-selectivity. One form may be due to an attention deficit and the other form may be due to a post-processing disorder. The form the over-selectivity effect takes is dependent upon the severity of the intellectual impairment. Reed et al. (2009) concluded that the participants with low intellectual functioning had deficits in attention as well as deficits in retrieval. These findings may help explain the discrepancies in the literature on attention, in that different samples often display different patterns of attention-switching deficit (Treisman 1969).

Reed et al. (2009) inferred that the procedure used for decreasing control by the previously over-selected stimulus has potential utility for remediating the negative effects of stimulus over-selectivity in individuals with ASC. Extinction is a simple technique for potentially increasing the number of cues that control the behaviour of this clinical population. One of the most prevalent approaches to remediate stimulus over-selectivity in the literature has been the administration of an observing response (e.g., Geren, Stromer, & Mackay, 1997; Gutowski, Geren, Stromer, & Mackay, 1995). However, the results of Broomfield, McHugh and Reed (2008), Dube and McIlvane (1999) and Constantine and Sidman (1975) suggest that the intervention effects are not maintained once the treatment is withdrawn. Therefore, the extinction procedure adopted by Reed et al. (2009) may offer post-intervention benefits to some individuals.

This was the first demonstration of extinction as a potential remedial intervention for individuals with ASC. Therefore, the results found in Reed et al. (2009) warrant further investigation. The current chapter investigated whether over-selective responding is a function of intellectual impairment or autism severity, an area of research not previously explored. Experiment 1A replicated Reed et al.'s (2009) study by analysing the relationship between over-selectivity and intellectual

functioning, as measured by full IQ scores. Experiment 1B extended this research by examining the impact of the severity of the individuals' ASC diagnosis, as measured by Autism Indices, on levels of over-selective responding.

Previous research has revealed inconsistent results during analyses of stimulus over-selectivity in terms of both IQ and severity of ASC diagnosis. Wilhelm and Lovaas (1976) concluded that over-selectivity was not an exclusive feature of ASC but rather of intellectual disability generally. However, similar to the results seen in Frankel, Simmons, Fichter, and Freeman (1984), Reed et al. (2009) found that the participants displayed a significant degree of over-selectivity, irrespective of IQ levels. Although stimulus over-selectivity is a phenomenon common in ASC, it is not restricted to individuals with this diagnosis, as outlined in Chapter 1. Therefore, ASC is not a reliable predictor of stimulus over-selectivity (Ploog, 2010).

The current chapter has three main aims. Reed et al. (2009) identified that different processes may explain over-selective responding in individuals with high and low functioning ASC. The two groups of participants in this study were classified according to their IQ scores from the British Picture Vocabulary Scale. These findings were preliminary and warrant further investigation. The first aim is to replicate and extend the findings of Reed et al. (2009) examining two variables: IQ scores and Autism Indices.

A key prediction of the comparator theory is that post-learning reduction in the importance of one stimulus should allow previously learned but unexpressed associations to emerge and to control behaviour. The second aim of this chapter is to further investigate the utility of the comparator theory as an explanation for stimulus over-selectivity.

Participants in Experiment 1 of the Reed et al. study were all high functioning in terms of intellect and had a mean IQ of 88. The high-functioning group in Experiment 2 had a mean IQ of 77 and the low-functioning group were severely impaired intellectually with a mean IQ of 29. The third aim of Experiment 1A was to extend this study to include a more representative range of IQ scores by including participants with moderate intellectual functioning. This extension enables further examination of the different processes occurring in over-selectivity in individuals with higher and lower intellectual functioning.

## **Experiment 1A**

Experiment 1A aimed to examine each of the three aims in children and adolescents with high, moderate and low intellectual functioning, as measured by full IQ scores.

### **Method**

#### ***Participants***

Twenty-seven children with ASC were recruited from three Applied Behaviour Analysis (ABA) schools for children with autism and complex needs and one mainstream primary school in North County Dublin. All participants had a diagnosis of ASC, which was made by a specialist paediatrician following referral from a general practitioner, both of whom were independent from this study. There were three experimental groups.

In the first group there were 8 boys and 1 girl who had high intellectual functioning (HIF). The participants' chronological age ranged from 6:0 to 11:10

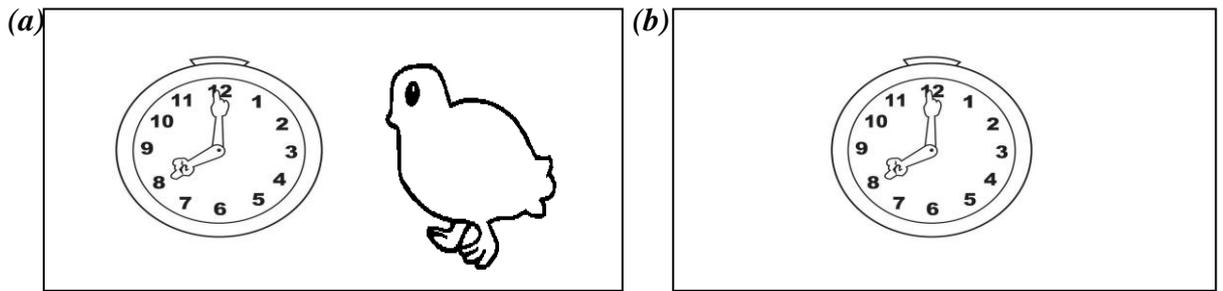
years (mean = 8.6, SD = 2:5). Full IQ scores as measured on the Leiter-R ranged from 63 to 97 (mean= 79.44, SD= 13.77). Participants had an Autism Index as measured by the GARS-2 of 55 to 158 (mean= 93.78, SD = 38.89).

In the second group there were 7 boys and 2 girls who had moderate intellectual functioning (MIF). The participants' chronological age ranged from 5:2 to 13:8 months (mean = 9.9, SD = 2:9). Full IQ scores as measured on the Leiter-R ranged from 44 to 58 (mean= 50.11, SD = 5.06). Participants had an Autism Index as measured by the GARS-2 of 76 to 165 (mean= 118.22, SD = 36.83)

In the third group there were 6 boys and 3 girls who had low intellectual functioning (LIF). The participants' chronological age ranged from 5:3 to 14:11 years (mean = 10:5, SD = 2:8). Full IQ scores as measured on the Leiter-R ranged from 32 to 42 (mean= 36.78, SD = 3.87). Participants had an Autism Index as measured by the GARS-2 of 79 to 164 (mean= 121.56, SD = 34.07).

### ***Apparatus and Materials***

***Stimulus over-selectivity testing materials.*** Levels of over-selectivity were tested using laminated stimulus cards measuring 12cm. by 10 cm. consisting of one black stimulus or two black stimuli on a white background. There were eight different picture stimuli: clock (A), flower (B), chicken (C), hand (D), eye (E), pencil (F), mouse (G) and book (H). These pictures were chosen in order that the participants would be able to acquire the discrimination during the training phase and to also ensure that materials were consistent with Reed et al.'s (2009) study.



**Figure 2.0: Example of Complex Stimulus (a) and Single Element Stimulus (b)**

**Leiter-Revised (Leiter-R, Roid, & Miller, 1997a).** Six subtests from the Visualization and Reasoning Battery in the Leiter-R were used to attain a full non-verbal IQ score (mean=100, SD = 15) for each participant. The subtests included figure ground, design analogies, form completion, sequential order, repeated patterns and paper folding. This instrument has a reliability ranging from 0.91 to 0.93; a test-retest reliability of 0.9 to 0.96 and a 0.86 correlation with the WISC-III full scale IQ measure (Roid & Miller, 1997b).

***Gilliam Autism Rating Scale: Second Edition (GARS-2; Gilliam, 2006).***

The GARS-2 is a norm-referenced instrument that consists of 42 items describing the characteristic behaviours of individuals with ASC. The items are grouped into three subscales: stereotyped behaviours, communication and social interaction. The respondent uses the likert scale to rate the frequency of the subscale items as 0 (never observed), 1 (seldom observed), 2 (sometimes observed), or 3 (frequently observed). The obtained raw scores are then converted into standard scores (mean= 10, SD = 3) which, when totalled, provides an Autism Index (mean = 100, SD = 15) for each participant. An Autism Index of 85 or higher, means that the probability of the individual having ASC is ‘very likely’, a score between 70 and 84 means that it is ‘possible’ that the individual has ASC, and a score of 69 or lower means that it is unlikely that the individual has ASC (Gilliam, 2006).

The internal consistency, measured using Cronbach's coefficient alpha (1951), was 0.94 for the total test. The test-retest reliability ranges from 0.64 to 0.84 and are all beyond the 0.01 level of significance. The GARS-2 was compared to the Autism Behavior Checklist to assess its concurrent validity. The correlation coefficient was statistically significant at 0.64 (Gilliam, 2006).

*Statistical Package for the Social Sciences* (SPSS) was employed to calculate inferential statistics.

### ***Procedure***

The experiment was conducted in a quiet classroom free from distraction in the participant's school. A classroom assistant familiar with the child was also present during testing. The Leiter –R and the GARS-2 were conducted prior to testing.

***Training phase.*** The stimuli were placed on the centre of the desk half-way between the participant and the experimenter. Participants were presented with two white cards simultaneously. Each card contained two black stimulus elements (see Figure 2.0 a). In this phase, the participants were either rewarded for picking the “clock and chicken” over the “hand and book”, *or* for selecting the “hand and book” over the “clock and chicken”. The rewarded stimuli were counterbalanced across participants to avoid the potential confounding variable of some stimuli being intrinsically more salient than others.

The stimuli were presented to the children, with a verbal instruction to pick a card. The experimenter waited for the participant to point to one of the cards. If the participant pointed to the predetermined reinforced compound they received positive feedback from the experimenter who said “yes” enthusiastically with a smile. The

participants received no feedback if they pointed to the other card. The positions of the cards were randomised so that 50% of the time the correct card was presented on the right, and 50% of the time on the left. During the training phase, the reinforced compound 'AB' was always paired with the non-reinforced compound 'CD'. Participants reached criterion in the training phase once they chose the reinforced compound ten times consecutively.

**Test phase.** Participants were presented with two cards simultaneously, each one comprising of just one picture from the compound stimulus. The pictures were paired so that the participants had a choice of a previously reinforced stimulus and a previously non-reinforced stimulus. There were five trials for each combination of previously positively reinforced and non-reinforced components of the compound stimuli (i.e. A v C, A v D, B v C, B v D). Therefore both 'A' and 'B' were presented ten times each, giving a total of 20 trials. No feedback was provided by the experimenter to the student during test trials.

The researcher immediately calculated how many times the two single stimuli from the previously reinforced stimulus were chosen within the ten trials. If 'A' was chosen more times than 'B' for example, 'A' was determined to be the over-selected stimulus and 'B' the under-selected stimulus. If both stimuli (i.e., A and B) were chosen an equal amount of times during the test phase, then 50% of the time the stimulus presented on the right side of the original complex compound was chosen as the over-selected stimulus and 50% of the time the stimulus presented on the left side of the original complex compound was chosen as the over-selected stimulus.

As noted by Reynolds and Reed (2011), this analysis produces a numeric difference between the most and least selected stimuli, and does not show that there

is stimulus over-selectivity per se. However, it does show whether there is a difference in the relative difference between the most-selected and least-selected stimuli in various conditions.

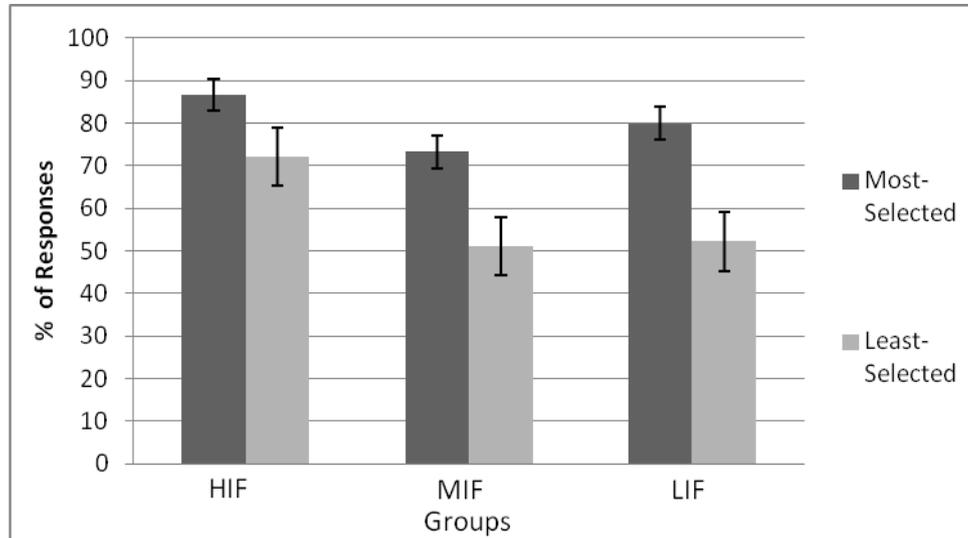
***Extinction phase.*** Once the over-selected stimulus was determined, it was paired with one of four novel stimuli (E, F, G, or H). Participants were positively reinforced (the experimenter says “yes” enthusiastically with a smile) for choosing the novel stimulus. The over-selected stimulus was extinguished by withholding reinforcement when this stimulus was selected. Criterion was reached when the participants chose the novel stimulus ten times consecutively.

***Re-testing phase.*** The same test procedure was used as the first testing phase, with no feedback provided to the student. Once again the researcher immediately calculated how many times the two single stimuli from the original reinforced complex stimulus (i.e., A or B) were chosen within the ten trials.

## **Results and Discussion**

All participants successfully completed the training phase. The HIF group on average took 32.00 (SD = 24.03) trials to reach criterion; the MIF group took 44.78 (SD = 32.00) trials on average; and the LIF group took 55.56 (SD = 35.89) trials on average to choose the Sr+ 10 times consecutively. Although there was a numeric trend where the LIF group needed more training trials than the MIF group and the HIF group needed more training trials than the MIF group, a one-way ANOVA revealed that there was no statistical difference between these scores,  $F(2,24) = 1.299, p = .291$ .

The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 2.1).

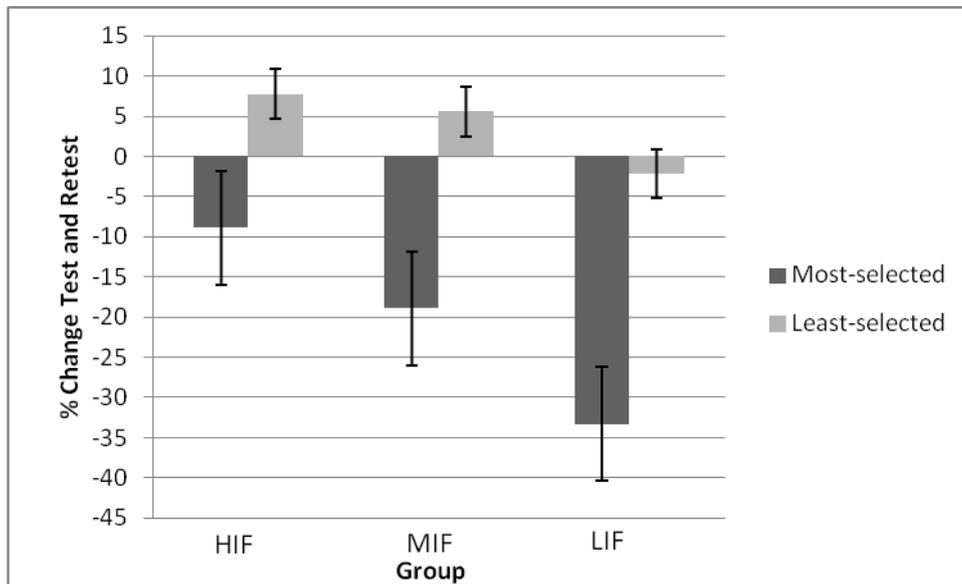


**Figure 2.1: Mean percentage scores for the most and least selected elements for the High Intellectual Functioning (HIF) group, Moderate Intellectual Functioning (MIF) group and Low Intellectual Functioning (LIF) group, categorised by IQ scores, in the test phase. The lines represent error bars with standard error.**

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and group (HIF versus MIF versus LIF) as the between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 24) = 14.15, p = 0.001$ , but neither the main effect of group,  $F(2, 24) = 2.02, p = 0.15$ , nor the interaction of group and stimulus type,  $F < 1$ , were statistically significant. Therefore, the participants showed a significant degree of stimulus over-selectivity, which replicates previous demonstrations of stimulus over-selectivity in individuals with

ASC (Reed et al., 2009; Anderson & Rincover, 1982; Allen & Fuqua, 1985; Koegel & Wilhelm, 1973; and Lovaas & Schreibman, 1971). This result was found irrespective of the participants' level of intellectual functioning.

All participants successfully completed the extinction phase. The mean percentage change from the test to the retest phase was calculated for all three groups by subtracting the test score from the retest score. Inspection of Figure 2.2 shows that in the HIF and MIF groups, the previously over-selected, and now extinguished, stimulus was chosen less in the retest phase than in the test phase, and there was an increase in the control exerted by the previously under-selected stimulus. In contrast, in the LIF group, while there was a reduction in the control exerted by the previously over-selected, and now extinguished, stimulus, there was no corresponding increase in control exerted by the previously under-selected stimulus.



**Figure 2.2: Mean percentage change from the test to the retest phase for the most and least selected stimuli in each group, categorised by IQ scores. The lines represent error bars with standard error.**

A two-factor, mixed-model ANOVA (stimulus type x group) revealed that stimulus type was statistically significant,  $F(1, 24) = 9.652, p = 0.005$ . Neither group

nor the interaction between the factors were statistically significant,  $F_s < 1$ . When tested against zero, the decrease in control exerted by the previously over-selected stimuli was statistically significant across all participants,  $t(26) = 2.89, p = 0.008$ , but the emergence of the previously under-selected stimulus across all participants was not significantly different from zero,  $t(26) = -.66, p = .518$ .

The main novel finding of Experiment 1A was the positive numeric emergence effect of the under-selected stimuli to control responding after extinction of the previously over-selected stimuli in individuals with moderate intellectual functioning, a population previously untested in the literature. This finding adds to the results found in the higher functioning group in the Reed et al. (2009) study and suggests that under-selected stimuli do not fail to control behaviour because they are not learnt about during training. If the attention deficit theory was correct, then there would be no evidence of an emergence effect of behavioural control of the previously under-selected stimulus.

## **Experiment 1B**

Experiment 1B aimed to examine each of the main aims of the current chapter in children and adolescents with ASC who were categorised as high, moderate or low functioning, according to Autism Indices.

### **Method**

#### ***Participants***

The participants included the same twenty-seven children with ASC from Experiment 1A. In the first group there were 7 boys and 1 girl who had high

functioning ASC (HFA). The participants chronological age ranged from 5:2 to 13:8 years (mean = 8.8, SD = 3:0). The Autism Indices as measured by the GARS-2 ranged from 55 to 83 (mean= 69.75, SD = 10.62). The full IQ scores as measured on the Leiter-R ranged from 41 to 97 (mean= 70.25, SD= 22.59).

In the second group there were 6 boys and 3 girls who had moderate functioning ASC (MFA). The participants chronological age ranged from 6:3 to 14:11 years (mean = 10.6, SD = 2:10). The Autism Indices for this MFA group ranged from 85 to 115 (mean= 99.44, SD = 10.16). The full IQ scores ranged from 34 to 92 (mean= 51.67, SD = 17.91).

In the third group there were 8 boys and 2 girls who had low functioning ASC (LFA). The participants chronological age ranged from 5:3 to 11:8 years (mean = 9:4, SD = 2:2). The LFA group had an Autism Index of 145 to 165 (mean= 154.90, SD = 8.71). The full IQ scores ranged from 32 to 68 (mean= 47.60, SD = 13.40).

### ***Apparatus and Materials***

The same apparatus and materials were used as in Experiment 1A.

### ***Procedure***

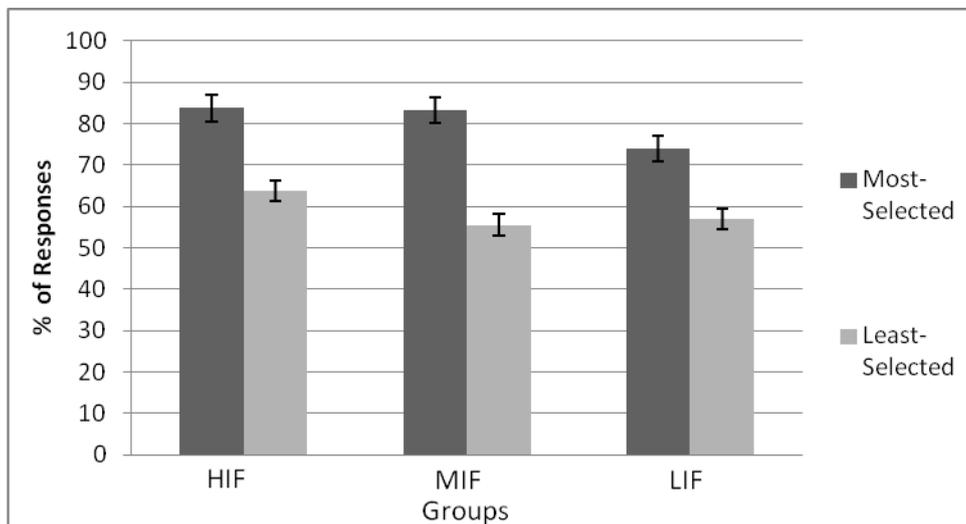
The same procedure was used as in Experiment 1A.

## **Results and Discussion**

All participants successfully completed the training phase. The HFA group on average took 23.63 (SD = 14.53) trials to reach criterion; the MFA group took 41.44 (SD = 40.18) trials; and the LFA group took 62.90 (SD = 21.82) trials to

choose the Sr+ 10 times consecutively. A one-way ANOVA revealed that there was a statistical difference in the number of trials it took for each the three groups to reach criterion in the training phase,  $F(2, 24) = 4.467, p = .022$ . Post hoc comparisons using the Tukey HSD test indicated that the mean score for the LFA group was significantly different from the HFA group. However, the MFA group did not significantly differ from the HFA or LFA groups.

The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 2.3).

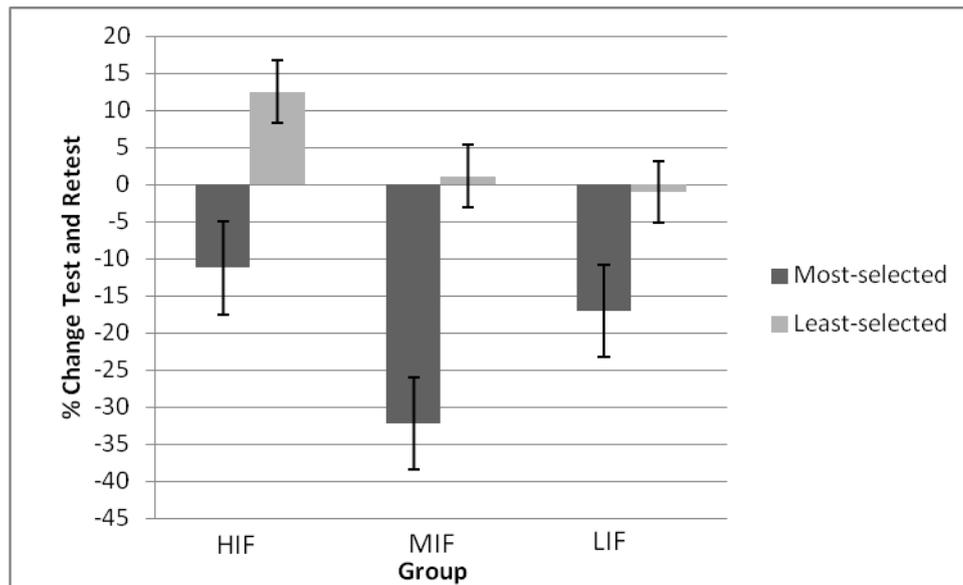


**Figure 2.3: Mean percentage scores for the most and least selected elements for the High Functioning ASC (HFA) group, Moderate Functioning ASC (MFA) group and Low Functioning ASC (LFA) group, categorised by Autism Index, in the test phase. The vertical lines represent error bars with standard error.**

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and group (HFA versus MFA versus LFA) as the between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 24) = 14.02$ ,

$p=0.001$ , but neither the main effect of group, nor the interaction of group and stimulus type, were statistically significant,  $F_s < 1$ . Therefore, the participants showed a significant degree of stimulus over-selectivity, which replicates previous demonstrations of stimulus over-selectivity in individuals with ASC including the findings from Experiment 1A. This result was found irrespective of the participants' level of functioning.

All participants successfully completed the extinction phase. The mean percentage change from the test to the retest phase was calculated for all three groups by subtracting the test score from the retest score. Inspection of Figure 2.4 shows that in the HFA group, the previously over-selected, and now extinguished, stimulus was chosen less in the retest phase than in the test phase, and there was an increase in the control exerted by the previously under-selected stimulus. A large decrease is seen in the results for the previously over-selected stimuli in the MFA group but only a slight emergence effect was evident. In contrast, in the LFA group, while there was a reduction in the control exerted by the previously over-selected, and now extinguished, stimulus, there was no corresponding increase at all in the control exerted by the previously under-selected stimulus.



**Figure 2.4:** Mean percentage change from the test to the retest phase for the most and least selected stimuli in each group, categorised by Autism Index. The vertical lines represent error bars with standard error.

A two-factor, mixed-model ANOVA (stimulus type x group) revealed that stimulus type was statistically significant,  $F(1, 24) = 9.925, p = 0.004$ . Group was not statistically significant,  $F(2, 24) = .76, p = 0.48$  and there was no statistically significant interaction between the factors,  $F(2, 24) = .445, p = 0.65$ . When tested against zero, the decrease in control exerted by the previously over-selected stimuli was statistically significant across all participants,  $t(26) = 2.89, p = 0.008$ , but the emergence of the previously under-selected stimulus across all participants was not significantly different from zero,  $t(26) = -.66, p = 0.518$ .

These data show that extinguishing a previously over-selected stimulus leads, not only to a reduction in the behavioural control exerted by that stimulus, but also to a subsequent emergence of behavioural control by a previously under-selected stimulus. This emergence effect occurred in the absence of direct training for the under-selected stimulus, and supports the findings from Experiment 1A. Evidence

of the emergence effect offers further corroboration for the predictions of the comparator theory of stimulus over-selectivity. However, these results also suggest a limitation to the generality of this finding, in that only a minimal numeric emergence effect was noted in the MFA group and no emergence of behavioural control was noted in the LFA sample. This was despite the extinction effect being as pronounced in the MFA and LFA groups as in the HFA group.

### **General Discussion**

The current experiments revealed a significant degree of stimulus over-selectivity in a population with ASC, using a simple visual discrimination task. This result replicated the findings of Koegel and Wilhem (1973) and Leader, Loughnane, McMoreland and Reed (2009). Specifically, the participants demonstrated over-selective responding irrespective of their level of intellectual functioning, thus supporting the findings of Reed et al. (2009) and Frankel, Simmons, Fichter and Freeman (1984); and irrespective of the severity of their diagnosis of ASC. In Experiments 1A and 1B, IQ and ASC severity were analysed cross-experimentally. In order to ascertain which variable is the stronger indicator of recovery from stimulus over-selectivity, an exploration of the two variables together was necessary.

Analysis of the effects of extinction as a remedial intervention across Experiments 1A and 1B was conducted employing a multi-nominal logistic regression using full IQ scores and Autism Index as the two predictors. The dependent variable was the presence or absence of the emergence effect, that is, whether the previously least-selected stimulus increased its control on the participants' responding post-extinction. A significant result was revealed, chi-

square = 37.393,  $p= 0.069$ . The Likelihood Ratio Test revealed an insignificant odds ratio for IQ at 8.318,  $p= 0.140$  but a statistically significant odds ratio for Autism Index at 13.863,  $p= 0.017$  demonstrating that ASC severity is a stronger predictor of recovery from over-selectivity than intellectual functioning.

This finding indicates that individuals with lower Autism Indices who present with milder deficits in stereotyped behaviours, communication and social interaction are more likely to demonstrate an extinction-induced emergence effect than individuals with higher Autism Indices. In terms of implications for the remediation of stimulus over-selectivity, it may be advisable to base clinical decisions upon ASC severity rather than intellectual functioning, and specifically to reserve extinction for individuals who demonstrate less severe symptoms of ASC.

Recovery from over-selectivity, that is, an emergence of behavioural control by the previously under-selected stimuli contradicts the hypothesis that over-selectivity is simply due to an attentional deficit. If a stimulus is not attended to during initial training, it cannot emerge to control responding post-intervention. Albeit not significant, the present study revealed numeric emergence effects in both the high functioning and moderate functioning groups in both experiments, thus replicating the findings of Reed and colleagues (2009). Due to the restricted number of participants in the current experiment, a significant emergence effect may be found with a larger sample size.

Regarding the theoretical relevance, the emergence effects found corroborate Reed's (2007; 2010) suggestion that stimulus over-selectivity may be the result of a retrieval deficit, rather than an attention deficit. That is, moderate or high functioning individuals with ASC do not just over-select because they are not

initially attending to each of the compound stimuli (Lovaas, Koegal, & Schreibman, 1979).

No extinction-induced recovery effect was observed in the low functioning group in either of the current experiments, replicating the results of the lower functioning group in Reed et al. (2009). Reed et al. (2012) suggested that there may be two forms of over-selectivity: one due to an attention deficit and one a post-processing deficit. In Experiments 1A and 1B, the lower functioning individuals may have displayed an initial pre-conditioning attentional deficit and thus, there was no suppressed learning about the under-selected stimulus to be revealed by extinguishing the over-selected stimulus. Reed et al. (2012) advised that the form that stimulus over-selectivity takes is related to the severity of the intellectual impairment. The results from Experiment 1B extend this hypothesis beyond the criterion of severity of intellectual impairment to also include severity of ASC diagnosis.

Taken together, these results suggest that extinction is an effective and simple technique for increasing the number of cues that control the behaviour of moderate and high functioning individuals with ASC, thus offering support for the comparator theory. In contrast, the emergence effect was not evident in individuals with low intellectual functioning and low functioning ASC. This finding may provide evidence for the attention deficit theory and limits the generality of extinction as a potential clinical remedial intervention for stimulus over-selectivity in an ASC population. These conclusions require replication however as statistically significant results were not found. Further investigation with a larger sample size is vital to confirm the current findings and to generalise the results.

## Chapter 3:

Stimulus Over-selectivity in Children with Autistic Spectrum

Conditions: Correlations with Attention, Flexibility, and

Stereotyped Behaviour

The attention deficit theory is one of the most popular theoretical perspectives of stimulus over-selectivity. This account posits that over-selectivity occurs due to an inability to attend to all available cues provided by component elements of a stimulus during initial training. Stimuli that are not attended to cannot be processed or learned about. Therefore only the elements of the stimulus that are attended to, can subsequently control behaviour (e.g., Lovaas et al., 1971; Koegel & Wilhelm, 1973; Dube & McIlvane, 1999; Dube et al., 1999). This limits the range, breadth, or number of stimuli or stimulus features that can control behaviour.

Past research has frequently used apparatus to measure eye movements as evidence for the attention deficit theory (e.g., Pelphrey, Sasson, Reznick, Paul, Goldman, & Piven, 2002; Dube et al., 2010). Dube, Lombard, Farren, Flusser, Balsamo, and Fowler (1999) used a head-mounted eye tracking device to monitor the observing behaviour of a boy with an intellectual disability. Irregular observing patterns were found as the participant only observed one of the two sample stimuli in one third of the trials. Dube and colleagues concluded that “stimulus over-selectivity may be accompanied by a failure to observe all of the relevant stimuli” (Dube et al., 1999; p. 13).

Further support for the attention deficit theory was provided by Anderson, Colombo, and Shaddy (2006). Eye tracking apparatus examined the visual scanning and pupillary responses to face and non-face stimuli in children with Autistic Spectrum Conditions (ASC), mental age matched children, and chronological age matched children. The findings revealed that the participants with ASC had a significant decrease in visual scanning to landscapes. Also, the control groups showed pupillary dilation to the face stimuli, but the children with ASC showed pupillary constriction to the same faces.

Studies that don't offer support for the attention deficit theory include Van der Geest, Kemner, Camfferman, Verbaten and van Engeland (2002). An eye tracking device was employed to compare the looking behaviour of children with high-functioning ASC and typically developing controls. The results revealed that the experimental group spent the same amount of time inspecting the pictures, had the same total number of fixations, and had a similar average and total scan-path length as the control group.

Furthermore, Kemner and van Engeland (2006) reviewed research that employed eye gaze and event related brain potentials (ERPs) to study perceptual and attentional processing in individuals with ASC. Results showed that eye movement research and ERP studies have failed to find consistent evidence of abnormal attentional processing in individuals with ASC. A further contradiction to the attention deficit theory is the imperfect correlation that has been revealed between eye movements and attention (Wurtz & Mohler, 1976; Shaw, 1978; Remington, 1980).

The first aim of Chapter 3 was to explore the relationship between attention and over-selective responding in children with ASC. A standardised measure of attention was employed due to the inconsistent findings revealed when eye tracking devices were used. Attention is usually described as an assortment of processes and cognitive skills (Sohlberg, Johnson, Paule, Raskin, & Mateer, 2001). Therefore, it is necessary to systematically analyse these attentional processes in relation to stimulus over-selectivity. The three processes investigated in the current chapter were selective attention, sustained attention and attentional switching.

The first attentional variable to be explored was selective attention. This process is defined by Manly, Robertson, Anderson and Nimmo-Smith (1999) as “the

efficiency with which information can be filtered to detect relevant information and reject or inhibit irrelevant or distracting information” (p. 26). Over-selectivity is a phenomenon whereby behaviour becomes controlled by one element or one piece of information available in the environment at the expense of other equally salient available information. Therefore it was postulated that correlations would exist between levels of selective attention and stimulus over-selectivity.

Sustained attention was the second attentional variable to be investigated. Manly and colleagues (1999) defined sustained attention as a “capacity to self-maintain an *actively attentive* stance to a task, goal, or your own behaviour despite there being little inherent stimulation for such continued processing” (p.27). Assessments of stimulus over-selectivity in the research and in the current chapter have required that participants actively stay on task during long discrimination tasks with arbitrary stimuli. It was hypothesised that a correlation would exist between sustained attention and over-selective responding.

The third attentional variable examined in the current chapter was attentional control/ switching. Manly and colleagues (1999) compare this attentional process with executive tests that involve more complex tasks such as tasks that require the co-ordination of different skills, or require the individual to plan to solve them.

Additional to the investigation of attention, Chapter 3 intended to further understand the processes and mechanisms of over-selectivity by examining other potential correlates. Ploog (2010) postulated that over-selective responding may be associated with “erratic, emotional, stereotyped, ritualistic, and inflexible behaviors” (p.1340). The current chapter explored two of these variables, stereotyped and inflexible behaviour, as possible correlating variables of stimulus over-selectivity.

The second aim of the current chapter was to examine the association between inflexible behaviour and over-selective responding. Cognitive flexibility or set shifting is one of several cognitive components that fall within the executive function domain, which enables individuals to disengage from the immediate context in order to guide performance by reference to future goals (Rabbitt, 1997; Roberts, Robbins, & Weiskrantz, 1998; Stuss & Knight, 2002; Pennington & Ozonoff, 1996). Investigations of cognitive flexibility in ASC have typically relied on two measures: the Wisconsin Card Sort Test (WCST; Grant & Berg, 1948) and the Intra/Extra Dimensional Set Shift test (IED; Cambridge Cognition, 2011). The WCST has been criticised for its lack of specificity to flexibility (Hill, 2004), social administration (Ozonoff, 1995), and language demands (Liss et al., 2001). In contrast, the IED test measures cognitive flexibility in a systematic fashion that allows for controlled increases in shifting demands (Yerys, Wallace, Harrison, Celano, Giedd, & Kenworthy, 2009).

Studies to date that have employed the IED with participants with ASC have yielded mixed results. Some investigations report deficits (Ozonoff, South & Miller, 2000; Ozonoff et al., 2004) while others do not (Edgin & Pennington, 2005; Goldberg et al., 2005; Happé, Booth, Charlton & Hughes, 2006; Landa & Goldberg, 2005). Hughes, Russell and Robbins (1994) employed the IED in their study as it can identify the exact source of any set shifting deficit by requiring the participants to complete a hierarchy of increasingly difficult task demands. Their findings demonstrated that in the final two stages of the IED (i.e., the extra-dimensional shift), participants with ASC were unable to identify the relevant response dimension and generalise it to a new set of exemplars when compared to the two control groups.

Corbett, Constantine, Hendren, Rocke and Ozonoff (2009) also employed the IED to examine cognitive flexibility in children with high functioning ASC, children with ADHD and typically developing children. Although the individuals with ASC showed poor performance relative to the typically developing controls in set shifting, there were no significant differences for the IED tasks across the groups. As well as investigating the relationship between over-selectivity and cognitive flexibility, Chapter 3 also explored behavioural flexibility as a potential correlate.

From its earliest description, behavioural inflexibility has been a defining feature of ASC (Kanner, 1943). Individuals with ASC may insist on sameness or show a resistance to change that is often evidenced by their apparent inability to cope with and adapt to minor changes to their environment or daily routine (Lewis & Bodfish, 1998; Prior & MacMillan, 1973). The current chapter aimed to explore the relationship between behavioural inflexibility and stimulus over-selectivity.

The third aim of Chapter 3 was to explore the association between over-selectivity and stereotyped behaviour. One of the diagnostic criteria for ASC is the demonstration of at least one feature from the list of restricted repetitive and stereotyped behaviours (American Psychiatric Association [DSM-IV-TR], 2000). These features include apparent inflexible adherence to routines, stereotyped and repetitive motor mannerisms and persistent preoccupation with parts of objects. The relationship between stereotyped behaviour and set shifting was investigated by Yerys et al. (2009). A positive correlation was revealed between the number of repetitive behaviours and extra dimensional reversal errors in individuals with ASC. Specifically, as levels of stereotyped behaviour increased, so too did the levels of cognitive inflexibility. Although stereotypy has therefore been examined in relation

to executive function, no research has been conducted to analyse the association between stereotypy and over-selectivity.

When an individual responds over-selectively, they only respond to a subset of all the cues available to them. Ploog (2010) offered the example of a child's toy to demonstrate how over-selectivity may correlate with stereotyped behaviour. A child might see a preferred toy only during his break time at school. If the child over-selects and only attends to the toy, without attending to other stimuli that define the context (such as the time he is allowed to play with the toy), the contingencies may appear arbitrary to the child. Sometimes he is encouraged to play with it, and other times he is reprimanded for attempting to do so. Under these circumstances where there is unpredictable access to external reinforcers, internal reinforcers (accessed from stereotyped behaviour such as flapping hands or spinning objects), can be predictably produced by the individual and thus, come to control the individual's behaviour. The current chapter aimed to investigate the correlation between stereotyped behaviour (where internal reinforcers control behaviour) and over-selectivity (where behaviour is controlled by a limited subset of the cues available) in individuals with ASC.

## **Experiment 2**

Experiment 2 aimed to explore the correlation between stimulus over-selectivity and three attentional processes in order to investigate the theoretical foundation of the attention deficit theory. The current experiment also aimed to examine the hypothesised correlation between over-selectivity and cognitive and behavioural inflexibility (Ploog, 2010). Finally, Experiment 2 aimed to test the

postulation that over-selectivity and stereotyped behaviour are associated in individuals with ASC (Ploog, 2010).

## **Method**

### ***Participants***

Twenty-four children, 12 diagnosed with ASC and 12 mental age matched typically developing children, participated in this study.

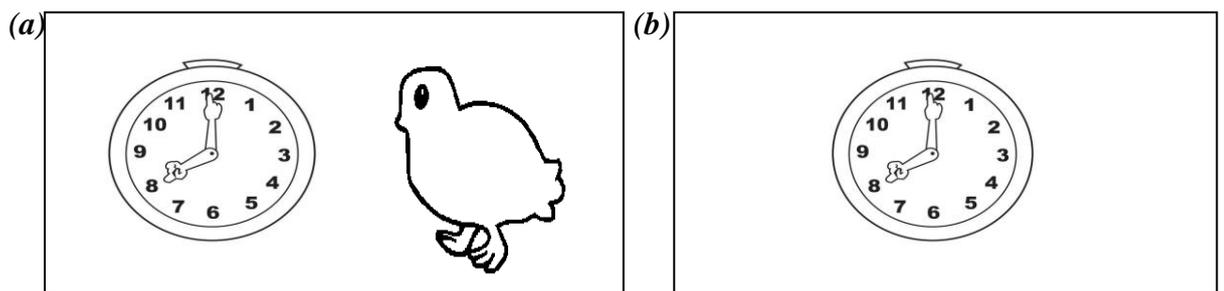
***Experimental Group.*** This group included 12 male children diagnosed with ASC by a psychologist who was independent from the study. The mean chronological age was 8 years 11 months (SD = 2:6; range = 6:0 to 13.8). The Leiter International Performance Scale-Revised (Leiter-R; Roid, & Miller, 1997) was utilised to obtain a non-verbal IQ for each individual in this group. The mean IQ was 62.92 (SD = 21.66; range = 32 to 97). The Peabody Picture Vocabulary Test Fourth Edition Form A (PPVT-4; Dunn & Dunn, 2007) was administered to obtain the group's verbal receptive language ability, providing a verbal mental age equivalent for each participant. This group scored a mean of 4years 1 month (SD = 0:11; range = 3:0 to 5:10).

***Control Group.*** This group included 12 typically developing children, 5 males and 7 females. The mean chronological age was 4 years 1 month (SD = 0:6; range = 3:1 to 4:11). The control group were assumed to be of average intelligence and did not have a diagnosis of any intellectual, learning or developmental disability.

### ***Materials***

***Stimulus over-selectivity testing materials.*** Laminated stimulus cards measuring 12cm. by 10 cm. consisting of one black stimulus or two black stimuli on

a white background. There were eight different picture stimuli: clock (A), chicken (B), flower (C), hand (D), eye (E), pencil (F), mouse (G) and book (H). These pictures were chosen in order that the participants would be able to acquire the discrimination during the training phase and to also ensure that materials were consistent with Experiments 1A and 1B in the current thesis and Reed et al.'s (2009) study.



**Figure 3.0: Example of Complex Stimulus (a) and Single Element Stimulus (b)**

*Leiter International Performance Scale, Revised* (Leiter-R; Roid, & Miller, 1997a). Six subtests from the Visualization and Reasoning Battery in the Leiter-R were used to attain a full nonverbal IQ score (mean=100, SD=15) for each participant with ASC. The subtests included figure ground, design analogies, form completion, sequential order, repeated patterns and paper folding. This instrument has a reliability ranging from 0.91 to 0.93 and has a test-retest reliability of 0.9 to 0.96 and a 0.86 correlation with the Wechsler Intelligence Scale for Children (3<sup>rd</sup> edition) full scale IQ measure (Roid & Miller, 1997b).

*Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4;* Dunn & Dunn, 2007). This norm-referenced instrument has 228 test items that measure the receptive vocabulary of children and adults by requiring discrimination of one target from an array of four pictures. The mean split-half reliability of the PPVT-4 is 0.94 and its test-retest reliability is 0.93 (Dunn & Dunn, 2007). The PPVT-4 has a

correlation ranging from 0.67 to 0.79 with the Clinical Evaluation of Language Fundamentals, Fourth edition (Semel, Wiig, & Secord, 2003).

*Test of Everyday Attention for Children (TEA-Ch*; Manly, Robertson, Anderson & Nimmo-Smith, 1999). This tool is a normed and standardized battery of nine subtests that measures attention in children and adolescents between the ages of six and 16. Three types of attention are measured: selective attention, sustained attention and attentional control/switching. The test-retest reliability for the TEA-Ch measures range from 0.57 to 0.87 and it has a Pearson correlation of between -0.01 and 0.31 with the Wechsler Intelligence Scale for Children (3<sup>rd</sup> edition) prorated IQ scores (Manly et al., 1999).

*Intra/Extra Dimensional Set Shift (IED*; Cambridge Cognition, 2011) is one of 22 neuropsychological tests in the Cambridge Neuropsychological Test Automated Battery (CANTAB) eclipse (version 3.2). The IED shift test is a computer-based cognitive assessment that tests for rule acquisition and reversal. It features visual discrimination and attentional set formation and maintenance, shifting and flexibility of attention. The two dependent variables utilised in the current study were number of stages completed and number of adjusted errors.

*Behavior Flexibility Rating Scale (BFRS*; Green, Sigafoos, Pituch, Itchon, O'Reilly & Lancioni, 2006) was designed to assess insistence on sameness or lack of behavioural flexibility. The rating scale items cover five areas based on the theoretical conceptualisation of behavioural flexibility. These five areas are: (i) a preferred item is unavailable or may have been broken, moved, or misplaced; (ii) a desirable event or activity is interrupted, cancelled, or delayed; (iii) the individual is subjected to unexpected sensory stimulation; (iv) the individual fails at a task; or (v) a task is left unfinished.

The severity of each potentially problematic situation is rated on a 4-point Likert scale ranging from 0 to 3. A rating of 0 indicates problem situations that “were not at all a problem for the person”. A rating of 1 indicates that the situation causes “only minor problems and that these [were] only short lived. The person might complain or fuss a little bit and for a short period of time (less than 1 min), but then accepts the change and copes with the situation.” A rating of 2 indicates the situation “caused moderate problems. The person might become agitated and upset for 1 to 2 min. He or she might even tantrum mildly (e.g., stomp their feet, cry), but eventually the person accepts the situation and calms down.” Finally, a rating of 3 indicates that “the situation caused severe problems. The situation may lead to a major tantrum. The tantrum might include aggression, screaming, and/or self-injury. The person never accepts the situation and things have to be returned to how they were before or the person has to be removed from the situation to calm down”.

***Gilliam Autism Rating Scale: Second Edition (GARS-2; Gilliam, 2006).***

The GARS-2 is a norm-referenced instrument that consists of 42 items describing the characteristic behaviours of individuals with ASC. The items are grouped into three subscales, one of which is stereotyped behaviours. The respondent uses the likert scale to rate the frequency of the subscale items as 0 (never observed), 1 (seldom observed), 2 (sometimes observed), or 3 (frequently observed). The obtained raw scores are then converted into standard scores (mean= 10, SD= 3) which, when totalled, provides an Autism Index (mean = 100, SD= 15) for each participant. An Autism Index of 85 or higher, means that the probability of the individual having autism is ‘very likely’, a score between 70 and 84 means that it is ‘possible’ that the individual has autism, and a score of 69 or lower means that it is unlikely that the individual has Autism (Gilliam, 2006).

The internal consistency was measured using Cronbach's coefficient alpha (1951). The resulting coefficients were 0.84 for the Stereotyped Behaviours subscale and 0.94 for the total test. The test-retest reliability ranges from 0.64 to 0.84 and are all beyond the 0.01 level of significance (Gilliam, 2006). The GARS-2 was compared to the Autism Behavior Checklist (ABC; Krug, Arick, & Almond, 1993) to assess its concurrent validity and the correlation coefficient was statistically significant at 0.64 (Gilliam, 2006).

### ***Procedure***

Parental and school consent was obtained for each participant. The study was conducted with the participant and experimenter sitting across from each other at a table in a quiet classroom free from distraction in the participant's own learning environment. The eight Leiter-R subtests, the PPVT-4, the GARS-2 and the BFRS were all completed for the experimental group before testing began. There were three experimental phases measuring stimulus over-selectivity, attention, and flexibility.

***Measure of Stimulus Over-selectivity.*** In the training phase, the stimuli were placed on the centre of the desk half-way between the participant and the experimenter. Participants were presented with two white cards simultaneously. Each card contained two black stimulus elements (see Figure 3.0, a). Participants were reinforced for pointing at, for example, the complex stimulus containing A and B over the complex stimulus containing C and D. The combination of stimulus elements on the reinforced card was predetermined and randomized (i.e., AB or AC

or BC or BD) for each of the participants to avoid any potential confounding variables of some stimuli being intrinsically more salient than others.

For each discrete trial, participants were presented with two compound stimuli (e.g., 'AB' and 'CD'). There were no vocal instructions. The experimenter waited for the participant to point to one of the cards. If the participant pointed to the predetermined reinforced compound (e.g., AB) they received positive feedback from the experimenter who said "yes" enthusiastically with a smile. If the student pointed to the other card (e.g., 'CD') they received no feedback. The positions of the cards were randomised so that 50% of the time the correct card was presented on the right, and 50% of the time on the left. During the training phase, the reinforced compound 'AB' was always paired with the non-reinforced compound 'CD'. Participants reached criterion in the training phase once they chose the reinforced compound ten times consecutively.

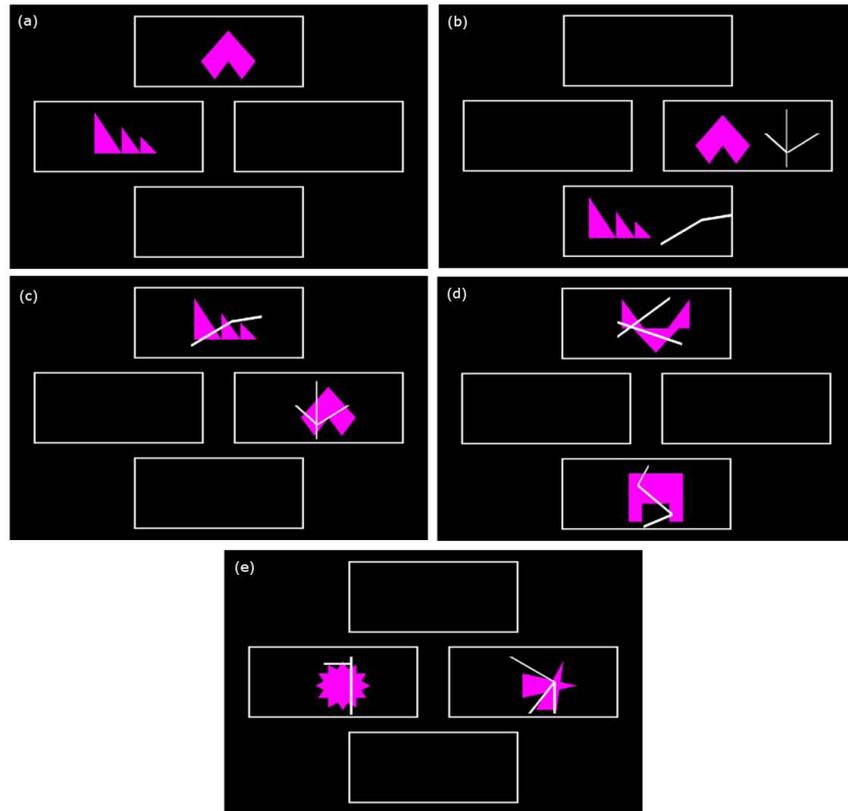
In the test phase, participants were presented with two cards simultaneously, each one comprising of just one picture from the compound stimulus (see Figure 3.0, b). The pictures were paired so that the participants had a choice of a previously reinforced stimulus and a previously non-reinforced stimulus. There were five trials for each combination of previously positively reinforced and non-reinforced components of the compound stimuli (i.e. A v C, A v D, B v C, B v D) giving a total of 20 trials. No feedback was provided by the experimenter to the student during test trials.

***Measure of Attention.*** All nine subtests of the TEA-Ch (Manly, Robertson, Anderson & Nimmo-Smith, 1999) were administered with the experimental group. If an individual did not reach criterion in the practice phase, the subtest was

discontinued, and the experimenter moved onto the practice trials in the following subtest. Subtests 1 and 5 are measures of selective attention. Subtests 2, 4, 6, 7, and 9 are measures of sustained attention. Subtests 3 and 8 are measures of attentional switching. Subtests 1 and 5 (measures of selective attention) were the only two subtests run with the control group due to time constraints imposed by the participants' schools.

***Measure of Cognitive Flexibility.*** In the IED Shift Test (Cambridge Cognition, 2011), four empty rectangles appear on the computer screen, and each trial starts with two stimuli in separate opposing rectangles. The stimuli are novel abstract pink shapes or white line drawings. Individuals are instructed to select a stimulus, are given computer feedback ('correct' in green with high beep or 'wrong' in red and lower beep) and must figure out the rule. This rule then changes after correctly selecting on six consecutive trials. To successfully complete the stage, individuals must make six consecutive correct selections in 50 trials. If an individual fails any stage, the task is ended (Yerys, Wallace, Harrison, Celano, Giedd, & Kenworthy, 2009).

The task has nine stages. Stages 1 to 5 are discrimination stages where individuals must ignore distracting shapes and distinguish correctly between one of two shapes throughout (see Figure 3.1). Stages 6 and 7 introduce intra-dimensional shifting demands to apply the old rule to new stimuli. Stages 8 and 9 require extra-dimensional shifting because the individual must attend to a previously ignored feature of the stimulus (Yerys et al., 2009). The dependent variables measured in this study include the number of stages completed and number of the adjusted errors.



*Figure 3.1: All nine stages of the Intra/Extra Dimensional Set Shift test. (a) Stimuli presented in Stages 1 and 2. (b) Stimuli presented in Stage 3. (c) Stimuli presented in Stages 4 and 5. (d) Stimuli presented in Stages 6 and 7. (e) Stimuli presented in Stages 8 and 9. (Yerys et al., 2009)*

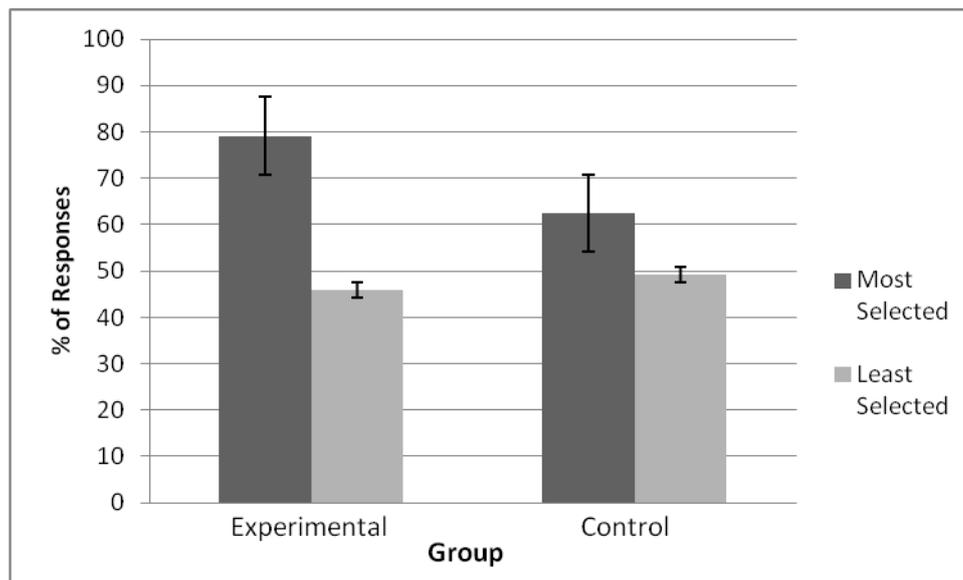
## Results

### *Stimulus Over-selectivity*

All participants successfully completed the training phase. The experimental group took 49.58 (SD = 28.73) trials on average to reach criterion. The control group took an average of 31.58 (SD = 36.98) trials to choose the ‘positive’ card 10 times consecutively. Although there was a numeric trend where the experimental group needed more training trials than the control group, an independent samples t-

test revealed that there was no statistical difference between the groups,  $t(22) = 1.33, p = .197$ .

The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 3.2).



*. Figure 3.2: Mean percentage scores for the most and least selected elements for the experimental and control groups in the test phase. The vertical lines represent error bars with standard error.*

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and group (experimental versus control) as the between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 22) = 187.478, p = 0.000$ . Although the main effect of group was not statistically significant,  $F(1, 22) = 0.867, p = 0.362$ , the interaction of group and stimulus type was significant,  $F(1, 22) = 34.435, p = .000$ .

Simple effect analyses were conducted to determine where the significant differences in element selection emerged with regard to group type. The findings revealed a statistically significant difference between the most and least selected stimuli for the experimental group,  $F(1, 22) = 192.933, p < 0.05$  and for the control group,  $F(1, 22) = 30.594, p < 0.05$ .

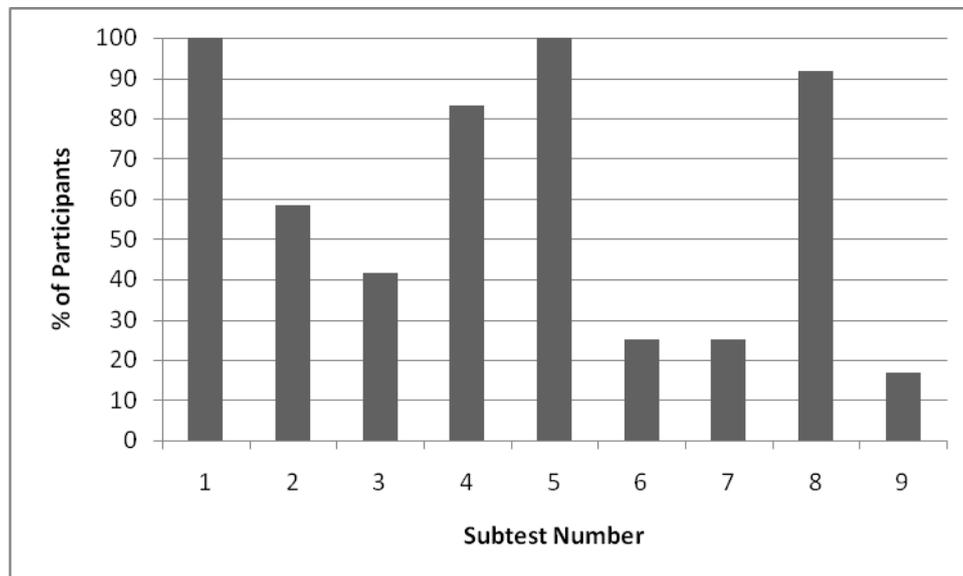
The average percentage difference between the most- and least-selected stimuli was calculated for both groups. There was a large percentage difference between the most and least selected stimulus for the experimental group (mean = 33.33, SD = 9.847) and a small percentage difference for the control group (mean = 13.33, SD = 6.513). An independent t-test revealed that this difference was statistically significant,  $t(22) = 5.868, p = 0.000$ .

### *Levels of attention*

Both the experimental and control groups completed Subtests 1 and 5. The mean of these group's raw scores for each subtest were analysed and the difference was tested for statistical significance. The experimental group also completed the other 7 subtests. The raw scores were analysed as opposed to the age scaled scores because they provided a clearer indication of the participants' performance in the TEA-Ch subtests. When the raw scores were converted to age scaled scores, the majority of the data resulted in the age scaled score of one year.

Inspection of Figure 3.3 reveals the difficulty that the participants in the experimental group had in completing the TEA-Ch as there were only two subtests (Subtests 1 and 5) where 100% of the participants were able to pass the practice phase in order to be officially tested. Participant 4 (IQ = 94; chronological age = 6:0; mental age = 4:9) and Participant 5 (IQ = 97; chronological age = 6:0; mental age =

5:10) were the only two participants to pass the practice phases of all 9 subtests in the TEA-Ch.



**Figure 3.3:** Percentage of participants in the experimental group who successfully passed the practice phase of each subtest in the Test of Everyday Attention for Children (TEA-Ch)

**Selective Attention: Subtests 1 and 5.** All participants successfully completed Sky Search and Sky Search (Motor Control). An attention score was obtained for all of the 12 participants in the experimental condition and the 12 participants in the control condition. The lower the attention raw scores the better (Manly, Robertson, Anderson, & Nimmo-Smith, 1999). The mean attention raw score for the experimental group was 17.78 (SD = 25.38) and the mean attention raw score for the control group was 13.64 (SD = 11.51). An independent t-test was employed to test the attention scores difference between these groups, and no statistical difference was found,  $t(22) = .516, p = .079$ . However, it should be noted, that the differences between the mean correct targets identified in the Sky Search

(Motor Control) task between the experimental group (mean= 15 targets) and the control group (mean= 9.5 targets) was statistically different,  $t(22) = 0.282, p=0.005$ .

All of the experimental and control participants successfully completed the Map Mission task. The mean number of correct targets identified in a minute was 10.67 (SD = 7.73) for the experimental group and 5.58 (SD = 3.85) for the control group. Therefore, the group of participants with ASC were able to identify more targets than the typically developing mental age matched control group. An independent t-test was conducted to test these difference between these groups and zero, and a statistical difference was found,  $t(22) = 2.04, p= 0.05$ .

***Sustained Attention: Subtests 2, 4, 6, 7, and 9.*** These subtests were only conducted with the experimental group (n=12). In Subtest 2, the participants achieved a mean raw score of 3 (SD = 3.65; range= 0-9) correctly identified number of tones out of a maximum total of 10 correct responses. In Subtest 4 they scored a mean raw score of 98.42 (SD = 189.73; range= -49.00- 615.38). In Subtest 6, the participants got a mean raw score of 5.33 (SD = 4.73; range= 0-9). Participant 1 was unable to complete this subtest due to high levels of vocal stereotyped behaviour. In Subtest 7 the group for a mean raw score of 5.27 (SD = 4.76; range= 0-13), out of a possible 20 correct responses. This was the only subtest (other than Subtests 1 and 5) that Participant 12 could attempt due to the fact that this individual is non-vocal verbal and used Picture Exchange Communication System (PECS; Bondy & Frost, 1994) to communicate. In Subtest 9 the mean raw score was 24.00 (SD = 9.90; range= 17-30), out of a possible 40 correct responses.

***Attentional Switching: Subtests 3 and 8.*** These subtests were only conducted with the experimental group (n=12). In Subtest 3, the mean raw score was 0.20 (SD = .045; range= 0-1) for the number of correct creatures counted (out of

a possible maximum of 7) and a mean raw score of 9.60 seconds (SD = 21.47; range= 0-48) for time taken to count the creatures. The mean total raw score for the time taken to complete the Same World sheets in Subtest 8 was 52.05 seconds (SD = 16.42, range= 31.80 – 79.60) and for the Opposite World sheets, the mean was 95.34 seconds (SD = 65.97, range= 37.90- 235.00). A paired-samples t-test showed that the difference between the Same World and Opposite World scores were statistically significant,  $t(10) = -2.82, p = 0.018$ .

### ***Cognitive Flexibility***

***Total IED stages complete.*** The experimental group completed an average of 3.25 stages (SD = 3.52; range= 0-8) in the IED and the control group completed an average of 5.00 stages (SD = 3.19; range 0-8). An independent t-test showed that there was no significant difference between the two groups,  $t(22) = -1.276, p = .215$ . No participant in either of the groups successfully completed Stage 9. One participant from each group completed Stage 8. And 33.33% of the experimental group and 16.67% of the control group failed to pass the first stage.

***IED adjusted errors.*** The experimental group made an average of 144.50 adjusted errors (SD = 75.99; range= 48-222) in the IED and the control group made an average of 117.25 errors (SD = 73.93; range 55-233). An independent t-test showed that there was no significant difference between the two groups,  $t(22) = .890, p = .383$ .

### ***Behavioural Flexibility***

The mean BFRS score for the experimental group was 8.83 (SD = 6.132; range= 2 to 21) out of a total possible score of 45.

***Stereotyped Behaviour***

The mean GARS-2 score for the experimental group was 87.17 (SD = 14.80; range = 66 to 111). The average subscale score was 7.42 (SD = 2.712; range 5 to 12) for stereotyped behaviours.

***Correlation Analysis***

Levels of stimulus over-selectivity were calculated by examining the percentage difference between the most and least selected stimulus elements. Spearman's rho was employed as the Kolmogorov-Smirnov test showed that this over-selectivity data was not normally distributed. Inspection of Table 3.1 reveals that over-selectivity did not significantly correlate with either of the subtests that measured selective attention (Subtests 1 and 5), or attentional switching (Subtests 3 and 8).

	<b><i>Subtest 1 Attention Score</i></b>	<b><i>Subtest 3 Total Correct</i></b>	<b><i>Subtest 5 Total Correct</i></b>	<b><i>Subtest 8 Same World</i></b>	<b><i>Subtest 8 Opposite World</i></b>
Over-selectivity					
Correlation coefficient	.117	-.612	.168	.405	.478
Sig. (2-tailed)	.585	.272	.432	.217	.137
N	24	5	24	11	11

***Table 3.1 Correlations between stimulus over-selectivity and selective attention (Subtests 1 and 5) and between stimulus over-selectivity and attentional switching (Subtests 3 and 8)***

Inspection of Table 3.2 reveals that although there were no significant correlations between stimulus over-selectivity and the sustained attention Subtests 2, 4, 6, and 9, there was a significant correlation with Subtest 7.

	<i>Subtest 2</i>	<i>Subtest 4</i>	<i>Subtest 6</i>	<i>Subtest 7</i>	<i>Subtest 9</i>
Over-selectivity					
Correlation coefficient	-.311	.326	-.866	-.645	-
Sig. (2-tailed)	.498	.359	.333	.032	-
N	7	10	3	11	2

**Table 3.2 Correlations between stimulus over-selectivity and sustained attention (Subtests 2, 4, 6, 7 and 9)**

A correlation analysis was conducted to analyse the relationship between over-selectivity and group, mental age, IQ, attention, Autism Index, stereotyped behaviour, IED stages completed, IED adjusted errors and behavioural flexibility.

	<i>Group</i>	<i>MA</i>	<i>IQ</i>	<i>AI</i>	<i>SB</i>	<i>IED Stages</i>	<i>IED Adj. Errors</i>	<i>BFRS</i>
Over-selectivity								
Correlation coefficient	-.830	-.556	-.647	.784	.581	-.279	.273	.493
Sig. (2-tailed)	.000	.061	.023	.003	.048	.187	.196	.103
N	24	12	12	12	12	24	24	12

**Table 3.3 Correlations between stimulus over-selectivity and group, mental age (MA), IQ, Autism Index (AI), stereotyped behaviour (SB), cognitive flexibility (Intra/Extra Dimensional Set Shift stages and Intra/Extra Dimensional Set Shift adjusted errors) and behavioural flexibility (Behavioural Flexibility Rating Scale)**

Inspection of Table 3.3 shows that there were statistically significant correlations between stimulus over-selectivity and four variables: group, IQ, Autism Index and stereotyped behaviours. The correlation between over-selectivity and mental age was just beyond the significance level. Cohen (1988, 1992) recommends that effect sizes are examined where  $r=.10$  is a small effect,  $r=.30$  is a medium effect and  $r=.50$  is a large effect. By this guideline, over-selectivity and mental age ( $r = -.556$ ) had a large effect size. Although over-selectivity was not significantly

correlated with cognitive and behavioural flexibility, small to medium effect sizes were revealed between over-selectivity and IED stages ( $r = -.279$ ), over-selectivity and IED adjusted errors ( $r = .273$ ) and over-selectivity and behavioural flexibility ( $r = .493$ ).

A Bonferroni correction was applied to each of the correlation analyses which were calculated at the .05 level. This correction procedure controls the overall Type 1 error rate when multiple significance tests are conducted. Thus, the corrected significance level is .002 (i.e., .05 divided by 18). Inspection of Tables 3.1, 3.2 and 3.3 reveals that group type was significant at this level ( $p = .000$ ) and Autism Index was just beyond statistical significance ( $p = .003$ ).

## Discussion

The aims of the current study were to demonstrate stimulus over-selectivity in individuals with ASC and to explore three potential correlates: attention, flexibility and stereotyped behaviour. A significant degree of stimulus over-selectivity was found in a population with ASC, using the current simple visual discrimination task. This finding replicated those reported by Koegel and Wilhelm (1973), Reed, Broomfield, McHugh, McCausland and Leader (2009) and offered further support to the results found in Chapter 2.

The first aim of Chapter 3 was to analyse the correlation between attention and over-selectivity using a standardised tool to measure three attentional processes. The findings from the selective attention task Sky Search revealed that the typically developing control group achieved a better (albeit insignificant) mean attention score than the experimental group. However, the control group identified a significantly

lower number of correct targets in the Map Mission task than the experimental group. This finding is consistent with research that shows that individuals with ASC have an enhanced ability to discriminate between visual stimuli (O’Riordan & Passetti, 2006; Plaisted, O’Riordan, & Baron-Cohen, 1998) and specifically, that children with ASC are superior to typically developing children in visual search tasks (O’Riordan & Plaisted, 2001; O’Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O’Riordan, & Baron-Cohen, 1998).

The correlation analysis revealed that Subtest 7, a measure of sustained attention, had the only significant association with over-selectivity. This finding suggests that an individual’s ability to self-maintain an actively attentive stance to a given task is correlated with their level of over-selective responding. However, it should be noted that none of the other four subtests measuring sustained attention reliably correlated with over-selectivity. The fact that only one of nine attention subtests was significantly associated with stimulus over-selectivity may indicate that the attentional processes under investigation in the current study are not reliable correlates of over-selectivity.

This finding is in contrast to research indicating that there is an association between eye movements and attention (Hoffman & Subramaniam, 1995; Findlay & Walker, 1999). The strength of stimulus control depends on how much contact is made by the individual to the stimuli. The type of contact involves two behaviours, observing behaviour (e.g., looking at and focusing on the stimuli) and attending behaviour (Dinsmoor, 1985).

In terms of the correlation with over-selectivity, there are two possibilities about the role of observing. Firstly, if the individual has observed all of the relevant stimuli, then the deficiency is related to attention (Dube et al., 2010). However if the

individual did not observe all of the relevant stimuli, then this inadequate contact with the stimuli could account for over-selective responding. The current standardised measure of attention did not assess the observing behaviour of the participants and thus, it is possible that only one significant correlation was found due to the participants' inadequate observing behaviour.

Replication of the current findings is essential for two reasons. Firstly, the current sample was too limited in size. Secondly, the TEA-Ch was possibly an unsuitable measure of attention for this clinical population as the lower functioning participants had difficulty passing the practice trials. Perhaps the use of this tool should be limited to just individuals with high functioning ASC. Another limitation of this tool was that its administration is restricted to individuals aged 6-16 years. Although the experimental group met this criterion in terms of chronological age (mean 8:11 years), the mean mental age equivalent was just 4:1 years. This may explain why only 16.67% of the children with ASC were able to pass the practice phases in all nine subtests.

A further problem with the TEA-Ch was that one participant with ASC was unable to attempt six of the subtests as he was non-vocal verbal and vocal responses were necessary to administer the tests. It should be noted that following extensive research into standardised measures of attention, this was the only available tool suitable for the current requirements. Further research is therefore necessary to investigate the correlation between attention and over-selectivity once a more appropriate measure is developed for individuals with lower functioning ASC.

The second aim of Chapter 3 was to explore the relationship between flexible behaviour and stimulus over-selectivity. In terms of cognitive flexibility, the control group completed more stages and emitted less adjusted errors than the experimental

group on average. However, similar to the findings of Corbett et al. (2009), there were no significant differences across the groups. Furthermore, the correlation analysis revealed that neither of the IED dependent variables was significantly associated with levels of over-selectivity in both the control and experimental groups. This result indicates that over-selective responding is not related to the level of executive function.

Similar to stimulus over-selectivity, executive dysfunction has been posited to underlie many of the key characteristics of ASC (Hill, 2004). Research has demonstrated that individuals with ASC show significant deficits in the formulation of rules and perseverative tendencies (Ozonoff, Pennington, & Rogers, 1991; Rumsey, 1985; McEvoy, Rogers, & Pennington, 1993; Reed, Watts & Truzoli, 2011). However, it should be noted that there are also some inconsistent findings in the literature investigating executive dysfunction in individuals with ASC (Reed, 2007; Wehner & Rogers, 1994; Turner, 1997; Ozonoff, South & Miller, 2000). One possibility for the lack of significant correlations between executive function and over-selectivity in the current study is the limited sample size. Therefore further investigation is vital with a larger population of individuals with ASC.

Similar results were found in the measure of behavioural flexibility whereby no significant correlation with stimulus over-selectivity was revealed following statistical analysis. This indicates that an individual's insistence on sameness is not related to levels of over-selective responding. The mean score for the experimental group on the BFRS was very low however and due to the small sample size, these flexibility scores may not be representative of this clinical population. Therefore future research should employ a larger sample. It would also be worthwhile to employ a second measure of behavioural flexibility such as the Sameness

Questionnaire (Prior & MacMillan, 1973) to further validate the findings. Taken together, these results from the IED and the BFRS offer experimental evidence contradicting the hypothesis that over-selectivity is associated with inflexible behaviour (Ploog, 2010).

The third aim of Chapter 3 was to conduct a correlation analysis of over-selectivity and stereotyped behaviour. The findings revealed a statistically significant correlation (prior to the Bonferroni correction) and a large effect size between the two variables. Specifically, stereotyped behaviour where internal reinforcers control behaviour and over-selectivity where behaviour is controlled by a limited subset of the cues available are reliably associated in individuals with ASC. Although this result supports the hypothesis that over-selectivity is associated with stereotypy (Ploog, 2010), further research is required with a larger sample.

Further analyses of the data employing Spearman's rho revealed that stimulus over-selectivity significantly correlated with group type, IQ, and Autism Index when  $p < 0.05$ . Once the Bonferroni correction was employed, group type remained significantly correlated. Therefore, if an individual has a diagnosis of ASC, there is an increased chance that they will respond over-selectively. This reliable finding confirms studies demonstrating stimulus over-selectivity in ASC (e.g., Lovaas et al., 1971; Anderson & Rincover, 1982; Chiang & Carter, 2008; Dube & McIlvane, 1999; Matthews, Shute & Rees, 2001).

Following the Bonferroni correction, Autism Index was just marginally beyond the significance level when tested in relation to stimulus over-selectivity. This finding offer further support for the results in Chapter 2 which revealed that ASC severity is a stronger predictor of recovery from over-selectivity than intellectual functioning. Further analysis of the correlation found in the current

study indicates that individuals with lower Autism Indices who present with milder deficits in stereotyped behaviours, communication and social interaction are less likely to respond over-selectively in a discrimination paradigm.

It is noteworthy that neither of the variables measuring cognitive flexibility was significantly correlated with stereotyped behaviour in the experimental group. This is in contrast to Yerys et al. (2009) who found a positive correlation between the number of repetitive behaviours and extra-dimensional reversal errors in individuals with ASC. Extra-dimensional shifting is required in Stages 8 and 9 of the IED. However, in the current study, only one participant from each group completed Stage 8 and no participant successfully completed Stage 9. Therefore this correlation analysis between stereotypy and set shifting warrants further examination with a larger and varied sample to ensure that a greater number of participants are able to complete the final two stages.

In summary, this study offered further evidence of the robustness of the over-selectivity phenomenon by replicating the effect in the current sample of individuals with ASC. The current chapter aimed to conduct an exploratory analysis of the correlations between stimulus over-selectivity and three variables: attention, flexibility and stereotyped behaviour. The novel findings to emerge from this experiment were that over-selectivity did not correlate with standardised measures of attention, cognitive flexibility or behavioural flexibility. However, significant correlations between over-selectivity and stereotyped behaviour and between over-selectivity and ASC severity emerged. These findings require consideration when designing behavioural interventions for individuals with ASC.

## Chapter 4:

Stimulus Over-selectivity in Typically Developing Children:

A Developmental Profile

The comparator theory postulates that stimulus over-selectivity is the result of a retrieval deficit, rather than an attention deficit. One prediction made by this theory is that post-learning manipulations of the over-selected cue should enhance the performance of the under-selected cue (Reed, 2007; Reed, 2010). The aim of the current chapter is to explore the comparator theory in a novel typically developing sample. In order for this perspective to be accepted as a valid theory to account for stimulus over-selectivity it requires thorough investigation across populations. If over-selectivity is modelled in a non-clinical population, the phenomenon can be thoroughly researched in a non-vulnerable population (with the attendant ethical advantages) before being applied to a clinically relevant population (Broomfield, 2008).

Previous research investigating over-selectivity in typically developing adults has demonstrated that adding a distractor task can induce higher levels of over-selective responding (Reed & Gibson, 2005; Broomfield, McHugh & Reed, 2010; Reed, Savile, & Truzoli, 2012; Reynolds, Watts & Reed, 2012; Reynolds & Reed, 2011a; Reynolds & Reed, 2011b). To assess the impact of additional distractor tasks on levels of over-selectivity in typically developing children, each of the current experiments added an extra task to the visual discrimination paradigm employed across five chronological age groups.

Once the over-selected stimuli were identified, extinction, a post-learning manipulation, was tested as a potential remedial intervention for the effect in typically developing children. Although extinction has been explored as a remediation strategy for over-selectivity in children with a diagnosis of ASC (Reed, Broomfield, McHugh, McCausland & Leader, 2009; Leader, Loughnane, McMoreland & Reed, 2009; current Chapter 2) and in typically developing adults

(Broomfield, McHugh & Reed, 2008; Reynolds, Watts & Reed, 2012) there has been no investigation of the effects of extinction on levels of over-selectivity in the current non-clinical population.

In fact, limited research has been conducted to examine the over-selectivity phenomenon itself in typically developing children. Bickel, Stella and Etzel (1984), examined auditory over-selectivity in preschoolers and found that 70% of the participants were over-selective. Eimas (1969) trained kindergarten, second and fourth grade children on a visual simultaneous discrimination task and found that over-selectivity decreased as a function of chronological age. Hale and Morgan (1973) found similar results whereby the 4-year old participants responded primarily to a single component during the acquisition of the discrimination and were more over-selective than the 8 year-old participants. Ross (1976) stated that young children attend to one aspect of a stimulus or to a limited portion of the stimulus area until about the age of six years. Children who continue to over-select past this typical age tend to display a range of learning handicaps.

In addition to the investigation of over-selectivity and extinction as a potential remediation strategy, the current chapter also aimed to produce a developmental profile of this non-clinical population aged three to seven years. Correlations between levels of over-selectivity and selective attention, and between over-selectivity and cognitive flexibility were analysed to create this profile and to contribute to the theoretical framework of stimulus over-selectivity.

Selective attention was investigated as a potential correlate due to the postulations of the attention deficit theory. This theory stipulates that individuals who over-select display an initial pre-conditioning attentional deficit which leads to a limited number of stimuli exerting control over behavioural responding (Lovaas et

al., 1971). Therefore, the lower the individual's attention is, the greater the degree of over-selectivity. In support of this view, eye tracking devices have frequently been employed to demonstrate that stimulus over-selectivity is accompanied by a failure to observe all of the relevant stimuli (Dube et al., 1999). Although in interpreting these results, it should be noted that an imperfect correlation has been revealed between eye movements and attention (Wurtz & Mohler, 1976; Shaw, 1978; Remington, 1980).

Due to this imperfect association between attention and eye movements, Chapter 3 in the current thesis employed a standardised measure of attention instead to investigate the correlation between attention and over-selectivity in individuals with ASC. Although no statistically significant correlation was revealed, it was advised that this finding be interpreted with caution due to the limited sample size. Furthermore, the assessment tool used to measure selective attention, sustained attention and attentional switching was deemed unsuitably challenging for the clinical population.

Similar results were found in Chapter 3 for the measure of cognitive flexibility whereby no significant correlation with over-selectivity was revealed. This was the first data set offering evidence contradicting the hypothesis that over-selectivity is associated with inflexible behaviour (Ploog, 2010). Both of these correlation analyses require exploration in typically developing children in order to investigate the generality of the processes at work. It may be that clinical populations are influenced by different factors than non-clinical populations (McHugh & Reed, 2007).

## Current Experiments

Experiments 3-7 aimed to investigate whether over-selectivity could be found in typically developing children using a simple visual discrimination task. This finding has been noted in numerous studies with individuals with ASC (see Chapter 2) and typically developing adults (see Chapter 5) but there are few demonstrations of this effect in the current population using such a procedure.

The second aim of Experiments 3-7 was to investigate if previously under-selected stimuli could come to control behaviour, when previously over-selected cues are extinguished. This would demonstrate that the results reported for individuals with high and moderate functioning ASC (Reed, Broomfield, McHugh, McCausland & Leader, 2009; current Chapter 2) and typically developing adults (Broomfield, McHugh and Reed, 2008; Broomfield, McHugh & Reed, 2010; Reynolds, Watts & Reed, 2012) regarding extinction could be generalised to a younger non-clinical population.

The final aim of the current chapter was to investigate correlations between over-selectivity and cognitive flexibility and between over-selectivity and selective attention. The rationale for conducting this analysis was to meet the paucity in the literature surrounding the relationship between inflexible behaviour and over-selectivity (Ploog, 2010). Furthermore, Chapter 4 aimed to offer evidence to the theoretical debate about why some individuals demonstrate stimulus over-selectivity and whether it is due to an attention deficit or a retrieval and performance deficit.

### Experiment 3

Experiment 3 examined the three aims of the current chapter in a group of typically developing children with a mean chronological age of three years.

#### Method

##### *Participants*

There were 20 (10 males and 10 females) typically developing 3-year old children, with a mean age of 41.50 (SD = 3.97) months. All participants were recruited from two Montessori schools based in Dublin.

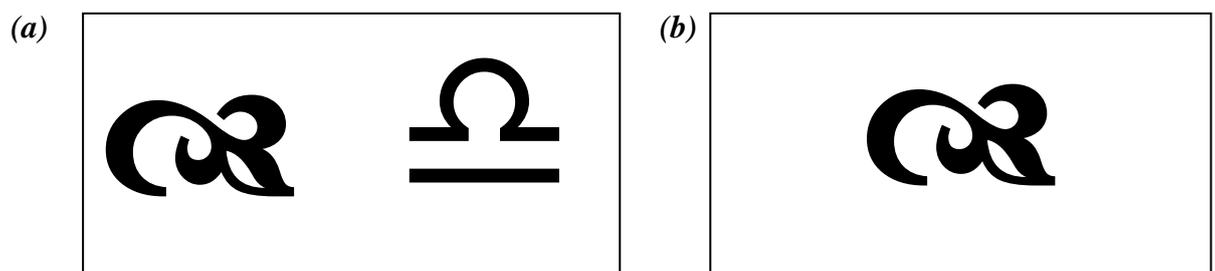
##### *Materials*

*The Test of Everyday Attention for Children* (TEA-Ch; Manly, Robertson, Anderson & Nimmo-Smith, 1999). This tool is a normed and standardized battery of nine subtests that measures attention in children and adolescents between the ages of 6:0 and 15:11. Three types of attention are measured: selective attention, sustained attention and attentional control/ switching. The test-retest reliability for the TEA-Ch measures range from 0.57 to 0.87 (Manly et al., 1999; p. 34). The TEA-Ch has a Pearson correlation of between -0.01 and 0.31 with the WISC-III prorated IQ scores (Manly et al., 1999; p. 37). Two subtests (subtests 1 and 5) were used in this study. Both subtests measure selective attention.

*Intra-Extra Dimensional Shift Test* (IED; Cambridge Cognition Limited, 2011) is one of 22 neuropsychological tests in the Cambridge Neuropsychological Test Automated Battery (CANTAB) eclipse (version 3.2). The IED is a computer-based cognitive assessment that tests for rule acquisition and reversal. It features visual discrimination and attentional set formation and maintenance, shifting and

flexibility of attention. This test has nine blocks of trials with a set criterion of learning at each stage of six consecutive correct responses. The two dependent variables employed in the current study were the number of stages completed and the number of adjusted errors.

***Stimulus over-selectivity*** testing materials. These consisted of laminated stimulus cards measuring 12cm. by 10 cm. These cards contained one black stimulus or two black stimuli on a white background. The stimuli were characters obtained from fonts available in Microsoft 2003. The fonts included symbol, wingdings and wingdings 2. These stimuli were different to the pictures employed in Experiments 1A, 1B and 2 (e.g., chicken, clock, and book). The Microsoft fonts were chosen to ensure that materials were consistent with McHugh and Reeds' (2007) study where the participants were typically developing individuals without a diagnosis of ASC. Cards were labelled A, B, C, D, E, F, G, H, AB, BA, CD, DC, EF, FE, GH, HG, I, J, K, and L.



***Figure 4.0: Example of Complex Stimulus (a) and Single Stimulus (b)***

### ***Procedure***

#### ***Assessment of Stimulus Over-selectivity***

Parental and school consent was obtained for each participant. The study was conducted with the participant and experimenter sitting across from each other

at a table in a quiet classroom free from distraction in the participant's own learning environment. A within-subjects design was employed where 50% of the participants in each age group completed the no distractor condition first and the other 50% completed the distractor condition first.

*No distractor condition.* In the training phase, the stimuli were placed on the centre of the desk half-way between the participant and the experimenter.

Participants were presented with two white cards simultaneously. Each card contained two black stimulus elements. Participants were reinforced for pointing at, for example, the complex stimulus containing A and B over the complex stimulus containing C and D. The combination of elements on the  $S_{r+}$  (e.g. AB, AC, BC or BD) was predetermined and randomised across participants. This was a control measure to avoid any potential confounding variables of some stimuli being intrinsically more salient than others.

For each discrete trial, participants were presented with two compound stimuli (e.g., 'AB' and 'CD'). Each student was given the same vocal instruction before the first discrimination was made, "Please point to a card without touching it." The experimenter waited for the participant to point to one of the cards. If the participant pointed to the predetermined reinforced compound (e.g., AB) they received positive feedback from the experimenter who said "yes" enthusiastically with a smile. If the student pointed to the other card (e.g., 'CD') they received no feedback from the experimenter. The vocal instruction was not provided for the remaining discriminations.

The positions of the cards were randomised so that 50% of the time the correct card was presented on the right, and 50% of the time on the left. During the training phase, the reinforced compound 'AB' was always paired with the non-

reinforced compound 'CD'. Participants reached criterion in the training phase once they chose the reinforced compound ten times consecutively. The training phase was terminated if a participant failed to make ten consecutive correct responses within 200 discrimination trials.

In the test phase, participants were presented with two cards simultaneously, each one comprising of just one picture from the compound stimulus. The pictures were paired so that the participants had a choice of a previously reinforced stimulus and a previously non-reinforced stimulus. There were five trials for each combination of previously positively reinforced and non-reinforced components of the compound stimuli (i.e., A v C, A v D, B v C, B v D) giving a total of 20 trials. No feedback was provided by the experimenter to the student during test trials.

***Distractor condition.*** The training phase consisted of the same procedure as in the no distractor condition, except that different stimuli were utilised. A concurrent task was given to each participant in this condition. Instead of instructing the 100 children in this study to continually subtract seven from a five-digit number (see Broomfield, McHugh & Reed, 2010; Reynolds & Reed, 2011a; Reynolds & Reed, 2011b; Reynolds, Watts, & Reed, 2012) the mathematical task was amended for this population. Each student was given the vocal instruction: "At the same time as pointing to a card, you must try your best to keep counting from 1 to 10 out loud over and over again like this." The experimenter then demonstrated counting forwards 1 to 10 repeatedly aloud.

Least-to-most guidance was used if the participant went quiet for three seconds. The first prompt level used was a vocal response prompt (e.g., 'th' for three) to continue to count aloud. If the participant did not emit the correct number aloud within three seconds, the experimenter provided a full echoic for the next

number in sequence (e.g., “three” for three). Participants reached criterion in the training phase once they chose the reinforced compound ten times consecutively. The training phase was terminated if a participant failed to make ten consecutive correct responses within 200 discrimination trials.

The test phase used the same procedure as in the no distractor condition, except the participant was instructed to continue counting from 1 to 10 aloud. The experimenter vocally prompted the participants with a response prompt or echoic prompt to continue to count aloud if the participants went quiet for three seconds.

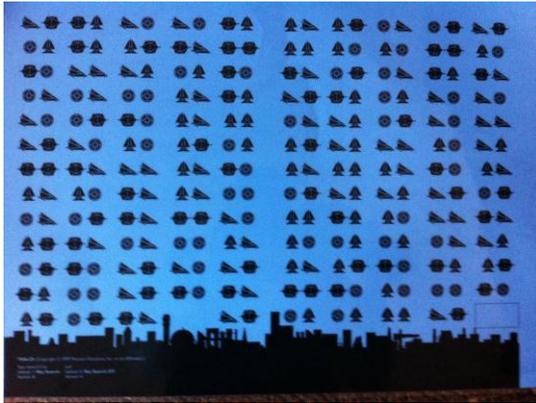
During the extinction phase, the participants were told that they did not have to count aloud for the remainder of the study. The over-selected stimulus was determined (i.e., A, B, C or D) and was paired with one of four novel stimuli (E, F, G, or H). Participants were positively reinforced (the experimenter says “yes” with a smile) for choosing the novel stimulus, and not the over-selected stimulus. Criterion was reached when the participants chose the novel stimulus ten times consecutively.

The retesting phase used the same test procedure that was used in the first testing phase, with no feedback provided to the student. The participants were not required to count aloud in this retesting phase.

### *Assessment of Selective Attention*

Two subtests of the TEA-Ch (Manly, Robertson, Anderson & Nimmo-Smith, 1999) were administered to all of the age groups. Subtest 1, “Sky Search”, took approximately two to six minutes to administer. It is a brief, timed test consisting of three sections. Section 1 was a practice sheet to ensure the participants understood the task. In Section 2 participants were instructed to find as many identical pairs of target spaceships as possible on a blue laminated test sheet filled

with very similar distractor spaceships (see Figure 4.1). There were a total of 20 correct targets. Section 3 was a test of motor control and was conducted to ensure that the ability of participants to find the targets was less confounded with difference in motor speed.



*Figure 4.1: Version B of the Sky Search*

The second subtest to be administered was Subtest 5 called “Map Mission”. In this test, participants were given a fixed time of one minute to find and circle as many of the specific target stimuli (a knife and fork in Version A) as they could from a detailed A3-size city map. There were a total of 80 possible correct targets (see Figure 4.2).



***Figure 4.2: Close-up section of Version A of Map Mission with one target circled in black***

### ***Assessment of Cognitive Flexibility***

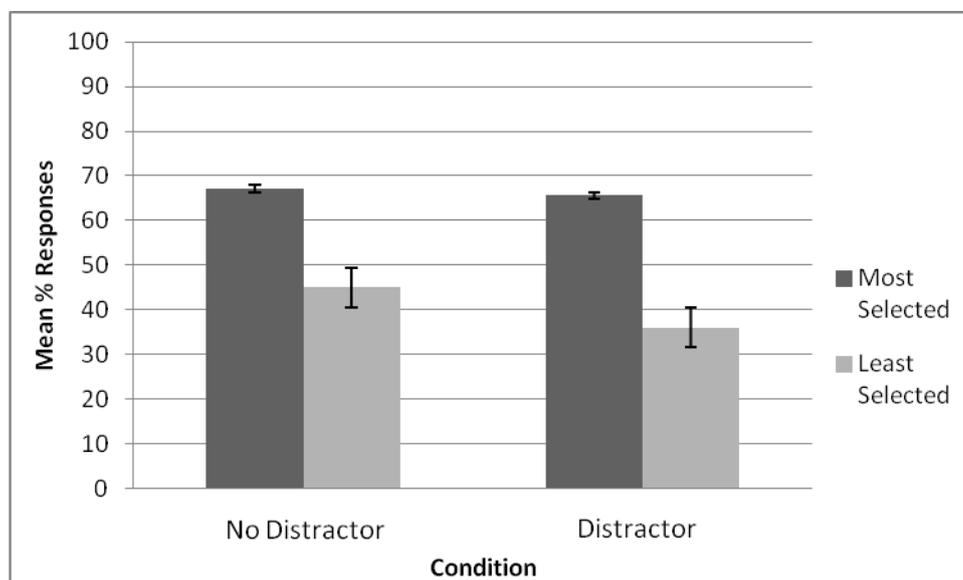
The IED task had nine stages. Stages 1 to 5 were discrimination stages where individuals had to distinguish correctly between one of two pink-filled shapes. Four empty rectangles appeared on the computer screen, and each trial starts with two stimuli in separate rectangles. The stimuli were novel abstract pink shapes or white line drawings. Individuals were instructed to select a stimulus, were given computer feedback ('correct' in green or 'wrong' in red); and had to figure out the rule. Auditory feedback was also given in the form of a high beep for correct answers and a lower beep for wrong answers. This rule then changed after correctly selecting on six consecutive trials. To successfully complete the stage, individuals had to make six consecutive correct selections in 50 trials. If an individual failed any of the stages, the task was terminated (Yerys, Wallace, Harrison, Celano, Giedd, & Kenworthy, 2009). Intradimensional (ID) shifting demands were introduced to apply the old rule to new stimuli in Blocks 6 and 7. Blocks 8 and 9 required Extra-Dimensional (ED) shifting because the individual had to attend to a previously ignored feature of the stimulus (Yerys et al., 2009).

## Results

### *Stimulus Over-selectivity*

Two of the participants failed to reach criterion in the training phase in both the no distractor and distractor conditions. That is, they both failed to make ten consecutive correct responses within 200 discrimination trials. The mean numbers of trials to criterion (including the ten consecutive correct trials) for the remaining 18 participants was 57.15 (SD = 63.09) in the no distractor condition and 66.35 (SD = 68.86) in the distractor condition. Although numerically fewer trials were required to reach criterion when there was no distractor, this finding was not statistically significant,  $t(19) = -1.638$ ,  $p = 0.118$ .

The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 4.3).

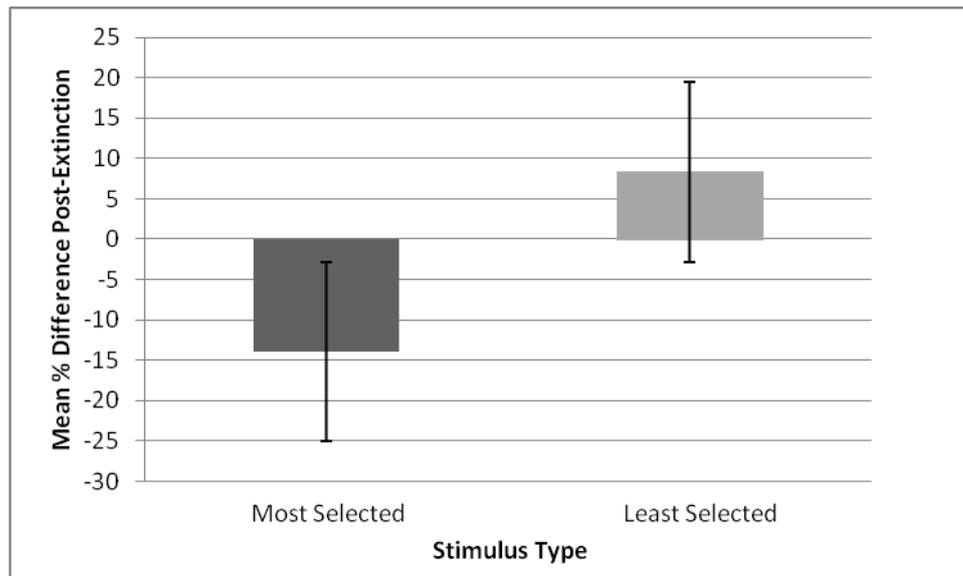


**Figure 4.3:** Mean percentage scores for the most and least selected elements for the 3 year old group in the test phase. The vertical lines represent error bars with standard error.

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and condition (distractor versus no distractor) as a between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 34) = 68.039$ ,  $p=0.000$ , but neither the main effect of condition,  $F < 1$ , nor the interaction of condition and stimulus type,  $F(1, 34) = 1.329$ ,  $p=0.257$ , were statistically significant. Therefore, the participants showed a significant degree of stimulus over-selectivity, irrespective of the condition.

The extinction phase was conducted directly after the test phase in the distractor condition. Criterion was reached when the participant chose the novel stimulus, which was presented with the previously over-selected stimulus, ten times consecutively. Only 18 participants in this 3-year old group completed the extinction phase because two of the children did not reach criterion in the training phase in the distractor condition. All 18 participants successfully reached criterion in this phase.

Post-extinction, the participants had a mean percentage chosen score for the previously most-selected stimuli of 51.67 (SD = 17.24), and a mean for the previously least-selected stimuli of 44.44 (SD = 15.04). The mean percentage change from the test (pre-extinction) to the retest (post-extinction) phase was calculated by subtracting the test score from the retest score (see Figure 4.4).



**Figure 4.4:** Mean percentage change from the test to the retest phase for the most and least selected stimuli in the 3 year old group. The vertical lines represent error bars with standard error.

When the test versus retest scores for each age group were tested against zero, the decrease in control of the previously over-selected stimulus was statistically significant,  $t(17) = 2.782, p = 0.013$ . The emergence of the previously under-selected stimulus, when tested against zero, was also statistically significant for the group,  $t(17) = -2.236, p = 0.039$ .

### ***Selective Attention***

The mean number of correctly identified targets in “Sky Search” (Subtest 1 of the TEA-Ch) was 3.50 (SD = 4.06) for the 3 year olds. The mean time spent correctly identifying these targets was 188.55 (SD = 155.62) seconds. The mean number of correctly identified targets in the motor control section of this subtest was 6.60 (SD = 5.91). The mean time spent correctly identifying these targets was 72.85 (SD = 44.00) seconds.

To calculate the attention score, time taken to completion and accuracy were recorded for each section of Subtest 1. A time-per-target score was calculated (time/targets found). Subtraction of the "motor control" time-per-target from the more attentionally demanding "Sky Search" time-per-item produced an "attention" score that was relatively free from the influence of motor slowness (Manly, Anderson, Nimmo-Smith, Turner, Watson, & Robertson, 2001). The lower the attention score in the TEA-Ch, the better the score. The mean attention score for the group was 34.87 (SD = 75.90). The mean number of targets found in Subtest 5 of the TEA-Ch was 2.30 (SD = 2.43).

A correlation analysis was conducted to investigate the associations between stimulus over-selectivity and selective attention scores. Over-selectivity scores were determined by subtracting the percentage for the least-selected stimuli from the most-selected stimuli in the distractor condition. The over-selectivity scores [ $D(18) = 0.211, p = 0.033$ ] were significantly non-normal and all associations were thus analysed using Spearman's correlation coefficient. There were insignificant relationships between over-selectivity and selective attention score,  $r_s = .060, p = .813$ , and between over-selectivity and Map Mission scores,  $r_s = -.375, p = .125$ .

### ***Cognitive Flexibility***

The two dependent variables of the IED analysed were the number of stages completed, and the number of adjusted errors. The participants successfully completed a mean number of 3.25 (SD = 3.40) stages and incurred a mean number of 164.40 (SD = 71.69) adjusted errors. A correlation analysis was conducted to investigate the associations between over-selectivity and these two dependent

variables. Both IED stages [ $r_s = -.180, p = .475$ ] and IED adjusted errors [ $r_s = -.057, p = .823$ ] were insignificantly related to how over-selective the participants were.

### **Discussion**

The results from Experiment 3 revealed that the typically developing children demonstrated stimulus over-selectivity in a simple visual discrimination task. This finding was revealed in the presence and absence of a concurrent cognitive task. Post-extinction, the control by the previously over-selected stimuli decreased while the previously under-selected stimuli emerged to exert control over the behavioural responding of these participants.

No significant relationships were found between over-selectivity and selective attention offering further contradictory evidence for the attention deficit theory of over-selectivity. Findings also revealed that there was no significant association between over-selectivity and cognitive flexibility in this group contradicting the postulation that inflexibility would correlate with over-selective responding (Ploog, 2010).

### **Experiment 4**

Experiment 4 investigated the three aims of the current chapter in a group of typically developing children with a mean chronological age of four years.

### **Method**

#### ***Participants***

There were 20 (9 males and 11 females) typically developing 4-year old children, with a mean age of 53.10 (SD = 3.26) months. All participants were recruited from two Montessori schools based in Dublin.

### ***Materials***

The materials were the same as in Experiment 3.

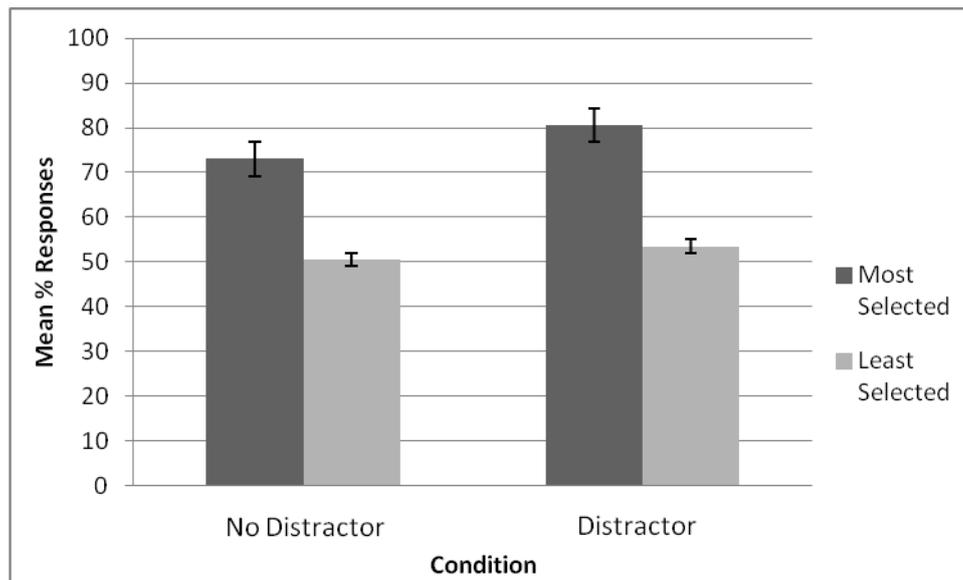
### ***Procedure***

The procedure was the same as in Experiment 3.

## **Results**

The mean numbers of trials to criterion (including the ten consecutive correct trials) was 33.10 (SD = 32.37) in the no distractor condition and 35.90 (SD = 38.99) in the distractor condition. Although numerically fewer trials were required to reach criterion when there was no distractor, this finding was not statistically significant,  $t(19) = -0.884, p = 0.388$ .

The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 4.6).

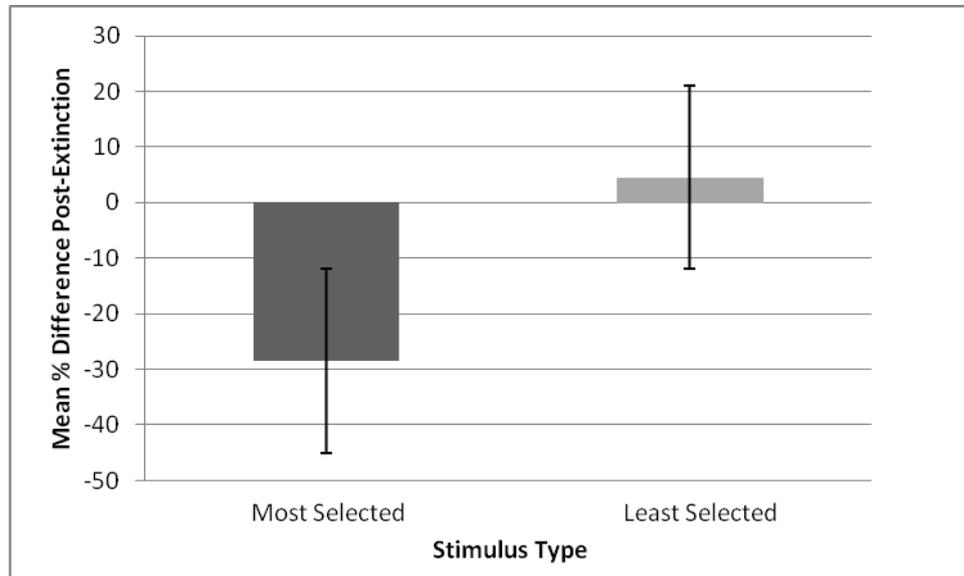


**Figure 4.6:** Mean percentage scores for the most and least selected elements for the 4 year old group in the test phase. The vertical lines represent error bars with standard error.

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and condition (distractor versus no distractor) as a between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 38) = 65.593$ ,  $p=0.000$ , but neither the main effect of condition nor the interaction of condition and stimulus type were statistically significant,  $F_s < 1$ . Therefore, the participants showed a significant degree of stimulus over-selectivity, irrespective of the condition.

All 20 participants successfully reached criterion in this extinction phase. Post-extinction, the 4 year old group had a mean percentage chosen score for the previously most-selected stimuli of 52.00 (SD = 26.28), and a mean for the previously least-selected stimuli of 58.00 (SD = 21.91). The mean percentage change

from the test (pre-extinction) to the retest (post-extinction) phase was calculated by subtracting the test score from the retest score (see Figure 4.7).



**Figure 4.7:** Mean percentage change from the test to the retest phase for the most and least selected stimuli in the 4 year old group. The vertical lines represent error bars with standard error.

When the test versus retest scores for each age group were tested against zero, the decrease in control of the previously over-selected stimulus was statistically significant,  $t(19) = 4.469, p = 0.000$ . However, the increase in control of the previously under-selected stimulus was not significant,  $t(19) = -1.088, p = 0.290$ .

### ***Selective Attention***

The mean number of correctly identified targets in “Sky Search” (Subtest 1 of the TEA-Ch) was 7.15 (SD = 5.50). The mean time spent correctly identifying these targets was 213.50 (SD = 175.35) seconds. The mean number of correctly identified targets in the motor control section of this subtest was 11.80 (SD = 6.83).

The mean time spent correctly identifying these targets was 60.45 (SD = 30.45) seconds. The mean attention score was 25.48 (SD = 60.96). The mean number of targets found in Subtest 5 of the TEA-Ch was 5.75 (SD = 4.48).

A correlation analysis was conducted to investigate the associations between stimulus over-selectivity and selective attention scores. The over-selectivity scores [ $D(20) = 0.276, p = 0.000$ ] were significantly non-normal and all associations were thus analysed using Spearman's correlation coefficient. There were insignificant relationships between over-selectivity and selective attention score,  $r_s = .145, p = .545$ , and between over-selectivity and Map Mission scores,  $r_s = -.007, p = .978$ .

### ***Cognitive Flexibility***

The participants successfully completed a mean number of 5.20 (SD = 3.24) stages and incurred a mean number of 115.10 (SD = 75.97) adjusted errors in the IED. A correlation analysis was conducted to investigate the associations between over-selectivity and these two dependent variables. Both IED stages [ $r_s = -.279, p = .233$ ] and IED adjusted errors [ $r_s = .129, p = .589$ ] were insignificantly related to how over-selective the participants were.

## **Discussion**

The findings from Experiment 4 revealed that the participants demonstrated stimulus over-selectivity in a simple discrimination task, irrespective of the presence or absence of extra cognitive demand. No significant relationships were found between over-selectivity and selective attention or between over-selectivity and cognitive flexibility in this group, contradicting the attention deficit theory and the

hypothesis that inflexibility is associated with over-selective responding (Ploog, 2010).

## **Experiment 5**

Experiment 5 investigated the three aims of the current chapter in a group of typically developing children with a mean chronological age of five years.

### **Method**

#### *Participants*

There were 20 (8 males and 12 females) typically developing 5-year old children, with a mean age of 65.65 (SD = 4.78) months. All participants were recruited from two Montessori schools based in Dublin and one primary school in Dublin.

#### *Materials*

The materials were the same as in Experiment 3.

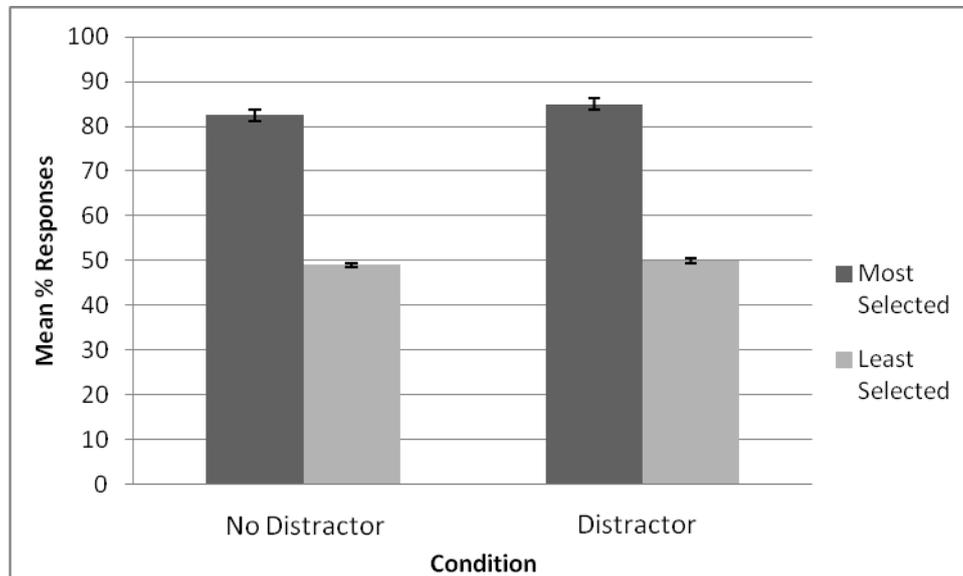
#### *Procedure*

The procedure was the same as in Experiment 3.

### **Results**

The mean numbers of trials to criterion (including the ten consecutive correct trials) was 22.35 (SD = 14.97) in the no distractor condition and 22.55 (SD = 14.82) in the distractor condition. The difference between these two conditions was not statistically significant,  $t(19) = -0.041$ ,  $p = 0.967$ .

The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 4.8).

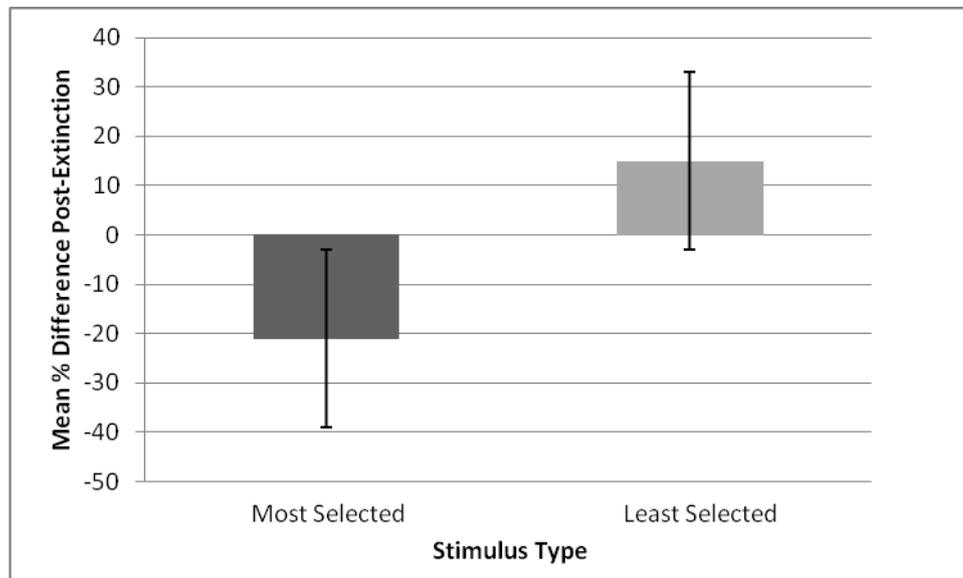


**Figure 4.8:** Mean percentage scores for the most and least selected elements for the 5 year old group in the test phase. The vertical lines represent error bars with standard error.

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and condition (distractor versus no distractor) as a between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 38) = 96.096$ ,  $p=0.000$ , but neither the main effect of condition nor the interaction of condition and stimulus type were statistically significant,  $F_s < 1$ . Therefore, the participants showed a significant degree of stimulus over-selectivity, irrespective of the condition.

All 20 participants successfully reached criterion in this extinction phase. Post-extinction, the participants ( $n=20$ ) had a mean percentage chosen score for the previously most-selected stimuli of 63.00 ( $SD = 30.28$ ), and a mean for the

previously least-selected stimuli of 65.00 (SD = 28.20). The mean percentage change from the test (pre-extinction) to the retest (post-extinction) phase was calculated by subtracting the test score from the retest score (see Figure 4.9).



**Figure 4.9:** Mean percentage change from the test to the retest phase for the most and least selected stimuli in the 5 year old group. The vertical lines represent error bars with standard error.

When the test versus retest scores for each age group were tested against zero, the decrease in control of the previously over-selected stimulus was statistically significant,  $t(19) = 3.661, p = 0.002$ . The emergence of the previously under-selected stimulus, when tested against zero, was also statistically significant for this group,  $t(19) = -2.801, p = 0.011$ .

### ***Selective Attention***

The mean number of correctly identified targets in “Sky Search” (Subtest 1 of the TEA-Ch) was 12.40 (SD = 5.19). The mean time spent correctly identifying

these targets was 190.95 (SD = 93.34) seconds. The mean number of correctly identified targets in the motor control section of this subtest was 16.90 (SD = 3.45). The mean time spent correctly identifying these targets was 53.00 (SD = 13.58) seconds. The mean attention score was 12.95 (SD = 12.95). The mean number of targets found in Subtest 5 of the TEA-Ch was 8.75 (SD = 4.24).

The over-selectivity scores [ $D(20) = 0.183, p = 0.077$ ] and scores for the Map Mission subtest [ $D(20) = 0.176, p = 0.103$ ] were significantly normally distributed and this association were thus analysed using Pearson's correlation coefficient. No significant relationship was revealed,  $r(20) = -.232, p = 0.324$ . Spearman's correlation coefficient was employed to test the association between over-selectivity and the selective attention score as the latter variable was not normally distributed,  $D(20) = .220, p = 0.012$ . This relationship was also not significant,  $r_s(20) = -.113, p = .636$ .

### ***Cognitive Flexibility***

The participants successfully completed a mean number of 6.45 (SD = 2.24) stages and incurred a mean number of 80.95 (SD = 53.03) adjusted errors in the IED. A correlation analysis using Spearman's correlation coefficient was conducted to investigate the associations between over-selectivity and these two dependent variables. The number of IED stages completed had a significant correlation with over-selective responding [ $r_s = .502, p = .024$ ]. The association between IED adjusted errors and over-selectivity was marginally insignificant [ $r_s = .432, p = .057$ ].

## Discussion

Experiment 5 showed that the typically developing children over-selected during a discrimination task with and without the addition of increased demand level. Extinction-based recovery of the previously under-selected stimuli was revealed in these participants offering further support for the comparator theory of over-selectivity

No significant relationships were found between over-selectivity and selective attention in this group, contradicting the attention deficit theory. However some support was found for the hypothesis that inflexibility is associated with over-selective responding (Ploog, 2010), as one of the cognitive flexibility dependent variable significantly correlated with levels of over-selectivity.

## Experiment 6

Experiment 6 investigated the three aims of the current chapter in a group of typically developing children with a mean chronological age of six years.

## Method

### *Participants*

There were 20 (5 males and 15 females) typically developing 6-year old children, with a mean age of 79.55 (SD = 2.21) months. All participants were recruited from three primary schools in Dublin, Clare and Cork.

### *Materials*

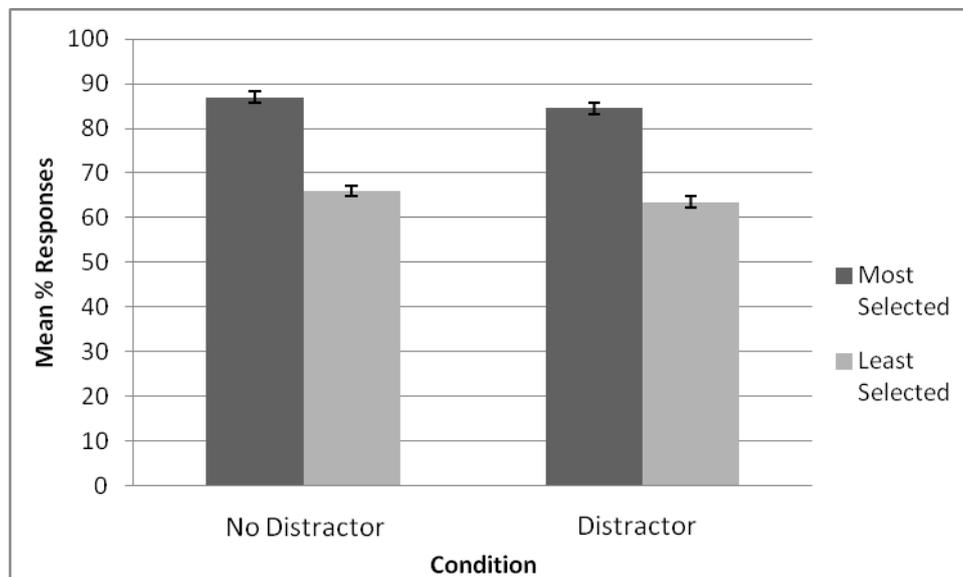
The materials were the same as in Experiment 3.

### Procedure

The procedure was the same as in Experiment 3.

### Results

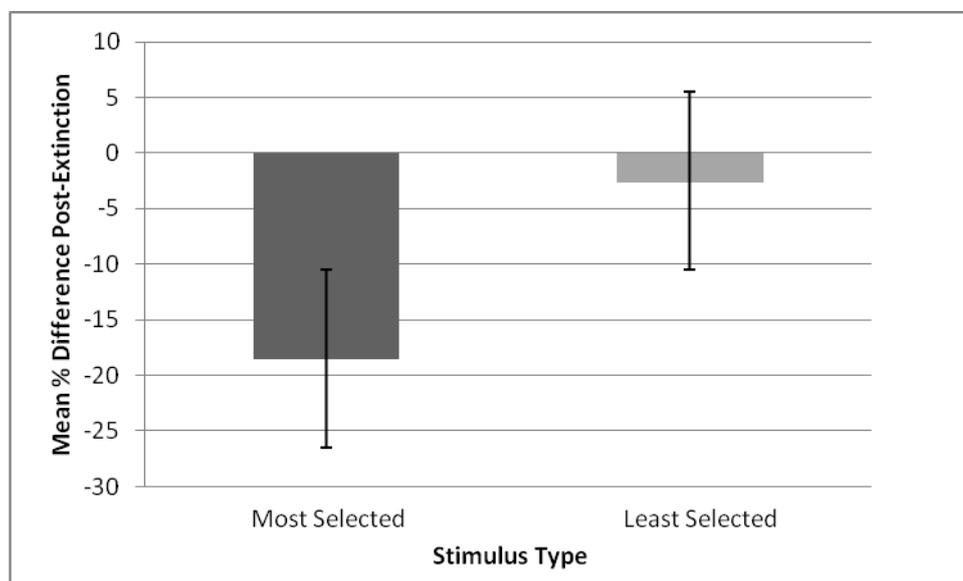
The mean numbers of trials to criterion (including the ten consecutive correct trials) was 15.70 (SD = 7.55), in the no distractor condition and 21.15 (SD = 10.73) in the distractor condition. The difference between these two conditions was not statistically significant,  $t(19) = -1.933, p = 0.068$ . The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 4.10).



**Figure 4.10:** Mean percentage scores for the most and least selected elements for the 6 year old group in the test phase. The vertical lines represent error bars with standard error.

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and condition (distractor versus no distractor) as a between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 38) = 70.117$ ,  $p = 0.000$ , but neither the main effect of condition nor the interaction of condition and stimulus type were statistically significant,  $F_s < 1$ . Therefore, the participants showed a significant degree of stimulus over-selectivity, irrespective of the condition.

All 20 participants successfully reached criterion in this extinction phase. Post-extinction, the participants had a mean percentage chosen score for the previously most-selected stimuli of 66.00 (SD = 27.80), and a mean for the previously least-selected stimuli of 61.00 (SD = 29.54). Figure 4.11 displays the mean percentage change from the test to the retest phase for the most-selected and least-selected stimuli.



**Figure 4.11:** Mean percentage change from the test to the retest phase for the most and least selected stimuli in the 6 year old group. The vertical lines represent error bars with standard error.

When the test versus retest scores for each age group were tested against zero, the decrease in control of the previously over-selected stimulus was statistically significant,  $t(19) = 3.969, p = 0.001$ . There was no emergence effect of the previously under-selected stimulus for the group,  $t(19) = 0.478, p = 0.638$ .

### ***Selective Attention***

The mean number of correctly identified targets in “Sky Search” (Subtest 1 of the TEA-Ch) was 16.15 (SD = 3.42). The mean time spent correctly identifying these targets was 206.05 (SD = 119.14) seconds. The mean number of correctly identified targets in the motor control section of this subtest was 17.75 (SD = 2.07). The mean time spent correctly identifying these targets was 41.15 (SD = 14.66) seconds. The mean attention score for this group was 10.60 (SD = 6.89). The mean number of targets found in Subtest 5 of the TEA-Ch was 16.45 (SD = 6.38).

The over-selectivity scores [ $D(18) = 0.211, p = 0.033$ ] were significantly non-normal and all associations were thus analysed using Spearman’s correlation coefficient. There were insignificant relationships between over-selectivity and selective attention score,  $r_s = .298, p = .201$ , and between over-selectivity and Map Mission scores,  $r_s = .308, p = .186$ .

### ***Cognitive Flexibility***

The participants successfully completed a mean number of 6.85 (SD = 2.50) stages and incurred a mean number of 73.25 (SD = 53.05) adjusted errors in the IED. A correlation analysis using Spearman’s correlation coefficient was conducted to investigate the associations between over-selectivity and these two dependent variables. Both the number of IED stages completed [ $r_s = .052, p = .827$ ] and the

IED adjusted errors [ $r_s = -.241, p = .306$ ] had insignificant correlations with over-selective responding.

### **Discussion**

The findings from Experiment 6 revealed that the typically developing participants demonstrated stimulus over-selectivity in a simple discrimination task, irrespective of the presence or absence of the extra cognitive task. Post-extinction, the control by the previously over-selected stimuli decreased. However an emergence effect was not evident. That is, the control exerted by the previously under-selected stimuli did not increase after the intervention phase. This result will be examined in the general discussion.

No significant relationships were found between over-selectivity and selective attention or between over-selectivity and cognitive flexibility in this group, contradicting the attention deficit theory and the postulation that inflexibility is associated with over-selective responding (Ploog, 2010).

### **Experiment 7**

Experiment 7 investigated the three aims of the current chapter in a group of typically developing children with a mean chronological age of seven years.

### **Method**

#### ***Participants***

There were 20 (1 male and 19 females) typically developing 7 year old children, with a mean age of 87.80 (SD = 1.99) months. All participants were recruited from three primary schools in Dublin, Clare and Cork.

***Materials***

The materials were the same as in Experiment 3.

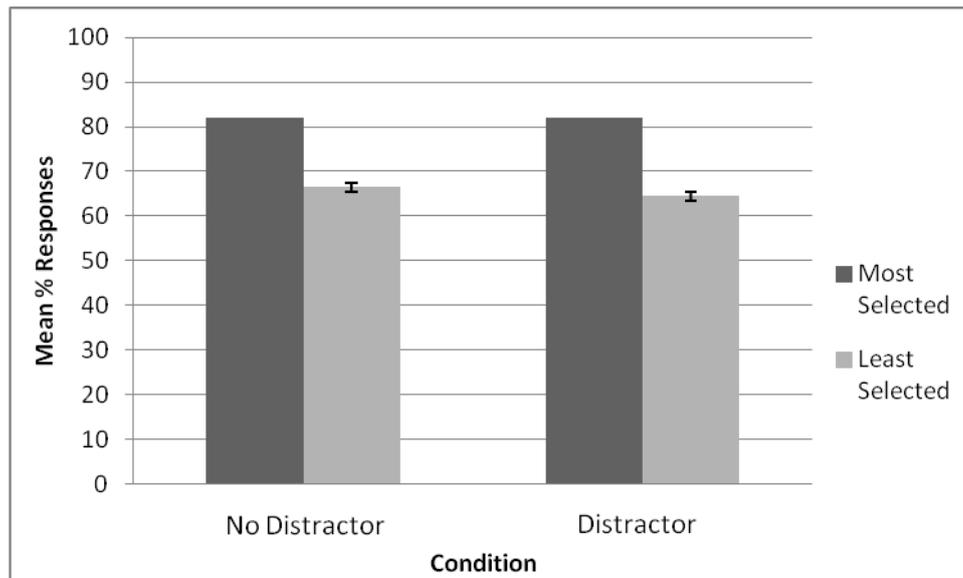
***Procedure***

The procedure was the same as in Experiment 3.

**Results**

The mean numbers of trials to criterion (including the ten consecutive correct trials) was 12.80 (SD = 3.85) in the no distractor condition and 23.35 (SD = 14.92) in the distractor condition. The difference between these two conditions was statistically significant,  $t(19) = -2.827, p = 0.011$ .

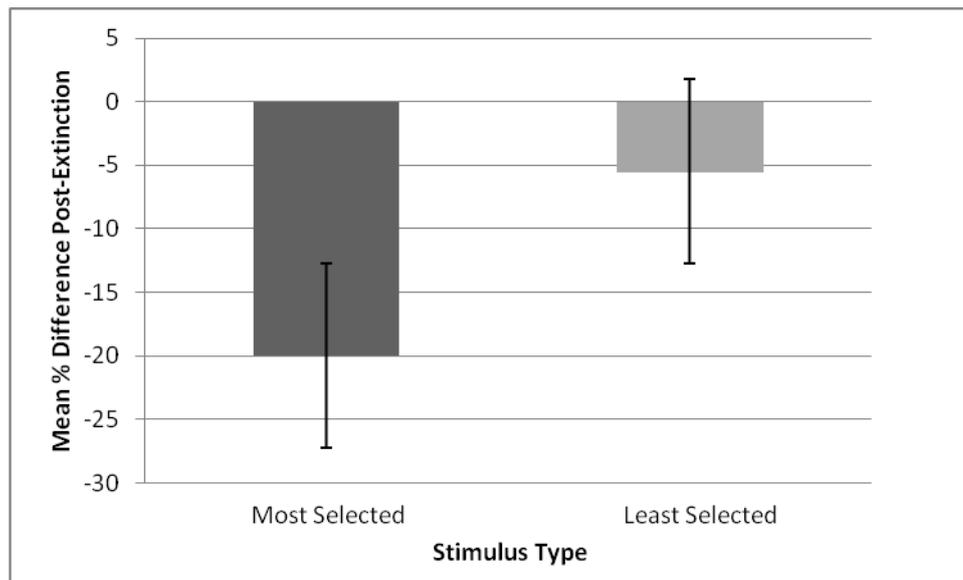
The mean number of times that each of the elements of the S+ stimuli (e.g., AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 4.12).



**Figure 4.12:** Mean percentage scores for the most and least selected elements for the 7 year old group in the test phase. The vertical lines represent error bars with standard error.

A two-way, mixed-model analysis of variance (ANOVA), with stimulus type (most-selected versus least-selected) as a within-subjects factor, and condition (distractor versus no distractor) as a between-subjects factor was employed. The ANOVA revealed that stimulus type was statistically significant,  $F(1, 38) = 47.730$ ,  $p=0.000$ , but neither the main effect of condition nor the interaction of condition and stimulus type were statistically significant,  $F_s < 1$ . Therefore, the participants showed a significant degree of stimulus over-selectivity, irrespective of the condition.

All 20 participants successfully reached criterion in the extinction phase. Post-extinction, the participants had a mean percentage chosen score for the previously most-selected stimuli of 62.00 (SD = 32.22), and a mean for the previously least-selected stimuli of 59.00 (SD = 31.77). The mean difference from the test to the retest phase for the most and least selected stimuli is displayed in Figure 4.13.



**Figure 4.13:** Mean percentage change from the test to the retest phase for the most and least selected stimuli in the 7 year old group. The vertical lines represent error bars with standard error.

When the test versus retest scores for each age group were tested against zero, the decrease in control of the previously over-selected stimulus was statistically significant,  $t(19) = 2.496, p = 0.022$ . There was no emergence effect of the previously under-selected stimulus for the group,  $t(19) = 0.674, p = 0.508$ .

### ***Selective Attention***

The mean number of correctly identified targets in “Sky Search” (Subtest 1 of the TEA-Ch) was 17.85 (SD = 2.03). The mean time spent correctly identifying these targets was 172.55 (SD = 47.52) seconds. The mean number of correctly identified targets in the motor control section of this subtest was 17.95 (SD = 2.06). The mean time spent correctly identifying these targets was 32.25 (SD = 11.40)

seconds. The mean attention score for the group was 8.03 (SD = 3.05). The mean number of targets found in Subtest 5 of the TEA-Ch was 22.55 (SD = 6.253).

The over-selectivity scores [ $D(18) = 0.193, p = 0.049$ ] were significantly non-normal and all associations were thus analysed using Spearman's correlation coefficient. There were insignificant relationships between over-selectivity and selective attention score,  $r_s = .136, p = .148$ , and between over-selectivity and Map Mission scores,  $r_s = -.033, p = .892$ .

### ***Cognitive Flexibility***

The participants successfully completed a mean number of 7.35 (SD = .59) stages and incurred a mean number of 59.30 (SD = 11.30) adjusted errors in the IED. A correlation analysis using Spearman's correlation coefficient was conducted to investigate the associations between over-selectivity and these two dependent variables. Both the number of IED stages completed [ $r_s = -.312, p = .180$ ] and the IED adjusted errors [ $r_s = .123, p = .606$ ] had insignificant correlations with over-selective responding.

### **Discussion**

The typically developing children in this experiment demonstrated stimulus over-selectivity in a simple discrimination task, irrespective of the presence or absence of the extra cognitive task. Post-extinction, it was revealed that both the control by the previously over-selected stimuli and the under-selected stimuli decreased. Therefore, no extinction-induced recovery effect was seen in this group. This finding will be explored in the general discussion.

No significant relationships were found between over-selectivity and selective attention or between over-selectivity and cognitive flexibility in this group,

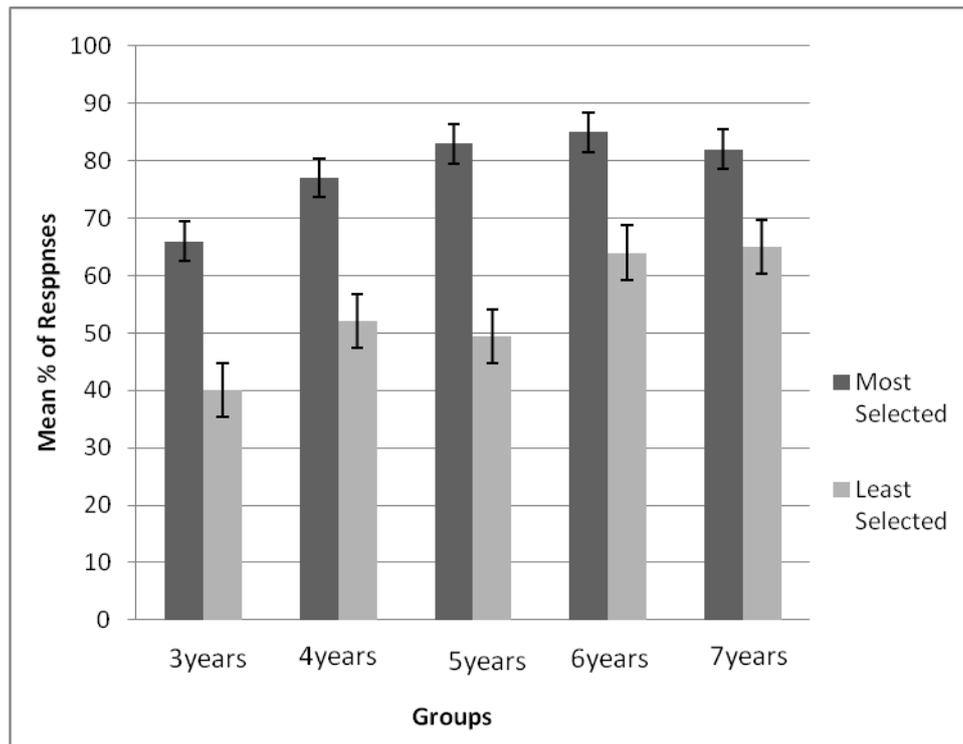
offering evidence against the attention deficit theory and the postulation that inflexibility is correlated with over-selective responding (Ploog, 2010).

### **Developmental Trend Analysis**

Experiments 3, 4, 5, 6, and 7 investigated stimulus over-selectivity in 20 typically developing children aged 3, 4, 5, 6 and 7 years old respectively. This section analyses the five groups together to examine the potential evidence of developmental trends in stimulus over-selectivity, selective attention and cognitive flexibility.

#### ***Stimulus Over-selectivity***

To investigate developmental age trends in over-selective responding across these five age groups, the mean number of times that each of the elements of the S+ stimuli was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified. The results from both the distractor and no distractor conditions were combined and are displayed in Figure 4.15.



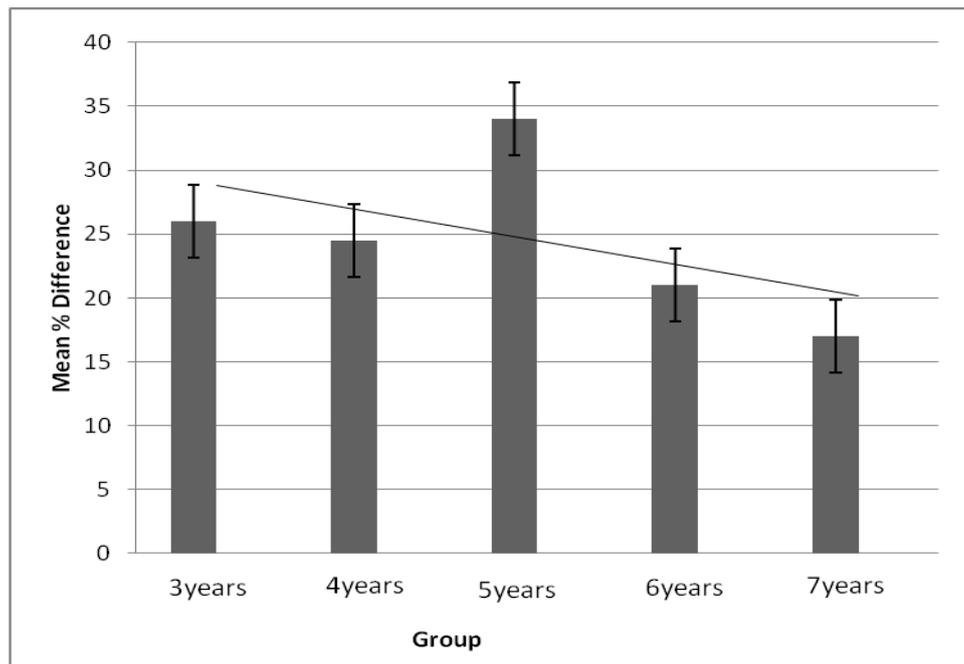
**Figure 4.15:** Mean percentage in the test phase of the most-selected and least-selected stimulus elements for the five age groups in both the distractor and no distractor conditions. The vertical lines represent error bars with standard error.

A 2x5 mixed-model ANOVA was performed with stimulus type (most versus least-selected) as the within- subjects variables, and age group (3, 4, 5, 6, and 7) as the between-subjects variable, and percentage of times the most-selected or least-selected elements were selected as the dependent measure. This analysis showed that there was a significant main effect for stimulus type [ $F(1, 93) = 303.66, p = 0.000$ ], a significant main effect for age group [ $F(4, 93) = 5.945, p = .000$ ] and a significant interaction effect for the two variables [ $F(4, 93) = 4.484, p = .001$ ].

Simple effects analyses were conducted to determine where the significant differences in stimulus selection emerged with regard to age group. The findings revealed a significant difference for the 3 year old group [ $F(1, 93) = 69.208; p < 0.05$ ], for the 4 year old group [ $F(1, 93) = 63.527; p < 0.05$ ], for the 5 year old group

[ $F(1, 93) = 121.655$ ;  $p < 0.05$ ], for the 6 year old group [ $F(1, 93) = 45.735$ ;  $p < 0.05$ ], and for the 7 year old group [ $F(1, 93) = 14.823$ ;  $p < 0.05$ ].

Inspection of Figure 4.16 reveals the mean difference in percentage of selection between the most-selected stimulus and the least-selected stimulus across all five age groups, with the results from the distractor and no distractor conditions combined.

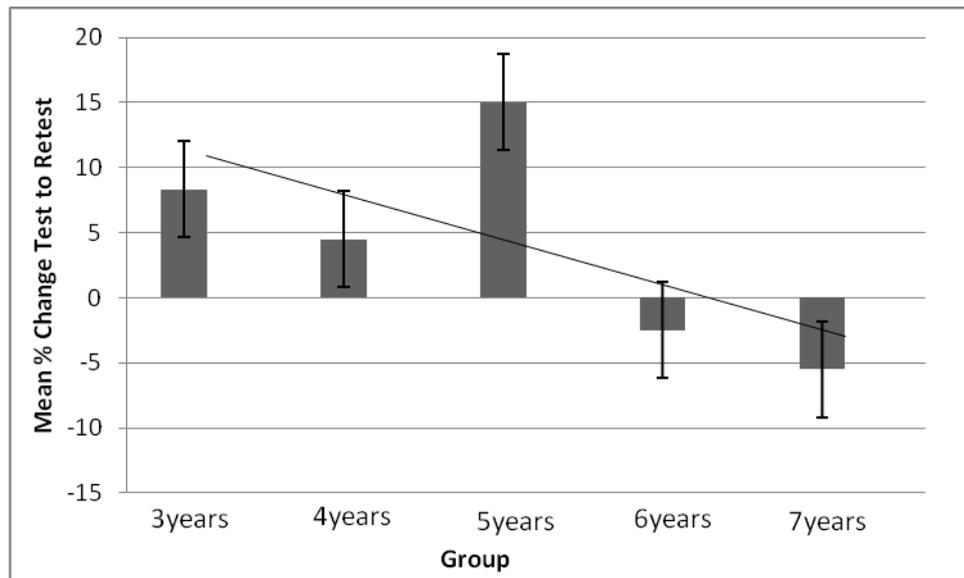


**Figure 4.16: Mean percentage difference between the most and least selected stimulus elements for the five age groups. The diagonal horizontal line indicates the trend line in the data. The vertical lines represent error bars with standard error.**

The decreasing trend-line demonstrates that the mean percentage difference (i.e., the level of over-selective responding) decreases as a function of chronological age. A one-way ANOVA revealed that there was a statistical difference in the level of stimulus over-selectivity demonstrated by the five age groups,  $F(4, 191) = 5.184$ ,  $p = .001$ . Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 5 year old group was significantly different from both the 6 year old

and 7 year old groups. However, the 3 and 4 year olds group did not significantly differ from the 5, 6, or 7 year old groups.

The mean percentage change for the under-selected stimulus from the test to the retest phase was calculated for all five groups by subtracting the test score from the retest score (see Figure 4. 17).



**Figure 4.17:** Mean percentage change from the test to the retest phase for the most and least selected stimuli in each group. The descending horizontal diagonal line indicates the trend line in the data. The vertical lines represent the error bars with standard error

The decreasing trend-line suggests that the emergence effect decreases as a function of chronological age. A one-way ANOVA revealed that the difference in the mean percentage change in the under-selected stimulus post-extinction across the five age groups was slightly insignificant,  $F(4, 93) = 2.195, p = .076$ .

When tested against zero, the decrease in control exerted by the previously over-selected stimuli was statistically significant across all age groups,  $t(97) = 7.545$ ,

$p=0.001$ , but the emergence of the previously under-selected stimulus across all age groups was not significantly different from zero,  $t(97) = -1.509$ ,  $p= .134$ .

**Correlation Analysis**

The over-selectivity scores [ $D(98) = 0.191$ ,  $p= 0.000$ ] were significantly non-normal and all associations were thus analysed using Spearman’s correlation coefficient. The associations between levels of over-selectivity and selective attention score, Map Mission score, number of IED stages completed and number of adjusted errors in the IED were explored.

Statistically significant correlations were found between over-selectivity and the Map Mission score, and between over-selectivity and the number of IED stages completed. There were no significant correlations between over-selectivity and the selective attention score, and between over-selectivity and the number of IED adjusted errors.

		<i>Selective Attention Score</i>	<i>Map Mission</i>	<i>IED Stages</i>	<i>IED Adjusted Errors</i>
Over-selectivity	Spearman’s rho	.144	-.261	-.277	.155
	Sig. (2-tailed)	.156	.009	.006	.128
	N	98	98	98	98

**Table 4.0: Spearman correlation coefficients for associations between scores for over-selectivity and selective attention score, Map Mission score, Intra/Extra Dimensional Set Shift stages completed and Intra/Extra Dimensional Set Shift adjusted errors**

A Spearman’s correlation coefficient analysis was also conducted to examine the relationship between chronological age and over-selectivity, selective attention score, Map Mission score, number of IED stages completed and number of adjusted

errors in the IED. This analysis was necessary to develop a developmental profile for this population.

		<i>Over-selectivity</i>	<i>Selective Attention Score</i>	<i>Map Mission</i>	<i>IED Stages</i>	<i>IED Adjusted Errors</i>
Chronological Age	Spearman's rho	-.253	-.222	.851	.417	-.561
	Sig. (2-tailed)	.012	.028	.000	.000	.000
	N	98	100	100	100	100

***Table 4.1: Spearman correlation coefficients between chronological age and mean scores for over-selectivity, selective attention, Map Mission score, Intra/Extra Dimensional Set Shift stages completed and Intra/Extra Dimensional Set Shift adjusted errors***

Inspection of Table 4.1 shows that statistically significant correlations were found between chronological age and stimulus over-selectivity, selective attention score, map mission score, IED stages completed and IED adjusted errors.

### **General Discussion**

The aim of the current chapter was to expand upon the theoretical framework of stimulus over-selectivity by exploring the Comparator Theory as a means of explaining over-selective responding in typically developing children, a population not examined in the research using the current procedure. Specifically, Chapter 4 aimed to investigate over-selective responding in this non-clinical sample and explore the effects of extinction as a potential remediation strategy for over-selectivity in 3 to 7 year old children.

A significant main effect was found across groups for the most versus least-selected stimuli and for age group, demonstrating that each of the five age groups demonstrated over-selectivity. The 5 year olds exhibited the greatest mean

percentage difference between the most and least selected stimuli in both the distractor and no-distractor conditions.

Following the extinction procedure, the greatest mean percentage difference was just 7.22% between the most and least selected stimuli in the 3 year old group. Interestingly, the 5 year old group had the greatest mean difference pre-extinction (35.00%) and the smallest mean difference post-extinction (2.00%). This supports Reynolds (2012) statement that extinction is most effective when initial levels of over-selectivity are high. When over-selectivity is low, the complex stimulus may be perceived as a compound rather than two independent stimuli. Generalisation may then occur to the under-selected stimulus when the over-selected stimulus is extinguished and thus may not emerge to control responding. However, when over-selectivity is high (as in the 5 year old group) the complex stimulus elements were more likely to have been perceived as individual stimuli, and therefore generalisation was less likely to occur (Reynolds, 2012).

Extinction was successful in significantly decreasing the behavioural control of the previously over-selected stimuli on the responses of each of the five age groups. The control exerted on responding by the previously under-selected stimuli emerged in the 3, 4 (albeit insignificantly) and 5 year old groups offering support for the comparator theory of over-selectivity. In contrast, the emergence effect was not found in the 6 or 7 year old groups providing evidence for the attention deficit theory. Specifically, these two groups might not have initially attended to the individual stimuli and therefore the previously under-selected element could not control responding post-extinction as it was never learned about in the first place.

Reed (2010) provided an alternative possibility for the lack of emergence effect in the oldest two groups. Less initial over-selectivity was shown by the 6 and

7 year olds relative to the 3, 4 and 5 year olds. This is in line with Ross (1976) who stated that children attend to one aspect of a stimulus only until about age six. If the 6 and 7 year old groups in the current study perceived the initial complex Sr+ as a compound stimulus as opposed to individual element, then they were less likely to over-select due to decreased chances of generalised extinction effects (Reynolds, 2012; Plaisted, O’Riordan, & Baron-Cohen, 1998).

In Experiments 6 and 7, it is possible that both stimulus elements were attended to by the participants but neither acquired substantial behavioural control. Therefore the previously ‘under-selected’ stimulus would not be able to ‘emerge’ as it was already controlling behaviour to some extent (Reed, 2010; Reynolds, 2012). The finding that the 5 year old group had the greatest emergence effect lends support to this rationale, as this group had the highest level of over-selectivity pre-extinction. Therefore, while it is possible that the 6 and 7 year olds simply did not initially attend to both stimulus elements, it appears that Reed’s (2010) rationale has face validity. That is, the 6 and 7 year old participants emitted lower over-selective responding and thus, the enhancement of stimulus control by what was termed the under-selected stimulus could not be facilitated. These findings warrant further replication and exploration to confirm this contribution to the current theoretical framework of stimulus over-selectivity.

This chapter also aimed to create a developmental profile of stimulus over-selectivity in 3 to 7 year old typically developing children and to conduct a correlation analysis between over-selectivity, chronological age, selective attention and cognitive flexibility. Several interesting findings were revealed. A significant association was found between over-selectivity and one of the two selective attention tasks offering support for the attention deficit theory. The fact that this correlation

was only evident in one of the two subtests does mean that further research is required to confirm that selective attention is associated with levels of over-selective responding.

A statistically significant correlation was also revealed between over-selectivity and one of the two cognitive flexibility dependent variables offering modest support to Ploog's (2010) postulation. However, further exploration is necessary to confirm that over-selectivity is in fact associated with inflexible cognitive behaviour.

The correlation analyses also revealed that chronological age had statistically significant associations with over-selectivity, selective attention, and cognitive flexibility. Visual inspection of trend lines demonstrated that over-selective responding decreased as a function of age, supporting Ross' (1976) postulation that children over-select only until about age six.

In the selective attention subtests, the number of correct targets identified increased and the time spent locating these targets decreased as a function of increasing chronological age. Thus, as the participants got older, their selective attention improved while their over-selective behaviour decreased. Finally, in terms of cognitive flexibility, the older the participants the more stages they completed in the IED and the less adjusted errors they emitted. Thus, as the participants got older, the levels of cognitive flexibility improved while the levels of over-selectivity decreased. Both of these findings confirm the necessity of further investigation into the associations between stimulus over-selectivity and selective attention and between stimulus over-selectivity and cognitive flexibility.

## Chapter 5:

Emergence of Under-selected Stimuli following Extinction of  
Over-selected Stimuli in Elderly Individuals

The comparator theory of stimulus over-selectivity predicts that post-learning manipulations of the over-selected cue should enhance the performance of the under-selected cue (Reed, 2007). Chapter 4 investigated the validity of this prediction in a novel population by examining the effects of extinction on over-selective responding in 100 typically developing children, aged three to seven years. The findings showed that extinction led to decreased control of the previously over-selected stimulus across all ages but that the previously under-selected cue only emerged to exert behavioural control over responding in the three youngest age groups (3 to 5 years). The aim of Chapter 5 was to extend this research and study the generality of extinction as an effective remediation strategy for over-selectivity by exploring its effects in typically developing elderly individuals. It is necessary to further develop a non-clinical model of over-selectivity so that the effect can be explored, and interventions developed, on a less vulnerable population prior to their use on clinical samples.

Previous research investigating stimulus over-selectivity has frequently employed the matching-to-samples paradigm (Wilhelm & Lovaas, 1976; Dube & McIlvane, 1999; Dube et al., 2000; Geren, Stromer, & Mackay, 1997; Gutowski, Geren, Stromer, & Mackay, 1995). Broomfield, McHugh and Reed (2008) used this procedure to investigate the emergence of under-selected stimuli to control behaviour post-extinction in typically developing students aged 18-32 years. Results showed that the previously under-selected stimuli did emerge to control behaviour. These findings suggest that under-selected cues are learned about during training but the test scores reflect a performance deficit, rather an initial failure to learn, or attend.

Reynolds, Watts and Reed (2012) found similar results in their examination of the effects of extinction in 16 typically developing adults (18-55 years) when a distractor task was employed. Results showed that in the experimental group (where the over-selected stimulus was extinguished) the previously most selected stimulus was chosen less and the previously least selected stimulus was chosen more in the retest phase. Therefore extinction allowed emergence of control of the previously under-selected stimulus, despite the fact that it was not directly conditioned. This finding offers further support for the comparator theory of stimulus over-selectivity that attributes this problem to a retrieval or performance deficit as opposed to an attention-deficit (Reed, 2007).

The presence of over-selectivity in elderly adults was first demonstrated by McHugh and Reed (2007) who employed a simple visual discrimination task, also utilised throughout the current thesis. A developmental trend was discovered whereby the level of over-selectivity increased as a function of chronological age. The authors identified and verbally punished the over-selected elements which resulted in the enhancement of the stimulus control by the previously under-selected elements in the two younger age groups (18-22 years and 47-55 years). If the participants had not attended to the stimuli, these elements could not have emerged to control responding following a post-learning manipulation. McHugh and Reed (2007) concluded that these results were in line with the comparator theory. That is, the originally under-selected stimuli did not go unattended and that the problem occurred at the retrieval level.

It should be noted that it is possible that separate processes affect stimulus control and that there are two forms of stimulus over-selectivity (White & Ruske, 2002;

Reed, Savile & Truzoli, 2012; Reed et al., 2009). This postulation is supported by the results of the oldest group (70-80 years) in McHugh and Reed's (2007) study where the previously under-selected stimuli did not emerge to control responding post-intervention as it did in the younger two age groups. The authors suggested that the reason for the absent emergence effect was that different processes may be involved in the oldest group of participants. Either the comparator theory did not apply to this age group or the elderly individuals may experience an attentional deficit.

## **Experiment 8**

McHugh and Reed (2007) identified that elderly typically developing adults may present with a different form of stimulus over-selectivity. These findings were preliminary and warrant further investigation. The first aim of this study is to replicate the findings of the oldest group in McHugh and Reed (2007). This will enable us to further examine the different processes occurring in over-selective responding in elderly individuals.

A key prediction of the Comparator Theory is that a post-learning decrease in the control exerted by one stimulus should allow previously learned but unexpressed stimuli to emerge and control behaviour. The second aim of this study is to further investigate the utility of the Comparator Theory as an explanation for over-selectivity.

The elderly participants in the McHugh and Reed (2007) study had a mean chronological age range of 70-80 years. The third aim of this study was to extend this study to include a more representative range of elderly typically developing individuals.

Individuals aged 60-90 years were assessed in order to ascertain if different processes are, in fact, involved in the over-selective responding in this non-clinical population.

## **Method**

### ***Participants***

There were sixty typically developing participants, 20 in each of three age categories: 60- 69 years (mean= 64:5, SD = 3:0); 70 -79 years (mean= 75:1, SD = 2:2); and 80- 89 years (mean= 83:2, SD = 2:2). All participants were volunteers recruited through personal acquaintances of the experimenters. The study employed a between-subjects design, with 50% of the participants in each age group randomly assigned to the experimental group and the other 50% to the control group. Participants did not receive any payment for participation.

### ***Materials***

***Mini-Mental State Examination*** (MMSE; Folstein, Folstein, & McHugh, 1975).

The MMSE is the most commonly used instrument for screening cognitive function.

This test is not suitable for making a diagnosis but can be used to indicate the presence

of cognitive impairment, such as in a person with suspected dementia. The MMSE is

far more sensitive in detecting cognitive impairment than the use of informal

questioning or overall impression of a patient's orientation. The MMSE test includes

simple questions and problems in a number of areas: the time and place of the test,

repeating lists of words, arithmetic such as the serial sevens, language use and

comprehension, and basic motor skills. Any score greater than or equal to 25 points (out

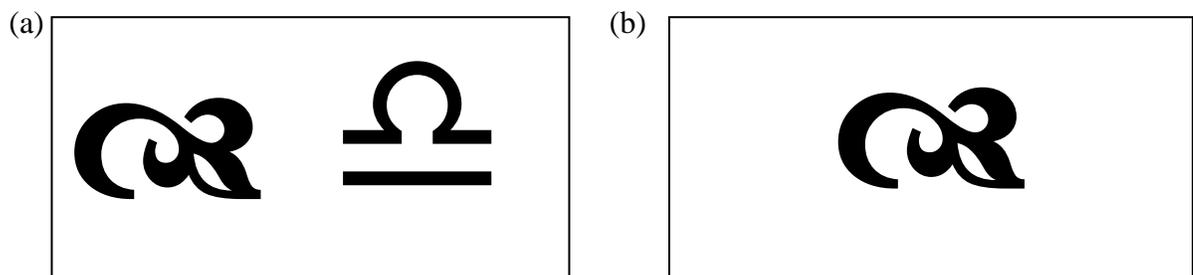
of 30) is effectively normal. Below this, scores can indicate severe ( $\leq 9$  points), moderate (10-20 points) or mild (21-24 points) cognitive impairment. The MMSE was used as a screening tool. Participants were excluded from the study if they did not obtain a score of greater than or equal to 25.

***Wechsler Adult Intelligence Scale- Fourth Edition*** (WAIS-IV; Wechsler, 2008). This is a paper-and-pencil test designed to measure intelligence in adults and older adolescents aged 16:0-90:11 years that takes approximately 60-90 minutes to complete. The WAIS-IV is comprised of ten core subtests and five supplementary subtests. Full Scale IQ (FSIQ) scores are based on the total combined performance of the Verbal Comprehension Index, Perceptual Reasoning Index, Working Memory Index and Processing Speed Index. The WAIS-IV was standardized on a sample of 2,200 people in the United States ranging in age from 16 to 90. The median FSIQ is centered at 100, with a standard deviation of 15. In a normal distribution, 68% of adults would fall within one standard deviation above and below the mean IQ score (i.e., between 85 and 115).

***Wisconsin Card Sort Test*** (WCST; Grant & Berg, 1948). The WCST is a neuropsychological test of set-shifting or “poor mental flexibility” (Hill, 2004; p. 197). Using a computerized version of the WCST, the participants were required to match response cards to four stimulus cards along one of three dimensions (colour, form or number) on the basis of verbal feedback (correct or incorrect). The participants were not given any information about the dimensions. After sorting a consecutive series of ten cards in one category, participants were asked to sort the cards in a different category. Perseveration errors are defined as a failure to shift set to the new sorting

criterion. The only dependent variable examined in the current experiment was percentage of perseverative errors, which is the most commonly used measure of WCST performance (Hsieh, Yeh, Lee, Huang, Chen, Yang, Chiu, Lu & Liao, 2010).

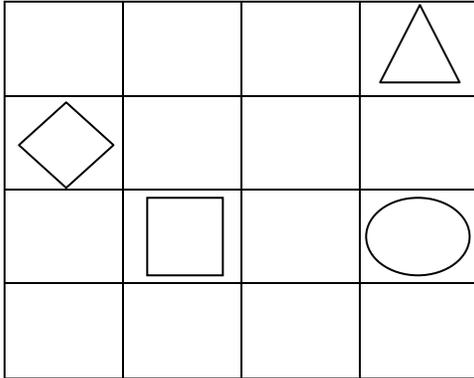
***Stimulus over-selectivity testing materials.*** These laminated stimulus cards, measuring 12cm. by 10 cm., consisted of one black stimulus or two black stimuli on a white background. The elements were characters obtained from fonts available in Microsoft 2003. The fonts were symbol, wingdings and wingdings 2. These stimuli were different to the pictures employed in Experiments 1A, 1B and 2 (e.g., chicken, clock, and book). The Microsoft fonts were chosen to ensure that materials were consistent with the materials utilised in Experiments 3 to 7 with typically developing children as well as McHugh and Reeds' (2007) study where the participants were elderly individuals without a diagnosis of ASC. Cards were labelled A, B, C, D, E, F, G, H, AB, BA, CD, DC, EF, FE, GH, HG, I, J, K, and L.



***Figure 5.0: Example of Complex Stimulus AB(a) and a Single Element Stimulus A(b)***

***Distractor Task.*** A 4x4 grid containing four different shapes, one in each of four of the 16 squares (see Figure 5.1), was used as the distractor task for each of the 60

participants. This is the same distractor task used by Reed and Gibson (2005) and McHugh and Reed (2007; see Chapter 1, Section 5.4 for details).



*Figure 5.1: An example of a memory grid used as a distractor task across participants in each age group*

### ***Procedure***

The MMSE, WCST and WAIS-IV were conducted in a quiet room prior to the test of stimulus over-selectivity. If a participant scored lower than 25 out of 30 in the MMSE, testing was terminated at this point.

***Distractor Task.*** A distractor task (eg., see Figure 5.1) was employed as a within-subjects variable for each of the participants. The participants were individually shown a distractor 4x4 grid for 20 seconds and were instructed to remember the shapes and the locations of the stimulus shapes in the grid as they would be asked to replicate it by drawing it at the end of the experiment. There was a choice of four different distractor cards that were randomly chosen for each participant in the distractor condition.

***Training Phase.*** This phase followed the presentation of the 4x4 grid and associated instructions. Each participant was trained individually. The experimenter sat

directly opposite the participant throughout the experiment. The stimulus cards were placed in the centre of the table half-way between the participant and the experimenter. Participants were instructed as follows: “You will be shown two cards containing two symbols on each. Please select a card by pointing to that card. Point to the card rather than to an individual symbol. You will be given feedback of “yes” for some cards and “no” for others. Your choices will be recorded.”

For each discrete trial, participants were presented with two compound stimuli (e.g., ‘AB’ and ‘CD’; see Figure 5.0a). If the participant pointed to the predetermined reinforced compound (e.g., AB) they received positive feedback from the experimenter who said “yes” enthusiastically with a smile. If the participant pointed to the other card (e.g., ‘CD’) they received negative feedback from the experimenter who said “no” in a flat tone without a smile. Each trial lasted until a response was made and each inter-trial interval was approximately five seconds long. The positions of the cards were randomised so that 50% of the time the correct card was presented on the right, and 50% of the time on the left. During the training phase, the reinforced compound ‘AB’ was always paired with the non-reinforced compound ‘CD’. Participants reached criterion in the training phase once they chose the reinforced compound ten times consecutively. The stimulus elements used in the compounds were different for each participant in order to prevent an intrinsically more salient stimulus from always having the same role.

***Test Phase.*** Participants were presented with two cards simultaneously, each one comprising of just one element from the complex stimulus from the training phase (e.g., see Figure 5.0b). The pictures were paired so that the participants had a choice of a previously reinforced stimulus (S+) and a previously non-reinforced stimulus (S-).

There were five trials for each combination of previously positively reinforced and non-reinforced components of the compound stimuli (i.e., A v C, A v D, B v C, B v D) giving a total of 20 trials. No feedback was provided by the experimenter to the participant during test trials. To ensure maintenance of trained discriminations of complex stimuli, ten probe trials were presented with no feedback throughout the test phase, giving a total of 30 test trials. The presentation order of the complex stimulus and single stimulus cards was randomised over the total trials (20 test trials and 10 probe trials). The training and test phases all occurred during the same session.

***Extinction Phase.*** For the experimental group, the over-selected stimulus was determined (i.e., A, B, C or D) and was paired with one of four novel stimuli (E, F, G, or H). Participants were positively reinforced (the experimenter says “yes” enthusiastically with a smile) for choosing the novel stimulus, and not the over-selected stimulus. Criterion was reached when the participants chose the novel stimulus ten times consecutively.

For the participants in the control group, the over-selected card was not determined. During this phase of the study, the 30 participants were shown the novel stimuli paired together. Of the pairs, one of the cards was given feedback of “yes”, while the other was given feedback “no”. No card was extinguished.

***Re-testing phase.*** The same test procedure was used as the first testing phase, with no feedback provided to the participants.

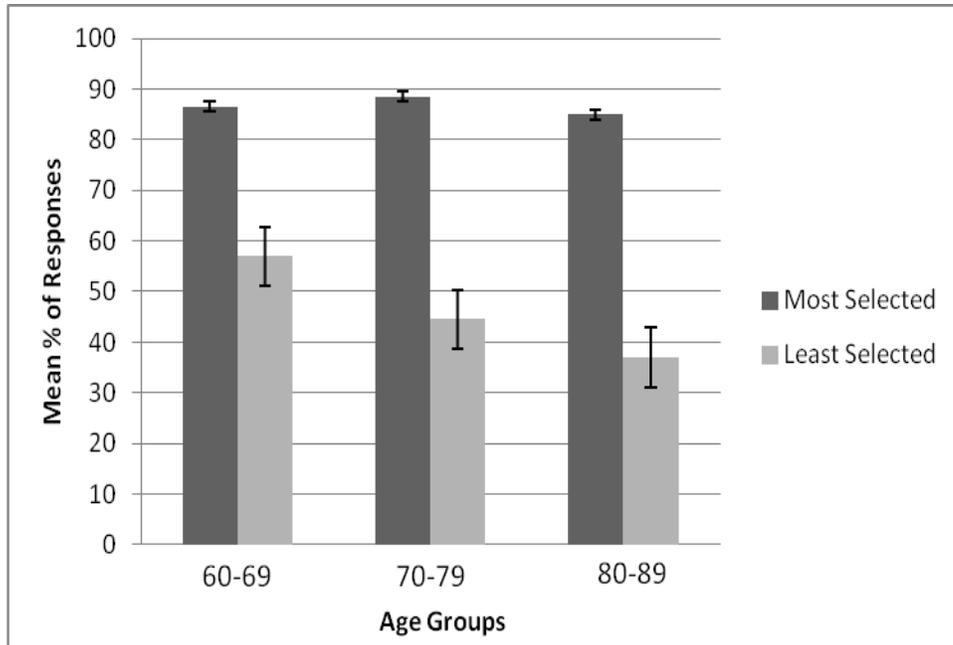
***Distractor Test.*** Each participant was instructed to replicate the memory grid by drawing the four shapes in the correct four positions onto the empty 4x4 grid provided by the experimenter.

## Results

### *Stimulus Over-selectivity*

All 60 participants successfully completed the training phase. The mean numbers of trials to criterion (including the ten consecutive correct trials) for the three age groups were: 24.80 (SD = 4.36) for the 60-69 year olds; 26.40 (SD = 4.78) for the 70-79 year olds; and 28.45 (SD = 3.87) for the 80-89 year olds. A one-way ANOVA was conducted with age group as the factor and trials to criterion as the dependent measure. The analysis revealed a statistically significant effect for age group,  $F(2, 57) = 3.53$ ,  $p = .036$ , indicating that the three age groups differed in the number of trials required to meet the criterion. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 60-69 year old group was significantly different from the 80-89 year old group but that the mean number of trials it took for the 70-79 year old group to reach criterion in the training phase did not differ significantly from the other two groups.

The mean number of times that each of the elements of the S+ stimuli (e.g. AB) was selected during the test phase was calculated in order that the most-selected and least-selected elements could be identified (see Figure 5.2).



**Figure 5.2: Mean percentage scores for the most and least selected elements for each age group in the test phase. The vertical lines represent error bars with standard error.**

A 2x3 mixed-model ANOVA was performed with stimulus type (most versus least-selected) as the within- subjects variables, and age group (60-69, 70-79 and 80-89) as the between-subjects variables, and percentage of times the most-selected or least-selected elements were selected as the dependent measure. This analysis showed that there was a significant main effect for stimulus type [ $F(1, 57) = 352.919, p = 0.000$ ], a significant main effect for age group [ $F(2, 57) = 8.037, p = .001$ ] and a significant interaction effect for the two variables [ $F(2, 57) = 6.796, p = .002$ ].

Simple effects analyses were conducted to determine where the significant differences in element selection emerged with regard to age group. The findings revealed a significant difference for the 60 to 69 year old group [ $F(1, 57) = 62.415; p <$

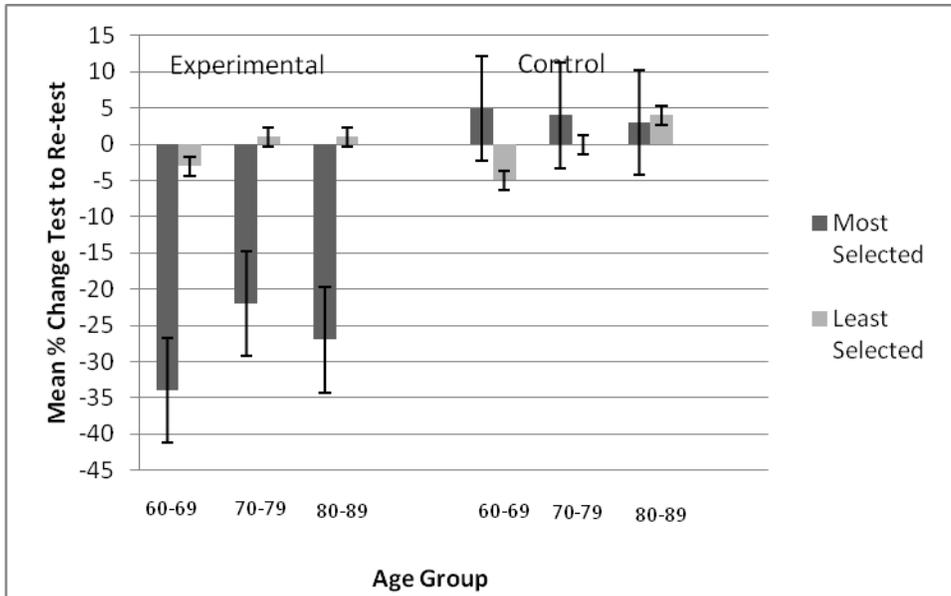
0.05], for the 70 to 79 year old group [ $F(1, 57) = 138.851; p < 0.05$ ], and for the 80 to 89 year old group [ $F(1, 57) = 165.244; p < 0.05$ ].

McHugh and Reed (2007) examined the numbers of participants who exhibited a difference of 20% or greater in their selection between the two types of stimulus elements. In the current study, 90% of the 60-69 year olds, 90% of the 70-79 year olds and 100% of the 80-89 year olds met this criterion. The mean percentage difference between the most and least selected stimulus was 29.50 (SD = 10.99) for the 60-69 group was, 43.00 (SD = 21.55) for the 70-79 year olds and 48.00 (SD = 16.73) for the 80-89 year olds. A one-way ANOVA revealed that there was a statistically significant difference between groups in the mean percentage different between the most and least selected stimuli,  $F(2, 57) = 6.353, p = 0.003$ . Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 60-69 year old group was significantly different from both the 70-79 year old group and 80-89 year old group. The mean difference for the 70-79 year old group was not significantly different from the 80-89 year old group.

The previously over-selected stimulus was only extinguished in the experimental group. All 30 participants successfully reached criterion in this extinction phase. The mean numbers of trials to criterion (including the ten consecutive correct trials) for the three age groups were: 15.25 (SD = 3.837) for the 60-69 year olds; 15.90 (SD = 2.751) for the 70-79 year olds; and 18.15 (SD = 4.603) for the 80-89 year olds. A one-way ANOVA revealed that these scores were statistically different,  $F(2, 57) = 3.196, p = 0.048$ . Tukey's HSD test indicated that the mean score for the 60-69 year old group

was significantly different from the 80-89 year old group. The mean difference for the 70-79 year old group was not significantly different from either of the other two groups.

The mean percentage change from the test to the retest phase was calculated for both the experimental and control groups by subtracting the test score from the retest score (see Figure 5.3).



**Figure 5.3: Mean percentage change from the test to the re-test phase for the most and least selected stimuli in the experimental and control groups across the three age groups. The vertical lines represent error bars with standard errors.**

A 2x2x3 mixed-model ANOVA was conducted with stimulus type (most versus least-selected) as the within- subjects variables, and group type (experimental versus control) and age group (60-69, 70-79 and 80-89) as the between-subjects variables, and percentage difference between the most or least selected elements from the test to re-test phase were selected as the dependent measure. This analysis showed that there was a significant main effect for stimulus type [ $F(1, 54) = 17.985, p = 0.000$ ], a significant

main effect for group type [ $F(1, 54) = 25.166, p = .000$ ] but an insignificant main effect for age group [ $F(2, 54) = 1.085, p = 0.345$ ]. The ANOVA also revealed that there was a significant interaction effect for stimulus type and group type [ $F(1, 54) = 33.827, p = 0.000$ ]. However, there were insignificant interaction effects for stimulus type and age group [ $F(2, 54) = 0.378, p = .678$ ], and age group and group type [ $F(2, 54) = 0.310, p = 0.734$ ]. Finally, the three-way interaction effect between the three variables was also not statistically significant [ $F(2, 54) = 0.672, p = 0.515$ ].

A simple effects analysis was employed to explore the significant interaction effect found for stimulus type and group type. This analysis revealed that there was a significant difference for both the experimental group [ $F(1, 54) = 57422.16; p < 0.05$ ], and the control group [ $F(1, 54) = 281.234; p < 0.05$ ]. When the mean scores from the experimental group were tested against zero, the decrease in control exerted by the previously over-selected stimuli was statistically significant,  $t(29) = 7.347, p = 0.000$ , but the emergence of the previously under-selected stimulus was not significantly different from zero,  $t(29) = -0.000, p = 1.000$ . When the mean scores from the control group were tested against zero, neither the decrease in control exerted by the previously over-selected stimuli [ $t(29) = -1.795, p = 0.083$ ] nor the emergence of the previously under-selected stimuli [ $t(29) = 0.141, p = 0.889$ ] were statistically significant across all age groups.

### ***Stimulus Over-selectivity and IQ***

The mean IQ scores were 109.05 (SD = 12.15) for the 60-69 year olds, 104.70 (SD = 12.74) for the 70-79 year olds, and 97.85 (SD = 12.23) for the 80-89 year olds

demonstrating a descending developmental trend where IQ scores decreased as a function of chronological age. A one-way ANOVA was conducted with age group as the factor and IQ score as the dependent measure. The analysis revealed a statistically significant effect,  $F(2, 57) = 4.164, p = .021$ , indicating that the three age groups differed in cognitive functioning. Post hoc comparisons using the Tukey HSD test revealed that the mean IQ scores for the 60-69 year old group was significantly different from the 80-89 year old group but that the mean IQ scores for the 70-79 year old group did not differ significantly from the other two groups.

A parametric Pearson's correlation analysis was conducted between levels of over-selectivity and IQ scores. Over-selectivity scores were determined by subtracting the percentage for the least-selected stimuli from the most-selected stimuli in the test phase. No statistically significant correlation was found,  $r = -.056, p = 0.673$ , indicating that over-selectivity is not correlated with IQ. However it should be noted that although IQ was not reliably correlated with the amount of over-selectivity exhibited there was a numerical trend in the differences showing that the lower the IQ the greater the over-selectivity.

### ***Stimulus Over-selectivity and Cognitive Flexibility***

The mean percentage of perseverative errors were 23.15 (SD = 7.869) for the 60-69 year olds, 23.90 (SD = 6.820) for the 70-79 year olds, and 25.95 (SD = 7.007) for the 80-89 year olds, indicating an ascending developmental trend where the number of perseverative errors emitted increased as a function of chronological age. A one-way ANOVA was conducted with age group as the factor and percentage of perseverative

errors as the dependent measure. The analysis revealed no statistically significant effect,  $F(2, 59) = 0.800, p = .454$ , indicating that the three age groups did not differ in levels of cognitive flexibility.

A parametric Pearson's correlation analysis was conducted between levels of over-selectivity and WCST perseverative errors. No statistically significant correlation was found,  $r = -.143, p = 0.275$ , indicating that over-selectivity is not correlated with cognitive flexibility. However it should be noted that although cognitive flexibility was not reliably correlated with levels of over-selective responding there was a numerical trend in the differences showing that the greater the percentage of perseverative errors made and the greater the over-selectivity responding.

## Discussion

The current experiment demonstrated the presence of stimulus over-selectivity in a simple visual discrimination task with an added distractor in each of the three elderly age groups. This finding replicated the results of all groups in the McHugh and Reed (2007) study as well as research exploring the effects of a distractor task on levels of over-selectivity in a non-clinical population (Reed & Gibson, 2005; Broomfield, McHugh & Reed, 2010; Reed, Savile, & Truzoli, 2012; Reynolds, Watts & Reed, 2012; Reynolds & Reed, 2011a; Reynolds & Reed, 2011b). An age trend in over-selective responding emerged where over-selectivity increased as a function of chronological age. Specifically, the oldest age group (80-89 years) displayed higher levels of over-

selectivity than those in the 70-79 year old group and the 70-79 year old group displayed greater over-selective responding than the 60-69 year old group.

The comparator theory of over-selectivity predicts that post-learning manipulations of the over-selected cue should enhance the performance of the under-selected cue (Reed, 2007, 2010). However, McHugh and Reed (2007) found no recovery effects in the 70-80 year old group. The results for the current three age groups aged 60-89 years replicated the findings of the oldest group in McHugh and Reed (2007) as well as findings from the current thesis for low functioning individuals with ASC (Chapter 2) and 6 and 7 year old typically developing children (Chapter 4). It is possible that the elderly participants displayed an initial pre-conditioning attentional deficit and thus, there was no suppressed learning about the under-selected stimulus to be revealed by extinguishing the over-selected stimulus.

As previously outlined the elderly individuals may present with a different form of stimulus over-selectivity (Reed, Savile & Truzoli, 2012) to the younger individuals tested in past research who demonstrated emergence effects post- extinction (Broomfield, McHugh & Reed, 2008; Reynolds, Watts & Reed, 2012). This suggestion is supported by the current results and indicates that different processes may be involved in this older sample. Further exploration is necessary to determine if either the comparator theory did not apply to this age group or to analyse if the elderly individuals experience an attentional deficit.

Future research might also investigate why the use of extinction to remediate over-selectivity is not found to be beneficial for all populations. Interventions other than extinction should be tested for their effectiveness to allow the under-selected stimuli to

emerge to control behaviour in an elderly population. For example, McHugh, Simpson and Reed (2010) found that mindfulness training showed positive effects in older adults where the level of over-selectivity in an elderly population aged 71-90 years was significantly reduced after a focused attention task when compared to an unfocused attention task.

A final area of exploration in the current chapter was the association between stimulus over-selectivity and two potential correlates within this elderly non-clinical population. The first variable under analysis was intellectual functioning as measured by full IQ scores. As ageing is related to significant declines in cognitive functioning, each participant was screened before testing using a standardised measure to ensure that the results would not be confounded by a cognitive impairment such as dementia. A significant descending trend was found where intellectual functioning decreased as a function of age.

In the correlation analysis, similar to the results of individuals with ASC in Frankel et al. (1984), Reed et al. (2009) and the current Experiment 1A, no significant association was revealed between IQ and over-selective responding in this elderly population. However, a numerical trend was revealed whereby over-selective responding increased as the participants grew older and IQ scores decreased. This non-significant trend was also found by Reed et al. (2009) and the current Experiment 1A, suggesting that perhaps statistical significance may have been revealed with a greater sample size (see Wilhelm & Lovaas, 1976). Additionally, the similar trends in the three aforementioned studies highlight the generality of the over-selectivity phenomenon across both clinical and non-clinical populations.

The second potential correlate of over-selectivity to be examined was cognitive flexibility, as measured by a standardised computerised instrument. Results showed that cognitive flexibility decreased as a function of chronological age. Specifically, as the participants got older, the number of perseverative errors they incurred increased. Although this was not a statistically significant finding, it does show that individuals tend to demonstrate greater cognitive flexibility the younger they were. This was in contrast to the results from the typically developing children in Chapter 4 where the trend line was in the opposite direction, that is, cognitive flexibility increased as a function of chronological age. It can thus be concluded that individuals who are very young (3 to 5 years) and very old (70 to 89 years) demonstrate the greatest levels of cognitive inflexibility.

In terms of the relationship between stimulus over-selectivity and cognitive flexibility in these elderly adults, no significant correlation was found. This result offers support to the findings of Chapter 4 where only one of subtests measuring cognitive flexibility was reliably associated with over-selective responding in non-clinical children. It should be noted that different flexibility measurement tools were employed in Chapters 4 and 5 and therefore statistical significance may have been revealed in the current experiment if the IED was utilised instead of the WCST. It is noteworthy that numerical analysis of the correlation showed that as cognitive flexibility decreased, over-selective responding increased.

Taken together, the results showed that as chronological age increased in the current population, three effects were revealed: levels of stimulus over-selectivity increased, IQ scores decreased and cognitive flexibility decreased. Ageing is thus

related to significant declines in effective stimulus control, intellectual functioning and cognitive functioning. These effects can have a serious impact on the physical and psychological health of the elderly as well as their quality of life and therefore, this area of research certainly warrants further exploration (McHugh, Simpson & Reed, 2010).

Chapter 6:  
General Discussion

## 1.0 Overview of the aims

The primary aim of the current thesis was to explore the theoretical foundation of stimulus over-selectivity, and attempt to contribute to the remediation of the defective stimulus control, for both clinical and educational purposes. Over-selectivity is a phenomenon that causes an individual to respond to only a limited subset of the total number of stimuli present in the environment, and thus, it may restrict learning of the range, breadth or number of stimuli, or features of a stimulus (Dube, 2009; Ploog, 2010). Over-selectivity has been shown to be a highly replicable phenomenon (e.g., Lovaas & Schreibman, 1971; Dube & McIlvane, 1999) and can lead to deficiencies in acquiring particular functional behaviours. The phenomenon has been implicated in a range of disorders (e.g., ASC and general learning disabilities) and situations (acquired brain injury and typically developing individuals undergoing a simultaneous distractor task), and can account for various deficits and characteristics within these populations.

In particular, stimulus over-selectivity may account for many of the deficits evident in individuals with ASC, including, deficits in communication skills (e.g., Chiang & Carter, 2008; Reynolds, Newsom, & Lovaas, 1974; Lovaas, Koegel & Schreibman, 1979), deficits in social behaviour (e.g., Schrandt, Townsend, & Poulson, 2009; Gena, Krantz, McClannahan & Poulson, 1996; Harris, Handleman, & Alessandri, 1990; Scherf, Behrmann, Minshew, & Luna, 2008), deficits in learning (e.g., Varni, Lovaas, Koegel, & Everett, 1979; Koegel & Rincover, 1976; Schreibman, 1975; Birnie-Selwyn & Guerin, 1997; Walpole, Roscoe & Dube, 2007) and deficits in generalising treatment gains (Rincover & Koegel, 1975; Falcomata, Roane & Pabico, 2007; Schreibman & Lovaas, 1973).

The current thesis aimed to investigate the phenomenon of stimulus over-selectivity, by employing a simultaneous discrimination task whereby clinical and non-clinical participants were trained to select a compound stimulus comprising of two elements over an alternative two-element compound. This method of assessing levels of over-selective responding has been utilised in previous research (e.g., Dube & McIlvane, 1997, 1999; Koegel & Wilhelm, 1973; Lovaas & Schreibman, 1971; Ploog & Kim, 2007; Leader et al., 2009; Reed et al., 2009; Reed & Gibson, 2005). Once discriminative control was established, the individual compound stimulus elements were presented separately, and the levels of behavioural responding to each element were calculated. Non-clinical populations tend to respond to each of the stimulus elements equally. However, individuals who are prone to displaying over-selective responding tend to select one of the elements at the expense of the other element, thereby indicating over-selectivity.

Specifically, the current thesis had three aims. As many theories of stimulus over-selectivity have been put forward, the first aim was to investigate some of these theories, in particular, the comparator theory that posits that over-selectivity may be due to a post-conditioning, or retrieval, problem, rather than a problem with initial attentional processing. There is evidence in the literature that over-selectivity in individuals with ASC may be due to an attentional deficit (e.g., Burack, 1994; Lovaas et al., 1971; Dube et al., 1999; Dube & McIlvane, 1999; Koegel & Schreibman, 1977; Koegel & Wilhelm, 1973). The current thesis aimed to examine the degree to which such an attentional deficit could predict over-selectivity, compared to the degree to which the problem is associated with the post-acquisition retrieval of stimulus cues (Wilkie & Masson, 1976; Reed & Gibson, 2005;

Broomfield et al, 2008, 2010; Leader et al., 2009; Reed, 2007, 2010; Reed et al., 2009; Reynolds, Watts & Reed, 2012).

This issue was investigated by extinguishing over-selected stimuli, and assessing if previously under-selected stimuli re-emerged to control behavioural responding. If this emergence effect occurred, it would suggest that the under-selected stimuli had been initially attended to, and learned about, in the previous conditioning phases, but that this learning was not controlled by the cues currently present, and, hence, did not manifest in the individual's behaviour. If the causes of over-selectivity can be identified, it is hoped that remediation strategies can be developed that will aid learning.

The second aim of the thesis was to explore the potential remediation of the over-selectivity effect. Specifically, the current thesis investigated the use of extinction as previous research has found that this simple intervention allows the under-selected stimulus to emerge to control behavioural responding once the over-selected stimulus is extinguished (Broomfield et al., 2008, 2010; Reed & Gibson, 2005; Leader et al., 2009; Reynolds, Watts & Reed, 2012). Removal of the excessive behavioural control that is exerted by the over-selected stimulus may result in new aspects of the environment being attended to which were previously ignored.

The third aim of the current thesis was to explore the correlation between over-selective responding and a number of key variables including stereotyped behaviour, attention, and flexible behaviour. Taken together, the current thesis aimed to develop a sound theoretical understanding of stimulus over-selectivity, focusing in particular on the comparator perspective, as well as attempting to contribute to the attenuation of the effect. These aims were investigated across three populations, individuals on the autism spectrum, typically developing children and

typically developing elderly participants, in order to confirm the generality of the over-selectivity effect in both clinical and non-clinical samples.

## **2.0 Summary of findings**

It should be noted that comparing the experiments in the current thesis with previous research in the area of stimulus over-selectivity is problematic as past studies differ in terms of their paradigms and procedures, populations employed, and the interpretation or analysis of the data (Ploog, 2010). However, Experiments 1 to 8 did replicate previous work indicating that stimulus over-selectivity is evident in individuals with ASC (e.g., Lovaas et al., 1971), typically developing children (e.g., Bickel, Stella & Etzel, 1984), and typically developing adults (e.g., McHugh & Reed, 2007).

The aim of Chapter 2 was to replicate and extend the findings of Reed et al. (2009) by establishing if over-selectivity is better explained by an attentional deficit (e.g., Dube, 2009), or by a performance deficit (e.g., Reed, 2007). The chapter investigated whether the control exerted over behaviour by over-selected stimuli can be extinguished, and, as a result of this intervention, whether other, previously under-selected, stimuli would then come to control behavioural responding. In two experimental analyses, children with ASC were trained and tested on a visual table-top trial-and-error discrimination learning task.

The participants' level of functioning was examined employing two different criteria, IQ scores as an indicator of cognitive functioning and Autism Index as an indicator of autism severity. This dual analysis revealed the novel finding that although IQ scores are the typical grouping variable used in the literature examining the extinction of over-selective responding in ASC (e.g., Reed et al, 2009) autism

indices were actually a stronger predictor of recovery from over-selectivity than IQ scores.

Chapter 2 revealed a significant degree of stimulus over-selectivity in a population with ASC irrespective of the participants' level of functioning, as determined by both IQ and severity of ASC. Responding to the over-selected stimulus was extinguished by reinforcing a novel stimulus in the presence of the previously over-selected stimulus in a second trial-and-error discrimination task. The results demonstrated that behavioural control by the under-selected stimulus emerged after the previously over-selected stimulus was extinguished. This effect occurred in the absence of any direct manipulation to the previously under-selected stimulus. It was suggested that a larger sample size may have resulted in these emergence effects being statistically significant.

The numeric emergence effect of the under-selected stimulus was however, restricted to the high functioning and to a lesser extent, the moderate functioning participants. This finding suggested that over-selectivity is not simply due to an attentional deficit in these individuals. For the emergence to take place the under-selected stimuli must have been attended to and learnt about in the training phase, but that this learning was not manifest in behaviour in the presence of the other stimulus.

No extinction-induced recovery effect was observed in the low functioning children with ASC in either of the experiments in Chapter 2, replicating the results of the lower functioning group in Reed et al. (2009). These findings suggest that different processes are involved in this population and that the lower functioning individuals did display an initial pre-conditioning attentional deficit and thus, there was no suppressed learning about the under-selected stimulus to be revealed by

placing the over-selected stimulus on extinction.

Chapter 3 explored the relationship between attention, inflexibility, and stereotypy with levels of stimulus over-selectivity in individuals with a diagnosis of ASC. A significant degree of stimulus over-selectivity was found in this sample, adding further support to the findings of Chapter 2. The analysis offered preliminary results that failed to support the attention deficit theory as there was a lack of significant correlations between over-selective responding and attention, as measured by a standardised assessment tool. It was highlighted, however, that the attention test was not suitable for this clinical population and did not provide an accurate measure of the participants' level of selective attention, sustained attention of attentional switching.

The findings from Chapter 3 also revealed that over-selectivity was not associated with cognitive flexibility or behavioural flexibility. A significant association was revealed however between over-selective responding and stereotyped behaviour, an important and novel finding to facilitate understanding of the over-selectivity effect. Finally, significant correlations were also found between over-selectivity and IQ, and between over-selectivity and Autism Index supporting the results from Chapter 2. The limited sample size in Chapter 3 necessitates replication of all the analyses conducted.

Whilst Chapters 2 and 3 explored stimulus over-selectivity in populations with ASC, it was deemed necessary to also examine the phenomenon in a typically developing sample in Chapter 4. This non-clinical model of over-selectivity was developed, so that the effect could be explored, and interventions developed, on a less vulnerable population prior to their use on clinical samples. Furthermore, evidence of the conditions under which over-selectivity is induced in typically

developing children aged three to seven years could lead to improved early educational outcomes.

Experiment 3 to Experiment 7 in Chapter 4 aimed to investigate the utility of the simple visual discrimination task employed in Chapters 2 and 3 to assess the presence of over-selectivity in typically developing children. The chapter also aimed to explore if this population would emit an extinction-based recovery from over-selective responding and also tested correlations between over-selectivity, selective attention and cognitive flexibility. The findings from Chapter 4 revealed that the three to seven year olds all demonstrated over-selectivity with and without a concurrent distractor task, offering experimental data to support Ross' (1976) postulation that children over-select until about the age of six years.

Contrary to the findings from studies with typically developing adults where an added distractor task induced higher levels of over-selective responding (e.g., Reed & Gibson, 2005; McHugh & Reed, 2007; Broomfield, McHugh & Reed, 2010; Reynolds, Watts & Reed, 2012) no significant differences were found in this population between the distractor and no distractor conditions. It was postulated that the reason for this was the quality of the task provided as the extra cognitive task.

Extinction was successful in significantly decreasing the control of the previously over-selected stimuli on the responses of each of the five age groups in Chapter 4. However, the emergence of the previously under-selected stimuli was only observed in the youngest three age groups and not in the 6 or 7 year olds. Although these findings may offer limited support to the attention deficit theory it is possible that both stimulus elements were attended to in the 6 and 7 year olds but neither acquired substantial behavioural control. Therefore the previously 'under-selected' stimulus would not be able to 'emerge' as it was already controlling

behaviour to some extent (Reynolds, 2012).

A developmental profile was produced by employing correlation analyses which revealed that over-selectivity was correlated with selective attention, offering support for the attention deficit theory; and cognitive flexibility, offering evidence for the postulation that inflexibility is associated with over-selective responding (Ploog, 2010). The profile also showed that chronological age had statistically significant associations with over-selectivity, selective attention, and cognitive flexibility. Thus, as the individuals grew older, levels of over-selectivity decreased, and both selective attention scores and cognitive flexibility scores improved.

Finally, Chapter 5 continued the exploration of the over-selectivity effect in a typically developing sample. However this chapter examined the different processes occurring in over-selectivity in elderly individuals, to replicate and extend the findings of McHugh and Reed (2007). Experiment 8 investigated the utility of the comparator theory as an explanation for over-selectivity in this sample of elderly adults aged 60-89 years and more specifically, aimed to test if a post-learning decrease in the control exerted by one stimulus allowed previously learned but unexpressed stimuli to emerge and control behavioural responding in a visual discrimination task.

The findings revealed the presence of age trends in over-selective responding, where over-selectivity increased as a function of chronological age. Over-selectivity levels also increased as IQ scores and level of cognitive flexibility decreased. Although extinction significantly reduced the control exerted by the previously over-selected stimuli across the three chronological age groups, no emergence effect was found. This finding supports the results of McHugh and Reed (2007) and suggests that elderly adults over-select due to an initial pre-conditioning

attentional deficit, as opposed to the retrieval deficit posited by the comparator theory.

Taken together, the findings of the current thesis indicate the robustness of the over-selectivity phenomenon across populations, and offer experimental data in support of both the comparator theory and attention deficit theory of stimulus over-selectivity. In terms of remediation of the effect, this thesis supported the use of extinction procedures but offered evidence that this simple and time-efficient intervention is restricted in its generality as it is not found to be beneficial for all populations. Furthermore, the thesis has aided the construction of a more detailed model of over-selectivity by analysing its correlating variables across an array of populations.

### **3.0 Theoretical implications of the findings**

The current thesis demonstrated the over-selectivity effect in individuals with ASC (Chapter 2 and Chapter 3), typically developing children (Chapter 4) and typically developing elderly individuals (Chapter 5), thus supporting previous research exploring the generality of stimulus over-selectivity across populations (e.g., Lovaas et al., 1971; Koegel & Wilhelm, 1973; Reed et al., 2009; Bickel, Stella & Etzel; Eimas, 1969; Hale & Morgan, 1973; McHugh & Reed, 2007; McHugh, Simpson & Reed, 2010). Given the range of populations in which the over-selectivity effect is observed, it is an important phenomenon to understand, both theoretically and for practical purposes (Reed, Savile, & Truzoli, 2012). The findings of the current thesis have enabled the further development of a theoretical framework of the effect. In particular, as discussed below, the results revealed by

the current thesis have implications for the retrieval versus attention deficit accounts of over-selectivity.

### **3.1 Comparator Theory of Over-selectivity**

An increasingly popular account of over-selectivity in the literature is the comparator perspective. Reed (2007) ascribes stimulus over-selectivity to a performance deficit, rather than an attentional problem, which is attributable to an oversensitive comparator mechanism (Miller & Matzel, 1988; Miller & Schachtman, 1985). This theory advocates that this comparator mechanism works at the retrieval level of the information processing system by making comparisons between the possible strengths of available cues to predict the appropriate outcome (Reed, 2007). Cues with relatively weaker strengths are inhibited, whilst cues with the greatest predictive values for outcomes are selected to control subsequent behavioural responses. In our environment, there are a large number of stimuli that can potentially form the basis upon which we act, and this comparator system simply chooses which stimuli are the most important.

Reed (2010) posited that the comparator mechanism focuses upon the relative strengths of the stimuli in the environment. Resultantly, the relative differences will be greater when learning is not as strong. Specifically to ASC, stimulus over-selectivity may be the result of an over-sensitive comparator mechanism. Thus, when presented with an array of stimuli or multiple pieces of information to discriminate, slight differences between the available stimuli are noted by the over-sensitive comparator system and only a subset of those stimuli come to control behaviour (Reed et al., 2009; Leader et al., 2009). In individuals with a typically functioning and therefore less sensitive comparator mechanism, the slight differences would tend not to provoke inhibition, and instead each stimulus controls subsequent

behaviour equally.

Unlike the attention deficit theory, the comparator perspective accommodates the emergence effects found in Chapter 2 and Chapter 4 as well as previous research (e.g., Reed et al., 2009; McHugh & Reed, 2007; Reynolds, Watts & Reed, 2012). In explaining these findings, Reed (2007, 2010) argues that the associative strength of the over-selected stimulus is stronger than that of the under-selected stimulus. Although both stimuli in the compound are associated with the feedback 'yes', there may have been a stronger association with this feedback for one of the elements, and, therefore, this stimulus comes to control behaviour at the expense of the other stimulus. Placing the over-selected stimulus on extinction reduces the strength and importance of the stimulus and thereby enables the under-selected stimulus to emerge with greater strength and control subsequent behaviour as its relative importance attributed by the comparator mechanism is increased.

There are two patterns of results emerging from the current thesis that are compatible with the predictions made by the comparator theory of stimulus over-selectivity (Reed, 2007). Firstly, as mentioned above, extinction of the over-selected stimulus lowers the strength of this comparator stimulus strength allowing the previously under-selected cue to emerge to control behaviour. Experiments 1A, 1B, 3, 4, and 5 supported the view that over-selectivity was potentially caused by problems in retrieval, rather than with acquisition of cues, as previously under-selected cues did come to control behaviour after extinction of the previously over-selected cues. This post-conditioning re-evaluation finding has previously been explained by the comparator hypothesis (Matzel, Schachtman, & Miller, 1985; Miller & Matzel, 1988; Miller & Schachtman, 1985), and this view has been applied to individuals with ASC (Leader et al., 2009; Reed et al., 2009) and typically

developing adults (Broomfield, McHugh & Reed, 2008; Reynolds, Watts & Reed, 2012).

It should be noted, however, that the use of extinction to remediate stimulus over-selectivity was not found to be beneficial for all populations in the current thesis. Emergence effects were only revealed in the high and to a lesser effect, the moderate functioning individuals with ASC in Chapter 2 and the 3, 4, and 5 year old typically developing children in Chapter 4. However, there were no significant emergence effects in the low functioning individuals with ASC tested in Experiments 1A and 1B, the 6 and 7 year old typically developing children in Experiments 6 and 7 and the typically developing adults aged 60 to 89 years in Experiment 8. This issue will be discussed further in Section 6.4 when exploring the implications of the current findings for the remediation of stimulus over-selectivity.

The second pattern of results to emerge from the current thesis was compatible with the prediction made by the Comparator theory that greater stimulus over-selectivity is observed when learning is weak, rather than strong (Reed, 2007). Specifically, the comparator hypothesis predicts larger over-selectivity when learning is weakest, or when there is a competing task (Broomfield, 2008). The findings from Experiment 8 supported previous demonstrations that the over-selectivity effect can be induced in an elderly population when a distractor task is utilised (McHugh & Reed, 2007; McHugh, Simpson & Reed, 2010)

### **3.2 Attention Deficit Theory of Over-selectivity**

The attention deficit theory is one of the most popular theoretical perspectives of stimulus over-selectivity. This account maintains that over-selectivity occurs due to an inability to attend to all available cues provided by component elements of a stimulus during initial training. Stimuli that are not

attended to cannot be processed or learned about. Therefore only the elements of the stimulus that are attended to, can subsequently control behaviour (e.g., Lovaas et al., 1971; Koegel & Wilhelm, 1973; Dube & McIlvane, 1999; Dube et al., 1999). This limits the range, breadth, or number of stimuli or stimulus features that can control behaviour (Reed, 2007).

Eye tracking apparatus has frequently been employed in the research to show that stimulus over-selectivity is accompanied by a failure to observe all of the relevant stimuli (Dube et al., 1999). Although Anderson et al. (2006) demonstrated that children with ASC have a reduced level of visual scanning compared to typically developing control participants, it should be acknowledged that an imperfect correlation has been revealed between eye movements and attention (Wurtz & Mohler, 1976; Shaw, 1978; Remington, 1980).

The current thesis offers evidence contradicting the postulations of this perspective of over-selectivity. The attention deficit account fails to explain the emergence effects found in Experiments 1A, 1B, 3, 4 and 5 as well as in previous research (e.g., Reynolds, Watts & Reed, 2012; Broomfield, McHugh & Reed, 2008; Reed et al, 2009; Leader et al, 2009). The emergence of the under-selected stimulus to increase control over behavioural responding following extinction of the over-selected stimulus, implies that the former cues were attended to during training, and that the over-selectivity problem was not simply attentional.

It is difficult for the attention deficit theory to explain how the previously under-selected cue could subsequently control responding if it was not attended to during initial discrimination training. As there was no direct manipulation of the previously under-selected cues, any emergence effect must thus be based upon their existing power to control behavioural responding established during conditioning.

Emergence effects were, however, not revealed in all of the experimental analyses in the current thesis. The previously under-selected stimulus did not emerge to control responding post-extinction in the lower functioning individuals with ASC in Chapter 2, the 6 and 7 year old typically developing children in Chapter 4 and in the elderly individuals in Chapter 5. These findings therefore potentially offer support for the attention deficit account of stimulus over-selectivity.

The low functioning individuals in Experiments 1A did not show the extinction-induced emergence effect found in the high functioning and to a lesser extent, moderate functioning individuals with ASC. In their examination of event related potentials, Reed, Savile and Truzoli (2012) suggested that there may be two forms of stimulus over-selectivity. One form affecting lower functioning individuals may be due to an attention deficit and the other form affecting higher functioning individuals may be due to a post-processing disorder. The form the over-selectivity effect takes is therefore, dependent upon the severity of the intellectual impairment.

Chapters 4 and 5 indicate that the two forms of over-selectivity proposed by Reed, Savile and Truzoli (2012) may also be affected by chronological age, as well as intellectual impairment. McHugh and Reed (2007) found emergence effects of the under-selected stimuli in the two younger groups in their study. However the same effect was absent in the oldest group of adults (70-80 years). The authors suggested that the participants may experience an attentional deficit. The results from the three groups of elderly adults (60-89 years) in Chapter 5 confirm the findings of McHugh and Reed (2007) and offer further support for the attention deficit theory of over-selectivity. Therefore, the older a person gets, the less likely they are to attend to and learn about stimulus elements during initial discrimination training. If the elements are not attended to, they cannot control behaviour in

subsequent test trials (McHugh & Reed, 2007). Similarly, no emergence effect was found in Experiments 6 and 7 indicating that at the chronological age of six years, the form that over-selectivity takes may change.

Taken together, these results indicate that different effects emerge with different ages and populations. Both the intellectual impairment and chronological age of the individual should be considered. This issue will be discussed in more detail in Section 4.0.

### **3.3 Other Theoretical Accounts of Over-selectivity**

Chapter 1 described both the Comparator Theory and the Attention Deficit Theory as potential accounts of the over-selectivity phenomenon. However, five other theories were also outlined in the first chapter including: sensory overload; tunnel vision, the limbic system hypothesis, increased cognitive load, and executive dysfunction. An analysis of how the experimental outcomes from Chapters 2, 3, 4 and 5 relate to these other five theories of stimulus over-selectivity warrants discussion.

The first of these theories posits that over-selectivity occurs due to a sensory overload which causes sensory information to be only partially processed. Evidence against this theory includes research showing over-selective responding when the compound stimuli are from the same modality (e.g., visual only; Reed et al. 2009; auditory only; Reynolds et al., 1974). The current eight experiments employed complex stimuli limited to the visual modality and stimulus over-selectivity was evident throughout each experimental chapter. Ploog (2010) describes these as cases where sensory overload seems unlikely.

The second of these theories posits that the only stimuli that become functional for the individual are those that are in their restricted field or “tunnel”

vision (Anderson & Rincover, 1982). The current eight experiments did not manipulate the relative distance or location between the two presented cues and therefore no evidence was offered in support of or against this theory. The same distance between the complex cue components was employed throughout each training and extinction trial in Experiments 1- 8.

The third of these theories, the limbic system hypothesis (Joseph, 1999), proposes that all stimuli are attended to, and processed. The problem occurs when retrieving the stimuli and focuses on attempting to identify a responsible brain-level mechanism (Reed, 2007). The MMSE was employed in Experiment 8 to screen for the presence of cognitive impairment (such as suspected dementia) in elderly adults. Participants were excluded from the study if they did not obtain a score of greater than or equal to 25. This ensured that the levels of over-selectivity displayed by the participants in the three experimental groups did not result from cognitive impairment.

The fourth theory, increased cognitive load, posits that stimulus over-selectivity may reflect the demand level, particularly the memory load, of a task (Reed & Gibson, 2005). Increased pressure on a person's information processing capacity may limit the number of cues that control behaviour. A distractor memory task was employed as a within-subjects variable in Chapter 4 (Experiments 3-7) to examine its effects on over-selective responding in typically developing children.

Previous research has shown that using a concurrent task load induces over-selectivity in non-clinical adults (e.g., McHugh, Simpson & Reed, 2010; Reynolds & Reed, 2011a; Reynolds & Reed, 2011b; Reynolds, Watts & Reed, 2012). However, the experimental outcomes from Chapter 4 did not support this finding. No

significant differences across the distractor and no distractor conditions for each of the five age groups were revealed.

One possible explanation for this contradictory evidence may be that the effects associated with the actual distractor task were not consistent across the 3-7 year olds. While continually counting from one to ten was quite challenging for the younger age groups, the older age groups did this with greater ease and automaticity and required less prompting by the experimenter. The effects of a distractor task on the over-selective responding of typically developing children, certainly warrants further investigation. Perhaps the memory load task employed by Reed and Gibson (2005) and McHugh and Reed (2007) may have been a more suitable distractor task for this population.

The fifth theory of over-selectivity also outlined in Chapter 1 was executive dysfunction. Assuming that the stimuli are processed, this theory states that stimulus over-selectivity may be produced by deficits that occur later in the information processing channel (Reed, 2007). Chapter 3 explored the relationship between cognitive flexibility (as measured by the IED) and stimulus over-selectivity in children with ASC. The correlation analysis revealed that neither of the IED dependent variables was significantly associated with levels of over-selectivity in the experimental group.

Chapter 5 investigated the relationship between executive dysfunction (as measured by the WCST) and over-selective responding in elderly adults. No statistically significant associations were revealed. This result offers support to the findings of Chapter 4 where only one of subtests measuring cognitive flexibility was reliably associated with over-selective responding in non-clinical children. These results suggest that there is no reliable association between executive dysfunction

and stimulus over-selectivity. This is the first experimental investigation of this correlation and therefore further analysis is required employing a variety of measurement tools and across populations.

#### **4.0 Implications for the remediation of over-selectivity**

One of the aims of the current thesis was to offer further experimental analysis of extinction, a post-learning strategy, for the remediation of stimulus over-selectivity. Chapter 1 described the range of deficits and real world implications that can be accounted for by over-selectivity. Amongst such deficits include: deficits in social and communicative interaction (Reynolds, Newsom, & Lovaas, 1974); deficits in the development of spontaneous language (Chiang & Carter, 2008); impaired social behaviour including problems with empathy (Schrandt, Townsend & Poulson, 2009) and affective behaviours (Gena, Krantz, McClannahan, & Poulson, 1996); limited observational learning (Varni, Lovaas, Koegel, & Everett, 1979); learning difficulties when prompts are employed (Koegel & Rincover, 1976) or during MTS tasks (Walpole, Roscoe & Dube, 2007); and finally deficits in the ability to generalise skills already learned (Rincover & Koegel, 1975). It is therefore, extremely important that an efficient and effective remedial intervention is identified for this effect to combat some of these detrimental behaviours in both clinical and non-clinical groups (Reynolds, 2012).

The eight experiments in the current thesis recruited both clinical and non-clinical populations. Both Chapters 2 and 3 investigated stimulus over-selectivity in children and adolescents with ASC. As discussed in Chapter 1, this problematic phenomenon has been demonstrated in many clinical populations including individuals with an ID (Smeets, Hoogeveen, Striefel & Lancioni, 1985); individuals

with a learning disability (e.g., Dube & McIlvane, 1999); females with Rett's Disorder (Fabio, Giannatiempo, Antonietti & Budden, 2009); individuals with an acquired brain injury (Wayland & Taplin, 1982) and individuals with schizophrenia (Feeny, 1972). However, the majority of studies demonstrating stimulus over-selectivity has been with individuals with ASC (e.g, Anderson & Rincover, 1982; Allen & Fuqua, 1985; Frankel, Simmons, Fichter & Freeman, 1984; Koegel & Wilhelm, 1973; Kolko, Anderson, & Campbell, 1980, Lovaas & Schreibman, 1971; Matthews, Shute & Rees, 2001). Therefore, since the over-selectivity effect is extremely prevalent in this particular clinical population, it was deemed necessary to further explore the effectiveness of extinction as a remedial strategy for over-selectivity in individuals with ASC in Experiments 1A and 1B.

Both Chapters 4 and 5 recruited non-clinical populations in order to develop a theoretical framework of stimulus over-selectivity and to test extinction as a potential means of remediation. Examination of the over-selectivity effect in typically developing individuals holds many benefits, one of which is that the phenomenon can be ethically explored in a population which is not as vulnerable as those with disabilities before being applied to a clinical population (Broomfield, 2007). Non-clinical samples are more straightforward to obtain, particularly the elderly adults who can offer their own informed consent. Non-clinical children and adults are also easier to work with than clinical populations in terms of motivation, following instructions and reinforcement.

As outlined in Chapter 1, over-selectivity has been shown to be a universal phenomenon and therefore replicating and extending the analysis of over-selectivity from clinical to non-clinical samples may have an advantage in terms of generalisation (McHugh & Reed, 2007). It is therefore imperative that extinction is

tested as a remediation strategy in non-clinical populations who have previously been shown to over-select (e.g., Bickel, Stella & Etzel, 1984; Eimas, 1969; Hale & Morgan, 1973; Reed & Gibson, 2005; Reynolds, Watts & Reed, 2012).

Previous attempts to remediate over-selectivity have not always been successful. The use of prompts and prompt fading as a remedial technique have led to prompt dependency whereby individuals respond only to the prompt rather than the actual stimulus itself (Ploog, 2010). The improved scores obtained in match-to-sample tasks by employing differential observing responses have been repeatedly shown to not maintain after the withdrawal of the technique (e.g., Constantine & Sidman, 1975; Broomfield, McHugh & Reed, 2008; Dube & McIlvane, 1999). Altering the schedule of reinforcement has also been utilised to attempt to reduce over-selective responding. However, partial reinforcement has been shown to have no beneficial effect as a remedial intervention (e.g., Reynolds & Reed, 2011a; Meisel, 1981; Remington & Clarke, 1993).

Each of these techniques is inadequate as clinical remediation of stimulus over-selectivity. Therefore, the current thesis focussed instead upon extinction, a procedure which has been widely used to decrease various problem behaviours. Specifically, previous research has indicated its utility as a simple and effective remediation strategy for over-selective responding in both the animal conditioning literature (Wilkie & Masson, 1976; Kaufman & Bolles, 1981; Matzel, Schachtman, & Miller, 1985; Reed & Reilly, 1990) and human participants (Reed, Broomfield, McHugh, McCausland & Leader, 2009; Leader, Loughnane, McMoreland & Reed, 2009; Broomfield, McHugh & Reed, 2008; Reynolds, Watts & Reed, 2012).

Extinction may be seen as a relatively simple intervention which targets the increase of the number of cues that control behaviour (Reed et al., 2009).

Furthermore, unlike the observing response method (e.g., Broomfield, McHugh & Reed, 2008), the beneficial effects of extinguishing the over-selected stimulus remain post-intervention (e.g., Leader et al., 2009).

The utility of extinction as a remediation strategy for over-selectivity was explored in children and adolescents with ASC in Chapter 2. Once the over-selected stimulus was established using a discrimination paradigm, it was extinguished by pairing it with a novel stimulus. For both the high functioning and moderate functioning groups in Experiments 1A and 1B the results were consistent with the comparator theory and revealed that extinction reduced the level of responding to the previously over-selected stimulus and led to the emergence of responding to a previously under-selected stimulus. Both of these effects are necessary to deem extinction a truly useful clinical intervention for stimulus over-selectivity.

In the low functioning groups in both Experiments 1A and 1B, no emergence effects were found, thus implying that extinction is not a suitable intervention for individuals who are intellectually impaired or who demonstrate more severe autism traits. Chapter 2 further analysed these results and found that emergence effects are better predicted by autism severity (Experiment 1B) than intellectual functioning (Experiment 1A). Specifically as autism severity gets milder, the more likely it is to see an emergence effect post-extinction. This confirms that it is better to reserve extinction as a remediation strategy for individuals who are less severely autistic.

Chapter 4 investigated the benefits of employing extinction to reduce the over-selective responding in typically developing children aged 3 to 7 years. Emergence effects were revealed in the 3, 4 and 5 year old groups, a finding that was in line with the comparator theory of over-selectivity indicating that extinction is a suitable intervention for this chronological age range. However, extinguishing the

previously over-selected cue did not lead to the previously under-selected cue to emerge to control responding in the 6 and 7 year old groups. One potential explanation for the discrepancy in the findings of Chapter 4 has been previously documented in the research (e.g., Broomfield et al., 2008; Reed, 2010) and implies that extinction procedures to remediate stimulus over-selectivity in a clinical setting are only useful when the initial level of over-selective responding is high.

When over-selectivity levels are low, it is possible that the stimulus is perceived as a compound rather than individual elements. Therefore, extinguishing the over-selected cue may generalise to the under-selected cue. However, when over-selectivity is high, generalisation is less likely to occur as the elements are more likely to have been perceived individually as opposed to as a compound.

Furthermore, if over-selectivity is low, then both cues are being attended to and neither cue is acquiring substantial behavioural control, then the cue labelled under-selected would not in fact be able to emerge as it is already controlling responding to some extent (Reed, 2010). This reasoning explains why no emergence effects were found in Experiments 6 and 7 and imply that extinction is a suitable intervention for children up to the chronological age of 6 years.

Chapter 5 examined extinction as a remediation strategy for over-selective responding in elderly typically developing adults. Extinguishing the over-selected stimulus did not result in an emergence of the under-selected stimulus in this sample aged 60-89 years, replicating the findings by McHugh and Reed (2007) where a vocal punisher was employed to attempt to remediate over-selectivity in 70-80 year olds. It is therefore implied that from the age of 60 years less initial learning is likely to occur during training. If learning does not accrue to the under-selected stimulus, then this stimulus is unable to subsequently dominate behavioural control (Reed et

al., 2009).

It is of note that there is inconsistent evidence regarding the usefulness of extinction (e.g., Holland, 1984). That said, the current thesis does provide initial support for the use of extinction procedures to remediate stimulus over-selectivity in a discrimination paradigm with experimental stimuli. However, it was not found to be beneficial for low functioning individuals with ASC, typically developing children over the age of 6 years and typically developing adults over the age of 60 years. As a result, it is important to modify and test the procedure on a range of populations and replicate the findings from Chapters 2, 4, and 5 to determine the appropriate parameters of this remediation strategy.

#### **4.1 Implications for the remediation of over-selectivity in applied settings**

The current thesis focussed upon extinction, a procedure which has been widely used to decrease various problem behaviours such as food selectivity, self-injurious behaviour and aggression within applied settings (e.g., Koegel, Egel & Williams, 1980; Anderson & Long, 2002; Goh & Iwata, 1994; LaRue, Stewart, Piazza, & Volkert, 2011). Extinction may be seen as a relatively simple intervention which targets the increase of the number of cues that control behaviour (Reed et al., 2009).

According to Reed et al. (2009) the extinction procedure is technically a Differential Reinforcement of Alternative (DRA) behaviour schedule whereby undesirable behaviours are not reinforced and alternative desirable behaviours are reinforced so that undesirable behaviours are reduced whilst desirable behaviours are promoted. The current author actually views the extinction procedure as a Differential Reinforcement of Incompatible (DRI) behavior schedule as pointing to

the novel stimulus during the extinction phase could not occur simultaneously with the problem behavior (i.e., pointing to the over-selected stimulus).

“Teachers, therapists, and parents have a long history of using DRI/DRA interventions in education, treatment, and everyday social interactions” (Cooper, Heron & Heward, 2007; p. 470). DRA has been shown to be an effective treatment in applied settings at full implementation (all appropriate behavior is reinforced and no problem behavior is reinforced; Vollmer, Roane, Ringdahl, & Marcus, 1999). More interestingly, Vollmer and colleagues (1999) found a general bias towards appropriate behaviour during partial implementation of DRA (some appropriate behaviour was not reinforced, some inappropriate behaviour was reinforced, or both). This finding is particularly relevant when one considers that the reduction of control by one stimulus to enhance the control by another stimulus may not always be desired or useful, for example, when provided with a stimulus array of letters in words or a countenance on the face of a social partner (Reed et al., 2009).

Furthermore, key aspects of the extinction procedure would have to be developed for use in an applied setting. In the current thesis, one stimulus element of a compound stimulus came to exert control over the participants’ behaviour and this over-selected cue was then extinguished. However, in an applied setting, to make use of the extinction procedure as a remedial strategy for over-selectivity, it would first have to be established what stimuli in the environment were controlling the individuals’ behaviour at the expense of other stimuli. One such example is found in Ducker and Van Lent (1991) who established high rate requests in children with developmental disabilities, and subsequently extinguished these high rate requests to induce the use of previously taught but unused gestures.

Initial identification of the over-selected stimulus in a natural setting may be difficult and this point should be considered during the design of behavioural intervention plans. This further supports the point outlined in Section 4.0 in the current chapter that extinction procedures may only be useful when the initial level of over-selective responding is high, and therefore easier to identify as an over-selective response.

## **5.0 Implications for future work**

The field of stimulus over-selectivity continues to necessitate further research in a range of areas. The current thesis has demonstrated that over-selectivity is caused by different mechanisms in different populations. Therefore, the current research exploring extinction as a remediation strategy for over-selectivity as well as correlates of over-selectivity should be replicated across further populations. One suggested sample would be individuals with attention deficits. McHugh and Reed (2007) suggested that comparing children with ASC and children with ADHD might provide insights into the behavioural differentiation of the two disorders. A selection of topics which warrant future investigation are outlined below.

### **5.1 Extinction**

Findings from the current thesis and previous research (e.g., Broomfield et al., 2008; Reed & Gibson, 2005; Leader et al., 2009; Reynolds, Watts & Reed, 2012) support the comparator theory of over-selectivity by offering evidence that extinguishing the over-selected stimulus results in an increase in control by the previously under-selected stimulus. However replications and extensions of Chapters 2, 4, and 5 are certainly required to explore the parameters of this effect.

Additionally, the investigation of extinction as a viable remediation strategy in a naturalistic environment is also fundamental.

### **5.2 Predicting recovery from over-selectivity in ASC**

Experiments 1A and 1B looked at the effects of intellectual functioning and autism severity on levels of stimulus over-selectivity in children and adolescents with ASC as well as the effects on the emergence of the previously under-selected cue following extinction of the over-selected cue. Autism severity was found to be a stronger predictor of the emergence effect than IQ. Specifically, the milder an individual is in terms of autism severity, the more likely that individual is to benefit from the extinction procedure whereby the previously over-selected cue is chosen less and the previously under-selected cue is chosen more post-intervention. This novel finding requires replication with a larger sample size in order to confirm that extinction should be reserved as a remediation strategy for individuals who are less severely autistic.

### **5.3 Over-selectivity and attention**

The attention deficit theory posits that individuals who display over-selectivity do not attend to all of the compound elements of the stimulus. The method used in the majority of the over-selectivity studies examining attention is eye tracking apparatus (e.g., Dube et al., 1999). However, Remington (1980) warned that the analysis of eye movements is only imperfectly correlated with attention. Due to the discrepancies in the literature using measures of eye movement, the current thesis employed a standardised measurement tool for attention, the TEA-Ch.

In Chapter 3, three attentional processes were examined in individuals with ASC: selective attention, sustained attention and attentional switching. Only one of the subtests, a measure of sustained attention, had a significant association with over-

selectivity. The reason for the lack of significant correlations requires further investigation with a larger sample size. During testing, it was evident that the TEA-Ch was not suitable for the clinical population in Experiment 2. The mean mental age of the participants was outside the age range suggested by the administration guidelines. Also a further problem with this tool is that non-vocal verbal participants cannot complete the majority of the subtests. Future research should employ a more suitable test of attention for individuals with ASC, although at the time of this thesis, no such resource was available.

Chapter 4 explored the correlation between selective attention and over-selectivity with typically developing children. A significant association was found between over-selectivity and one of the two selective attention tasks offering some support for the attention deficit theory. Specifically, as the participants got older, selective attention scores improved while over-selective responding decreased. Once again, this result is preliminary and warrants replication with a range of standardised measurement tools for attention, for example, the Test of Variables of Attention (TOVA; The TOVA Company, 2009).

#### **5.4 Over-selectivity and flexible behaviour**

Chapter 3 investigated the association between over-selectivity levels and two types of flexible behaviour, cognitive flexibility and behavioural flexibility. Although no significant correlations were found in either analysis, it should be noted that the research in Experiment 2 was restricted by its sample size. Therefore, replication is required with a larger number of participants. Additionally, other measures of flexibility could be employed with this clinical population to offer further validation of the findings. Future research could also employ the Wisconsin Card Sort Task (Grant & Berg, 1948; Reed, Watts & Truzoli, 2011) to assess

cognitive flexibility or the Sameness Questionnaire (Prior & MacMillan, 1973) to measure behavioural flexibility

In Chapters 4 and 5, the relationship between cognitive flexibility and over-selectivity in typically developing children and adults was investigated, respectively. In Chapter 4, a statistically significant correlation was revealed between over-selectivity and one of the two cognitive flexibility dependent variables. As the chronological age of the children increased, levels of cognitive flexibility also increased while levels of over-selectivity decreased. This finding suggests that the more efficient the child's executive function is, the less likely they are to demonstrate over-selective responding and experience all its attendant problems.

In contrast, no significant associations were found in Chapter 5 between cognitive flexibility and over-selective responding in elderly adults. It is noteworthy however that as the participants' level of cognitive flexibility decreased, the levels of over-selective responding increased. Thus, ageing is related to declines in both effective stimulus control and cognitive functioning which can seriously impact an individual's quality of life (McHugh, Simpson & Reed, 2010). The findings from Chapters 4 and 5 warrant further investigation to explore if significant correlations are obtainable and generalisable to other populations including typically developing children beyond the age of 7 years and adults with diminished cognitive functioning such as individuals with dementia or acquired brain injury.

### **5.5 Over-selectivity and stereotyped behaviour**

Chapter 3 offered the first experimental investigation of stereotyped behaviours as a correlate with stimulus over-selectivity. In theory, if an individual only responds to a subset of all the cues available to him at one time, then there are no effective or predictable contingencies to earn access to external reinforcers. In

contrast, internal reinforcers, accessed by engaging in stereotyped behaviour, can be predictably produced by the individual and thus, come to control the individual's behaviour (Ploog, 2010). A significant correlation was revealed between stimulus over-selectivity and stereotyped behaviour, a finding that should be considered when designing behavioural interventions. The fact that the sample size in Experiment 2 was limited necessitates that this finding is replicated with a larger sample size. Furthermore, the correlations should be analysed to explore which specific types of stereotyped behaviour (e.g., hand flapping, echolalia) are correlated most significantly with levels of over-selective responding.

## **6.0 Limitations of the current thesis**

As with all research, there are some areas that need to be acknowledged as limitations to the generality of the results, and which may inform any ongoing, or future work in the field. The various potential weaknesses in the current research are considered below.

### **6.1 Participants and matched controls**

In Experiment 2, the participants were matched based upon the mental age of the individuals with ASC. However, employing mental age matched control groups has been criticised by researchers such as Gersten (1980) who described mental age as a "dubious construct". Gersten (1983) claimed that research on stimulus over-selectivity has been flawed by relying "on the controversial technique of matching on mental age" (p.61). It is controversial as it is unclear if experimenters can "equate" a 6-year old child with ASC with an IQ of 33 with a typically developing 2-year old child with an IQ of 100. The reasons for this problem include their different social, learning and reinforcement histories.

The reliability of this construct is also questionable as the mental age of a child may vary from test to test. Silverstein (1976) reported consistently lower mental ages for children with ASC when the Peabody Picture Vocabulary Test (the tool used in Chapters 2 and 3), rather than the Leiter International Performance Scale, was used. Baumeister (1967) noted that mental age is merely the mean performance on a variety of subtests on a standardized test of intelligence. Two individuals matched on mental age may differ significantly in their performance on an IQ test- one may excel on the verbal subtests while the other may excel on the spatial and motor subtests.

### **6.2 Power**

Caution is advised when considering the findings of Chapters 2 and 3 due to the limited sample sizes. Ideally more participants would have been recruited so that potentially, more statistically significant results may have been revealed. Due to the changing status of the Applied Behaviour Analysis (ABA) schools in the Republic of Ireland over the last 2 years, there were major difficulties in gaining access to schools to request permission from parents and guardians to complete the research. As such, replications with increased group sizes are required before generalisation of the results can be made.

### **6.3 Non-automated procedures**

In each of the Experiments 1-8, stimulus over-selectivity was assessed via a non-automated procedure. Although table top procedures are frequently employed in behavioural research they do have inherent limitations. One of the main concerns when utilising this methodology is that it allows interaction between the researcher and the participant and may lead to the experimenter unintentionally prompting the participant (Dymond, Rehfeldt, & Schenk, 2005). Other potential limitations are that

the comparison stimuli may not be consistently positioned in the same place and that counterbalancing the stimuli is made more difficult to keep track of. It is also possible that the participants may be affected by the experimenter recording the data by hand. This was not an issue in Experiment 1A, 1B and 8. However, the typically developing children in Experiments 3-7 had a tendency to request if they got each response “right” or “wrong”.

It is recommended that when non-automated procedures are used, inter-observer agreement scores are employed (Dymond, Rehfeldt, & Schenk, 2005). However, due to the difficulty in accessing participants and the unavailability of resources, recruiting a second observer was unfortunately not possible in the current thesis.

#### **6.4 Generalisation of results**

The participants with ASC employed in Experiments 1A, 1B, and 2 were mostly recruited from ABA schools in North County Dublin. Only two of the 27 participants in Experiments 1A and 1B were recruited from an alternative setting. Students of these ABA schools would be adept with table-top discrete trial training in discriminating between multiple stimuli and thus the findings require further replication in a sample of individuals with ASC who attend non-ABA educational settings.

Experiments 1-8 were all conducted in an experimental, rather than an applied, manner. That is, over-selectivity was assessed using table top simultaneous discrimination procedures as opposed to assessing pre-existing over-selective behaviour in a naturalistic environment. Such controlled environments question the validity of applying the current findings to a clinical setting (Reynolds, 2012).

It should be considered that different attentional processes may operate

during the restricted time of the actual experiment. In natural settings, individuals may not attend in the same way and would most likely have their attention diverted by a greater number of stimuli to attend to. Therefore, although Chapter 2 recruited a clinical population, it is still necessary to confirm these findings outside of an experimental setting to investigate if extinction may be a suitable procedure to remediate over-selective responding in high and moderate functioning individuals with ASC.

## **7.0 Conclusions**

The findings from the current thesis, along with previous research employing both clinical and non-clinical populations, demonstrate that stimulus over-selectivity is a highly robust and universal phenomenon that warrants continued exploration and investigation. The eight experiments comprising the current thesis successfully explored the theoretical framework of the effect and continued the analysis of extinction as a potential remediation strategy across populations with varying chronological ages and levels of functioning.

The development of well-researched remediation procedures is imperative in order to aid in remediating stimulus over-selectivity, and subsequently reduce a range of detrimental behaviours evident in a range of disorders and situations. Results indicate that extinction may be a relatively simple intervention which targets the increase of the number of cues that control responding. However, the viability of this technique is limited in its parameters. The current thesis indicate that extinction is ineffective in the recovery of the previously under-selected cues for elderly adults, children over the age of six years and for low functioning individuals with ASC.

Theoretically, the current findings offer support for both the Attention Deficit

theory and the Comparator Theory. In fact, it may not be necessary to decide between these two theories as the sole explanation of the over-selectivity effect since the postulation was made that there may actually be two different forms of stimulus over-selectivity occurring across different populations. Thus, both theories may correctly account for over-selective responding and remediation interventions should be designed accordingly.

Future work remains essential in the exploration of stimulus over-selectivity in terms of its correlates, across populations and most importantly the potential strategies to reduce the effect. Whilst the current thesis is not without its weaknesses, the findings offer an important insight into the model of over-selectivity and add to the current literature in terms of both theoretical findings and the potential remediation of the phenomenon.

## References

- Allen, K. D., & Fuqua, R. W. (1985). Eliminating selective stimulus control: A comparison of two procedures for teaching mentally retarded children to respond to compound stimuli. *Journal of Experimental Child Psychology*, 39, 55–71. doi:10.1016/0022-0965(85)90029-3.
- Ameli, R., Courchesne, E., Lincoln, A., Kaufman, A.S., & Grillon, C. (1988). Visual memory processes in high-functioning individuals with autism. *Journal of Autism and Developmental Disorders*, 18, 601–615. doi:10.1007/BF02211878
- American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC.
- Anderson, C.J., Colombo, J., & Shaddy, J. (2006). Visual scanning and pupillary responses in young children with autistic spectrum disorder. *Journal of Clinical Experimental Neuropsychology*, 28, 1238-1256. doi:10.1080/13803390500376790
- Anderson, C. M., & Long, E. S. (2002). Use of a structured descriptive assessment methodology to identify variables affecting problem behavior. *Journal of Applied Behavior Analysis*, 35, 137-154.
- Anderson, N. B., & Rincover, A. (1982). The generality of overselectivity in developmentally disabled children. *Journal of Experimental Child Psychology*, 34, 217-230. doi:10.1016/0022-0965(82)90043-1
- Arcediano, F., Escobar, M., & Miller, R. R. (2003). Temporal integration and temporal backward associations in human and nonhuman subjects. *Learning & Behavior*, 31, 242–256. doi:10.3758/BF03195986
- Autism Speaks (2012). *Symptoms*. Retrieved September 17<sup>th</sup>, 2012, from <http://www.autismspeaks.org/what-autism/symptoms>
- Bachevalier, J. (1994). Medial temporal lobe structures and autism: A review of clinical and experimental findings. *Neuropsychologia*, 32, 627-648. doi:10.1016/0028-3932(94)90025-6
- Baddeley, A. (1992). Working memory, *Science*, New Series, 255 (5044), 556-559. doi:10.1126/science.1736359
- Baer, D. M., Wolf, M. M., & Risley, T. R. (1987). Some still current dimensions of applied behavior analysis. *Journal of Applied Behavior Analysis*, 20, 313-327. doi:10.1901/jaba.1987.20-313

- Bailey, S. L. (1981). Stimulus over selectivity in learning disabled children. *Journal of Applied Behavior Analysis*, 14, 239–248. doi:10.1901/jaba.1981.14-239
- Bandura, A. (1969). *Principles of behaviour modification*. New York: Holt.
- Barthold, C. H., & Egel, A.L. (2001). Stimulus overselectivity and generative language instruction for students with autism: An issue that needs to be revisited. *The Behavior Analyst Today*, 2(1), 33-39.
- Bashinski, H. S., & Bacharach, V. R. (1980). Enhancement of perceptual sensitivity as the result of selectively attending to spatial locations. *Perception & Psychophysics*, 28, 241-280. doi:10.3758/BF03204380
- Bauman, M.L., & Kemper, T.L. (1994). *Neurobiology of autism*. Baltimore, MD: Johns Hopkins University Press.
- Baumeister, A. A. (1967). Problems in comparative studies of mental retardates and normals. *American Journal of Mental Deficiency*, 71, 869-875.
- Bennetto, L., Pennington, B., & Rogers, S. (1996). Intact and impaired memory functions in autism. *Child Development*, 67, 1816–1835. doi:10.2307/1131734
- Berg, E.A., (1948). A simple objective technique for measuring flexibility in thinking. *Journal of General Psychology*, 39, 15-22. doi:10.1080/00221309.1948.9918159
- Bickel, W. K., & Etzel, B. C. (1985). The quantal nature of controlling stimulus response relations as measured in tests of stimulus generalization. *Journal of the Experimental Analysis of Behavior*, 44, 245-270. doi:10.1901/jeab.1985.44-245
- Bickel, W. K., Stella, M. E., & Etzel, B. C. (1984). A reevaluation of stimulus overselectivity: Restricted stimulus control or stimulus control hierarchies. *Journal of Autism and Developmental Disorders*, 14, 137-157. doi:10.1007/BF02409657
- Birnie-Selwyn, B., & Guerin, B. (1997) Teaching children to spell: Decreasing consonant cluster errors by eliminating selective stimulus control. *Journal of Applied Behavior Analysis*, 30, 69-91. doi:10.1901/jaba.1997.30-69
- Bondy, A.S., & Frost, L. (1994). The picture exchange communication system. *Focus on Autistic Behavior*, 9(3), 1-19.

- Boucher, J. (1981). Memory for recent events in autistic children. *Journal of Autism and Developmental Disorders*, 11, 293 – 30. doi:10.1007/BF01531512
- Boucher, J., & Warrington, E.K. (1976). Memory deficits in early infantile autism: Some similarities to the amnesic syndrome. *British Journal of Psychology*, 67, 73–87. doi:10.1111/j.2044-8295.1976.tb01499.x
- Broomfield, L. (2008). *Stimulus over-selectivity*. (Doctoral Dissertation). Swansea University, Wales, United Kingdom.
- Broomfield, L., McHugh, L., & Reed, P. (2008). Re-emergence of under-selected stimuli, after the extinction of over-selected stimuli in an automated match to samples procedure. *Research in Developmental Disabilities*, 29(6), 503-512. doi:10.1016/j.ridd.2007.09.001
- Broomfield, L., McHugh, L., & Reed, P. (2010). Factors impacting emergence of behavioral control by underselected stimuli in humans after reduction of control by overselected stimuli. *Journal of the Experimental Analysis of Behavior*, 94(2), 125-133. doi: 10.1901/jeab.2010.94-125.
- Brown, S.M., & Bebko, J.M. (2012). Generalization, overselectivity, and discrimination in the autism phenotype: A review. *Research in Autism Spectrum Disorders*, 6(2), 733–740.
- Burack, J. A. (1994). Selective attention deficits in persons with autism: Preliminary evidence of an inefficient lens. *Journal of Abnormal Psychology*, 103, 535–5
- Cambridge Cognition (2011). *The cambridge neuropsychological test automated battery*. Cambridge, England: Cambridge Cognition Limited.
- Center for Disease Control and Prevention (2008). *New data on autism spectrum disorders*. Retrieved September 17<sup>th</sup>, 2012, from <http://www.cdc.gov/Features/CountingAutism/>
- Chiang, H., & Carter, M. (2008). Spontaneity of communication in individuals with autism. *Journal of Autism and Developmental Disorders*, 38, 693–705. doi:10.1007/s10803-007-0436-7
- Cohen, L. R., Brady, J., & Lowry, M. (1981). The role of differential responding in matching-to-sample and delayed matching performance. In M. L. Commons & J. A. Nevin (Eds.), *Quantitative analysis of behavior: Vol. 1. Discriminative*

- properties of reinforcement schedules* (pp. 345–364). Cambridge, MA: Ballinger.
- Constantine, B., & Sidman, M. (1975). The role of naming in delayed matching to sample. *American Journal of Mental Deficiency, 79*, 680–689.
- Cooper, J.O., Heron, T.E., & Heward, W.L. (2007). *Applied Behavior Analysis* (2nd ed.) Upper Saddle River, NJ: Pearson
- Corbett, B.A., Constantine, L.J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development, *Psychiatry Research, 166*(2-3), 210-22. doi:10.1016/j.psychres.2008.02.005
- Credon, M. P. (1999). AcuVision 1000™ practice and functional visual skills performance by students with autism. *Proceedings of the 32nd Annual Gatlinburg Conference on Research and Theory in Mental Retardation and Developmental Disabilities, 150*.
- Damasio, A. R., & Maurer, R. G. (1978). A neurological model for childhood autism. *A Archives of Neurology, 35*, 777-786. doi:10.1001/archneur.1978.00500360001001
- Dawson, G., Meltzoff, A.N., Osterling, J., & Rinaldi, J. (1998). Neuropsychological correlates of early symptoms of autism. *Child Development, 69*, 1276–1285. doi:10.2307/1132265
- Debener, S., Makeig, S., Delorme, A., & Engel, A. K. (2005). What is novel in the novelty oddball paradigm? Functional significance of the novelty P3 event related potential as revealed by independent component analysis. *Cognitive Brain Research, 22*, 309–321.

- DeLong, G.R. (1992). Autism, amnesia, hippocampus, and learning. *Neuroscience and biobehavioral reviews*, 16 (1), 63–70. doi:10.1016/S0149-7634(05)80052-1
- Diez-Chanizo, V., Sterio, D., & Mackintosh, N.J. (1985). Blocking and overshadowing between intra-maze and extra-maze cues: a test of the independence of locale and guidance learning. *Quarterly Journal of Experimental Psychology*, 37B, 235-253.
- Dinsmoor, J.A. (1985). The role of observing and attention in establishing stimulus control. *Journal of the Experimental Analysis of Behavior*, 43, 693-728. doi:10.1901/jeab.1985.43-365
- Dirlich-Wilhelm, H., & Muller, M. (1982). Extreme Reizselektion- eine Funktion des Entwicklungsalters. *Zeitschrift fur Klinische Psychologie, Forschung, und Praxis*, 11, 177-185.
- Doughty, A. H., & Hopkins, M. N. (2011). Reducing stimulus overselectivity through an increased observing-response requirement. *Journal of Applied Behavior Analysis*, 44, 653-657.
- Downing, C. J. (1988). Expectancy and visual-spatial attention: Effects on perceptual quality. *Journal of Experimental Psychology: Human Perception & Performance*, 14, 188-202. doi:10.1037//0096-1523.14.2.188
- Dube, W. V. (2009). Stimulus overselectivity in discrimination learning. In P. Reed (Ed.), *Behavioral theories and interventions for autism* (pp. 23-46). New York: Nova Science Publishers.
- Dube, W. V., Dickson, C. A., Balsamo, L. M., O'Donnell, K. L., Tomanari, G. Y., Farren, K. M., & McIlvane, W. J. (2010). Observing behavior and atypically restricted stimulus control. *Journal of the Experimental Analysis of Behavior*, 94, 297-313. doi:10.1901/jeab.2010.94-297
- Dube, W.V., Lombard, K.M., Farren, K.M., Flusser, D., Balsamo, L.M. & Fowler, T.R. (1999). Eye tracking assessment of stimulus over selectivity in individuals with mental retardation. *Experimental Analysis of Human Behavior Bulletin*, 13, 267-271.
- Dube, W. V., Lombard, K. M., Farren, K. M., Flusser, D. S., Balsamo, L. M., Fowler, T. R., & Tomanari, G. Y. (2003). Stimulus overselectivity and observing behavior

- in individuals with mental retardation. In S. Soraci & K. Murata-Soraci (Eds.), *Visual Information Processing* (pp. 109-123). Westport, CT: Praeger.
- Dube, W. V. & McIlvane, W. J. (1997). Reinforcer frequency and restricted stimulus control. *Journal of the Experimental Analysis of Behavior*, *68*, 303-316.  
doi:10.1901/jeab.1997.68-303
- Dube, W.V. & McIlvane, W.J. (1999) Reduction of stimulus over selectivity with nonverbal differential observing responses. *Journal of Applied Behavior Analysis*, *32*, 25-33. doi:10.1901/jaba.1999.32-25
- Ducker, P.C., & van Lent, C. (1991). Inducing variability in communicative gestures used by severely retarded individuals. *Journal of Applied Behavior Analysis*, *24*(2), 379-386, doi: 10.1901/jaba.1991.24-379
- Duncan, J. (1986). Disorganisation of behavior after frontal lobe damage. *Cognitive Neuropsychology*, *3*, 271-290.
- Dunlap, G., Koegel, R.L., & Burke, J.C. (1981). Educational implications of stimulus overselectivity in autistic children. *Exceptional Education Quarterly*, *2*(3), 37-48.
- Dymond, S., Rehfeldt, R., & Schenk, J. J. (2005). Nonautomated procedures in derived stimulus relations research: A methodological note. *The Psychological Record*, *55*, 461-482.
- Edgin, J.O., & Pennington, B.F. (2005). Spatial cognition in autism spectrum disorders: Superior, impaired, or just intact? *Journal of Autism and Developmental Disorders*, *35*(6), 729-745.
- Eimas, P.D. (1969). Multiple-cue discrimination learning in children. *Psychological Record*, *19*, 417-424.
- Etzel, B. C., Bickel, W. K., Stella, M. E., & LeBlanc, J. M. (1982). The assessment of problem solving skills of atypical children. *Analysis and Intervention in Developmental Disabilities*, *2*, 187-206. doi:10.1016/0270-4684(82)90018-0
- Fabio, R.A., Giannatiempo, S., Antonietti, A. & Budden, S. (2009). The role of stereotypies in overselectivity process in Rett syndrome. *Research in Developmental Disabilities*, *30*(1), 136-145.

- Fairbank, D., Powers, A., & Monaghan, C. (1986). Stimulus overselectivity in hearing-impaired children. *Volta Review*, 88, 269-278.
- Falcomata, T. S., Roane, H. S., & Pabico, R. R. (2007). Unintentional stimulus control during the treatment of pica displayed by a young man with autism. *Research in Autism Spectrum Disorders*, 1, 350-359. doi:10.1016/j.rasd.2006.12.004
- Feeney, S. (1972). *Breadth of cue utilization and ability to attend selectively in schizophrenics and normals*. (Doctoral dissertation), University of California, Los Angeles.
- Feldman, R. S., Philippot, P., & Custrini, R. J. (1991). Social competence and nonverbal behavior. In R. S. Feldman & B. Rime (Eds.), *Fundamentals of nonverbal behavior* (pp. 329–350). New York: Cambridge University Press.
- Findlay, J. M., & Walker, R. (1999). A model of saccade generation based on parallel processing and competitive inhibition. *Behavioral and Brain Sciences*, 22(4), 661–721. doi:10.1017/S0140525X99002150
- Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician". *Journal of Psychiatric Research*, 12(3), 189–98. doi:10.1016/0022-3956(75)90026-6
- Frankel, F., Simmons, J.Q., Fichter, M., & Freeman, B.J. (1984). Stimulus overselectivity in autistic and mentally retarded children: A research note. *Journal of Child Psychology and Psychiatry*, 25, 147-155.
- Gena, A., Krantz, P.J., McClannahan, L.E., & Poulson, C.L. (1996). Training and generalization of affective behaviour displayed by youth with autism. *Journal of Applied Behavior Analysis*, 29, 291-304.
- Geren, M. A., Stromer, R., & Mackay, H. A. (1997). Picture naming, matching to sample and spelling instruction. *Journal of Applied Behavior Analysis*, 30, 339–342.
- Gerrig, R.J. & Zimbardo, P.G. (2002). *Psychology and Life: 16<sup>th</sup> Edition*. Allyn and Bacon: Boston, MA. Retrieved September 17<sup>th</sup>, 2012, from <http://www.apa.org/research/action/glossary.aspx#m>
- Gersten, R. M. (1980). In search of the cognitive deficit in autism: Beyond the stimulus overselectivity model. *Journal of Special Education*, 14, 47–65.

- Gersten, R. M. (1983). Stimulus overselectivity in autistic, trainable mentally retarded, and non-handicapped children: Comparative research controlling chronological (rather than mental) age. *Journal of Abnormal Child Psychology*, 11, 61–75. doi:10.1007/BF00912178
- Geurts, H. M., Verte, S., Oosterlaan, J., Roeyers, H., & Sergeant, J. A. (2005). ADHD subtypes: Do they differ in their executive functioning profile? *Archives of Clinical Neuropsychology*, 20(4), 457–477. doi:10.1016/j.acn.2004.11.001
- Gibson, E., & Reed, P. (2002). Stimulus over selectivity and early behavioural intervention for autism. *Studi di Psicologia dell'Educazione*, 21, 13-25.
- Gibson, E., & Reed, P. (2005). Stimulus Overselectivity in Rats. *Journal of Autism and Developmental Disorders*, 35(6). doi:10.1007/s10803-005-0030-9
- Gilliam, J.E. (2006) *Gilliam Autism Rating Scale (Second edition)*. Austin, TX: Pro-Ed.
- Goffart, L. (2008), *Saccadic eye movements*. In Squire L. (Ed.) *New Encyclopedia of Neuroscience*, Academic Press, Oxford.
- Goh, H.L. & Iwata, B.A. (1994). Behavioral persistence and variability during extinction of self-injury maintained by escape. *Journal of Applied Behavior Analysis*, 27(1), 173–174.
- Goin-Kochel, R.P., Mazefsky, C.A., & Riley, B.P. (2008). Level of functioning in autism spectrum disorders: Phenotypic congruence among affected siblings. *Journal of Autism and Developmental Disorders*, 38, 1019–1027. doi: 10.1007/s10803-007-0476-z
- Goldberg, M.C., Mostofsky, S.H., Cutting, L.E., Mahone, E.M., Astor, B.C., Denckla, M.B., & Landa, R.J. (2005). Subtle executive impairment in children with autism and children with ADHD. *Journal of Autism and Developmental Disorders*, 35(3), 279-93. doi:10.1007/s10803-005-3291-4
- Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in Weigl-type card-sorting problem. *Journal of Experimental Psychology*, 38, 404–411.
- Gray, J.A. (1995). The contents of consciousness: A neuropsychological conjecture. *Behavioral and Brain Sciences*, 18, 659-722. doi:10.1017/S0140525X00040395

- Gray, J. A., & McNaughton, N. (2000). *The neuropsychology of anxiety: An enquiry I into the functions of the septohippocampal system* (2nd ed.). Oxford, UK: Oxford University Press.
- Green, V.A., Sigafoos, J., Pituch, K.A., Itchon, J., O'Reilly, M., & Lancioni, G.E. (2006). Assessing behavioral flexibility in individuals with developmental disabilities. *Focus on Autism and Other Developmental Disabilities*, 21(4), 230-236.
- Gutowski, S. J., Geren, M. A., Stromer, R., & Mackay, H. A. (1995). Restricted stimulus control in delayed matching to complex samples: A preliminary analysis of the role of naming. *Experimental Analysis of Human Behavior Bulletin*, 13, 18–24.
- Hale, G.A. & Morgan, J.S. (1973). Developmental trends in children's component selection. *Journal of Experimental Child Psychology*, 15, 302-314.
- Happe, F., Booth, R., Charlton, R., & Hughes, C. (2006). Executive function deficits in autism spectrum disorders and attention-deficit/hyperactivity disorder: examining profiles across domains and ages. *Brain and Cognition*, 61, 25-39.
- Harris, S. L., Handleman, J. S., & Alessandri, M. (1990). Teaching youths with autism to offer assistance. *Journal of Applied Behavior Analysis*, 23, 297–305.
- Hedbring, C., & Newsom, C. (1985). Visual overselectivity: A comparison of two instructional remediation procedures with autistic children. *Journal of Autism and Developmental Disorders*, 9-22. doi:10.1007/BF01837895
- Hill, E.L. (2004). Evaluating the theory of executive dysfunction in autism. *Developmental Review*, 24, 189–233. doi:10.1016/j.dr.2004.01.001
- Hintgten, J. N., & Churchill, D. W. (1971). Differential effects of behavior modification in four mute autistic boys. In D. W. Churchill, G. D. Alpern, & M. K. De Myer (Eds.), *Infantile autism: Proceedings of the Indiana University Colloquium*. S Springfield, 111: Charles C. Thomas.
- Hoffman, J. E. (1975). Hierarchical stages in the processing of visual information. *Perception & Psychophysics*, 18, 348-354. doi:10.3758/BF03211211

- Hoffman, J.E., & Subramaniam, B. (1995). The role of visual attention in saccadic eye movements. *Perception & Psychophysics*, 57 (6), 787-795.  
doi:10.3758/BF03206794
- Hoffner-Barthold, C.H., & Egel, A.L. (2001). Stimulus overselectivity and generative 1 language instruction for students with autism: An issue that needs to be revisited. *The Behavior Analyst Today*, 2, 33-39.
- Holland, P.C. (1984). Differential effects of reinforcement of an inhibitory feature after serial and simultaneous feature negative discrimination training. *Journal of Experimental Psychology: Animal Behavior Processes*, 10(4), 461-475.  
doi: 10.1037/00977403.10.4.461
- Honey, R.C., Watt, A., & Good, M. (1998). Hippocampal lesions disrupt an associative mismatch process. *The Journal of Neuroscience*, 18 (6), 2226-2230.
- Hsieh, P.C., Yeh, T.L., Lee, I.H., Huang, H.C., Chen, P.S., Yang, Y.K., Chiu, N.T., Lu, R.B., & Liao, M. (2010). Correlation between errors on the Wisconsin Card Sorting Test and the availability of striatal dopamine transporters in healthy volunteers. *Journal of Psychiatry and Neuroscience*, 35 (2), 90-94.  
doi: 10.1503/jpn.090007
- Hughes, C., & Russell, J. (1993). Autistic children's difficulty with mental disengagement from an object: Its implications for theories of autism. *Developmental Psychology*, 29, 498-5510. doi:10.1037//0012-1649.29.3.498
- Hughes, C., Russell, J., & Robbins, T.W. (1994). Evidence for executive dysfunction in autism. *Neuropsychologia* 32(4), 477-92. doi:10.1016/0028-3932(94)90092-2
- Joseph, R. M. (1999). Neuropsychological frameworks for understanding autism. *International Review of Psychiatry*, 11, 309-325. doi:10.1080/09540269974195
- Jordan, T.R., & Thomas, S.M. (2001). Effects of horizontal viewing angle on visual and audiovisual speech recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 1386-1403.  
doi:10.1037//00961523.27.6.1386
- Just, M. A., & Carpenter, P. A. (1987). *The psychology of reading and language comprehension*. Boston: Allyn & Bacon.

- Kamin, L. J. (1968). "Attention-like" processes in classical conditioning. In M. R. Jones (Ed.), *Miami symposium on the prediction of behavior, 1967: aversive stimulation*. Coral Gables, Fla.: University of Miami Press, 1968. Pp. 9-31.
- Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, 2, 217–50.
- Katayama, J., & Polich, J. (1996). P300 from one-, two-, and three-stimulus auditory paradigms. *International Journal of Psychophysiology*, 23, 33–40.
- Katoh, T., & Kobayashi, S. (1985). A behavior analysis study on auditory discrimination learning in autistic children: Analysis of responses to speech and nonspeech sounds. *Japanese Journal of Special Education*, 23, 35–46.
- Kaufman, M.A., & Bolles, R.C. (1981). A non-associative aspect of overshadowing. *Bulletin of the Psychonomic Society*, 18, 318-320.
- Kemner, C., & van-Engeland, H. (2006). ERPs and eye movements reflect atypical visual perception in pervasive developmental disorder. *Journal of Autism and Developmental Disorders*, 36, 45-54. doi:10.1007/s10803-005-0041-6
- Kerns, K.A. & Mateer, C.A., 1996. Walking and chewing gum: The impact of attentional capacity on everyday activities. In: Sbordone, R.J. and Long, C.J. (Eds.), 1996. *Ecological validity of neuropsychological testing* GR Press/St. L Lucie Press, Delray Beach, FL, pp. 147–169.
- Klein, R. (1980). Does oculomotor readiness mediate cognitive control of visual attention? In R. S. Nickerson (Ed.), *Attention and performance VIII* (pp. 259-276). Hillsdale, NJ: Erlbaum.
- Koegel, R. L., Egel, A. L., & Williams J. (1980). Behavioral contrast and generalization across settings in treatment of autistic children. *Journal of Experimental Child Psychology*, 13(1), 91–99.
- Koegel, R. L., & Rincover, A. (1976). Some detrimental effects of using extra stimuli for guiding responding in autistic and normal children. *Journal of Abnormal Child Psychology*, 4, 59-71. doi:10.1007/BF00917605
- Koegel, R. L., & Schreibman, L. (1977). Teaching autistic children to respond to simultaneous multiple cues. *Journal of Experimental Child Psychology*, 24, 299-311. doi:10.1016/0022-0965(77)90008-X

- Koegel, R.L., Schreibman, L., Britten, K., & Laitinen, R. (1979). The effects of schedule of reinforcement on stimulus overselectivity in autistic children, *Journal of Autism and Developmental Disorders*, 9, 383–397.  
doi:10.1007/BF01531446
- Koegel, R. L., Schreibman, L., Good, A. B., Cerniglia, L., Murphy, C., & Koegel, L. K. (1989). *How to teach pivotal behaviors to autistic children: A training manual*. Santa Barbara: University of California.
- Koegel, R. L., & Wilhelm, H. (1973). Selective responding to multiple cues by autistic children. *Journal of Experimental Child Psychology*, 15, 442-453.  
doi:10.1016/0022-0965(73)90094-5
- Kolko, D.J., Anderson, L., & Campbell, M. (1980). Sensory preference and overselective responding in autistic children. *Journal of Experimental Child Psychology*, 10, 259-271. doi:10.1007/BF02408285
- Kovattana, P. M., & Kraemer, H. C. (1974). Response to multiple visual cues of color, size and form by autistic children. *Journal of Autism and Childhood Schizophrenia*, 1974, 4, 251- 261. doi:10.1007/BF02115231
- Krug, D. A., Arick, J. R., & Almond, P. J. (1993). *Autism Screening Instrument for Educational Planning*. Austin, Texas: Pro Ed.
- Landa, R.J. & Goldberg, M.C. (2005). Language, social, and executive functions in high functioning autism: A continuum of performance. *Journal of Autism and Developmental Disorders*, 35, 557-573. doi:10.1007/s10803-005-0001-1
- LaRue, R. H., Stewart, V., Piazza, C. C., & Volkert, V. M. (2011). Escape as reinforcement and escape extinction in the treatment of feeding problems *Journal of Applied Behavior Analysis*, 44, 719-735.
- Leader, G., Loughnane, A., Mc Moreland, C., & Reed, P. (2009). The effect of stimulus salience on over-selectivity. *Journal of Autism and Developmental Disorders*, 39, 330-338. doi:10.1007/s10803-008-0626-y
- LeBlanc, L.A., Carr, J.E., Crossett, S.E., Bennett, C.M., & Detweiler, D.D. (2005). Intensive outpatient behavioural treatment of primary urinary incontinence of children with autism. *Focus on Autism and Other Developmental Disabilities*, 20, 98-105. doi:10.1177/10883576050200020601

- Lewis, M. H., & Bodfish, J. W. (1998). Repetitive behavior disorders in autism. *Mental retardation and developmental disabilities research reviews*, 4, 80–89.  
doi:10.1002/(SICI)1098-2779(1998)4:2\80::AID-MRDD4[3.0.CO;2-0.
- Liberman, A.M., Cooper, F.S., Shankweiler, D.P., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review*, 74, 431-461.  
doi:10.1037/h0020279
- Lionello-DeNolf, K.M., McIlvane, W.J., Canovas, D.S., de Souza, G.D., & Barros, R.S. (2008). Reversal learning set and functional equivalence in children with and without Autism. *Psychological Record*, 58, 15-36.
- Litrownik, A.J., McInnis, E.T., Wetzel-Pritchard, A.M., & Filipelli, D.L. (1978). Restricted stimulus control and inferred attentional deficits in autistic and retarded children. *Journal of Abnormal Psychology*, 87, 554-562.
- Lord, C. & Volkmar, F. (2002). Genetics of childhood disorders: XLII. Autism part 1: Diagnosis and assessment in autistic spectrum disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*. 41(9) 1134-1136.
- Lovaas, O. I. (1979) Contrasting illness and behavior models for the treatment of autistic children: A historical perspective. *Journal of Autism and Development Disorders*, 9, 315-323. doi:10.1007/BF01531442
- Lovaas, O. I., Berberich, J.P., Perloff, B.F., & Schaeffer, B. (1966) Acquisition of imitative speech in schizophrenic children, *Science*, 151, 705-707.  
doi:10.1126/science.151.3711.705
- Lovaas, O. I., Koegel, R. L., & Schreibman, L. (1979). Stimulus overselectivity in autism: A review of research. *Psychological Bulletin*, 86, 1236- 1254.  
doi:10.1037//0033-2909.86.6.1236
- Lovaas, O. I., & Schreibman, L. (1971). Stimulus overselectivity of autistic children in a two-stimulus situation. *Behavior Research and Therapy*, 9, 305-310.  
doi:10.1016/0005-7967(71)90042-8
- Lovaas, O.I., Schreibman, L., Koegel, R., & Rehm, R. (1971). Selective responding by autistic children to multiple sensory inputs. *Journal of Abnormal Psychology*, 77, 211-222. doi:10.1037/h0031015
- Mackintosh, N. J. (1974). *The psychology of animal learning*. London: Academic Press.

- Mackintosh, N. J. (1975). A theory of attention: Variations in associability of stimuli with reinforcement. *Psychological Review*, 82, 276-298. doi:10.1037/h0076778
- Mackintosh, N.J. (1976). Overshadowing and stimulus intensity. *Animal Learning and Behavior*, 4, 186-192. doi:10.3758/BF03214033
- Manly, T., Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1999). *The Test of Everyday Attention for Children (TEA-CH)*. Bury St. Edmunds: Thames Valley Test Company.
- Matthew, B., Shute, R., & Rees, R. (2001). An analysis of stimulus overselectivity in adults with autism. *Journal of Intellectual & Developmental Disability*, 26 (2), 161-176.
- Matzel, L.D., Schachtman, T.R., & Miller, R.R. (1985). Recovery of an overshadowed association achieved by extinction of the overshadowing stimulus. *Learning and Motivation*, 16, 398-412. doi:10.1016/0023-9690(85)90023-2
- McEvoy, R. E., Rogers, S. J., & Pennington, B. F. (1993). Executive function and social communication deficits in young autistic children. *Journal of Child Psychology and Psychiatry*, 34, 563-578. doi:10.1111/j.1469-7610.1993.tb01036.x
- McHugh, L., & Reed, P. (2007). Age trends in stimulus overselectivity. *Journal of the Experimental Analysis of Behavior*, 88, 369-380. doi:10.1901/jeab.2007.88-369
- McHugh, L., Simpson, A., & Reed, P. (2010). Mindfulness as a potential intervention for stimulus over-selectivity in older adults. *Research in Developmental Disabilities*, 31, 178-184.
- Meisel, C. J. (1981). Stimulus over-selectivity by mentally retarded adolescents: Effects of pre-training on cue identification. *American Journal of Mental Deficiency*, 86, 317-322.
- Miller, R. R., & Matzel, L. D. (1988). The comparator hypothesis: A response rule for the expression of associations. In G. H. Bower (Ed.), *The psychology of learning and motivation*, Vol. 22 (pp. 51-92). San Diego, CA: Academic Press.
- Miller, R.R. & Schachtman, T.R. (1985). The several roles of context at the time of retrieval. In, P.D. Balsam & A. Tomie (Eds.), *Context and Learning*. Hillsdale, NJ.: Laurence Erlbaum.

- Miltenburger, R.G. (2001). *Behavior Modification: Principles and Procedures*. Toronto: Wadsworth/Thomson Learning.
- Minschew N.J., & Goldstein G. (1993). Is autism an amnesic disorder? Evidence from the California verbal learning test. *Neuropsychology*, 7, 209– 216.  
doi:10.1037//0894-4105.7.2.209
- Minschew, N.J., Goldstein, G., & Siegel, D.J. (1997). Neuropsychologic functioning in a autism: Profile of a complex information processing disorder. *Journal of the International Neuropsychological Society*, 3, 303-316
- O’Riordan, M., & Passetti, F. (2006). Discrimination in autism within different sensory modalities. *Journal of Autism and Developmental Disorders*, 34, 139-150. doi: 10.1007/s10803-006-0106-1
- O’Riordan, M., & Plaisted K.C . (2001). Enhanced discrimination in autism. *The Quarterly Journal of Experimental Psychology*, 54A(4), 961-979.
- O’Riordan, M., Plaisted K.C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 719-730. doi:10.1037//0096-1523.27.3.719
- Ozonoff, S., Cook, I., Coon, H., Dawson, G., Joseph, R.M., Klin, A., McMahon, W.M., Minschew, N., Munson, J.A., Pennington, B.F., Rogers, S.J., Spence, M.A., Tager- Flusberg, H., Volkmar, F.R., & Wrathall, D. (2004). Performance on cambridge neuropsychological test automated battery subtests sensitive to frontal lobe function in people with autistic disorder: Evidence from the collaborative programs of excellence in autism. *Journal of Autism and Developmental Disorders*, 34, 139-150. doi:10.1023/B:JADD.0000022605.81989.cc
- Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry*, 32, 1081–1105.  
doi:10.1111/j.1469-7610.1991.tb00351.x
- Ozonoff, S., South, M., & Miller, J. N. (2000). DSM-IV-defined Asperger syndrome: Cognitive, behavioral, and early history differentiation from high-functioning autism. *Autism*, 4, 29–46. doi:10.1177/1362361300041003

- Ozonoff, S., & Strayer, D.L. (1997). Inhibitory function in nonretarded children with autism. *Journal of Autism and Developmental Disorders*, 27, 59-77.  
doi:10.1023/A:1025821222046
- Pelphrey, K.A., Sasson, N.J., Reznick, J.S., Paul, G., Goldman, B.D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders*, 32 (4), 249-261. doi:10.1023/A:1016374617369
- Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, 37, 51–87.  
doi:10.1111/j.1469-7610.1996.tb01380.x
- Plaisted, K., O’Riordan, M.A., & Baron-Cohen, S. (1998). Enhanced visual search for a conjunctive target in autism. A research note. *Journal of Child Psychology and Psychiatry*, 39, 777–783.
- Ploog, B. O. (2010). Stimulus overselectivity four decades later: A review of the literature and its implications for current research in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 40, 1332-1349.  
doi:10.1007/s10803-010-0990-2
- Ploog, B. O., Banerjee, S., & Brooks, P. J. (2009). Attention to prosody (intonation) and content in children with autism and in typical children using spoken sentences in a computer game. *Research in Autism Spectrum Disorders*, 3, 743-758.  
doi:10.1016/j.rasd.2009.02.004.
- Ploog, B. O. & Kim, N. (2007). Assessment of stimulus overselectivity with tactile compound stimuli in children with autism. *Journal of Autism and Developmental Disorders*, 78, 1514-1524. doi:10.1007/s10803-006-0244-5
- Prior, M. R., & MacMillan, M. B. (1973). Maintenance of sameness in children with Kanner’s syndrome. *Journal of Autism and Childhood Schizophrenia*, 3, 154–167.
- Rabbitt, P. (1997). *Methodology of frontal and executive function*. Hove: Psychology Press. Robbins, T. W. (1997). Integrating the neurobiological and neuropsychological dimensions of autism. In J. Russell (Ed.), *Autism as an executive disorder* (pp. 21–53). Oxford: Oxford University Press.

- Raymond, G.V., Bauman, M.L., & Kemper, T.L. (1996). Hippocampus in autism: a Golgi analysis. *Acta Neuropathologica*, 91, 117-119.  
doi:10.1007/s004010050401
- Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology*, 7, 65-81. doi:10.1016/0010-0285(75)90005-5
- Rayner, K., & Pollatsek, A. (1989). *The psychology of reading*. Englewood Cliffs, NJ: Prentice-Hall.
- Reed, P. (2007). Comparator deficits in autism during discrimination learning: Theory to treatment. In, P.C. Carlisle, *Progress in Autism Research*. New York: Nova Science Publishers, Inc. ISBN: 978-1-60021-630-5
- Reed, P., Broomfield, L., McHugh, L., McCausland, A., & Leader, G. (2009). Extinction of overselected stimuli causes emergence of underselected cues in higher-functioning children with Autistic Spectrum Disorders. *Journal of Autism and Developmental Disabilities*, 39, 290-298. doi:10.1007/s10803-008-0629-8
- Reed, P. & Gibson, E. (2005). The effects of concurrent task load on stimulus overselectivity. *Journal of Autism and Developmental Disorders*, 35(5), 601-614. doi: 10.1007/s10803-005-0004-y
- Reed, P., & Reilly, S.R. (1990). Context extinction following conditioning with delayed reward enhances subsequent instrumental responding. *Journal of Experimental Psychology: Animal Behavior Processes*, 16, 48-55.  
doi:10.1037//0097-7403.16.1.48
- Reed, P., Savile, A., & Truzoli, R. (2012). Event related potential analysis of stimulus over-selectivity. *Research in Developmental Disabilities*, 33(2), 655-662.
- Reed, P., Watts, H., Truzoli, R. (2011). Flexibility in young people with autism spectrum disorders on a card sort task, *Autism*, 1-12.  
doi: 10.1177/1362361311409599
- Remington, R.W. (1980). Attention and saccadic eye movements. *Journal of Experimental Psychology: Human Perception and Performance*, 6, 726-744.  
doi:10.1037//0096-1523.6.4.726
- Remington, B., & Clarke, S. (1993). Simultaneous communication and speech comprehension. Part II: Comparison of two methods of overcoming selective

- attention during expressive sign training. *Augmentative and Alternative Communication*, 9, 49-60.
- Reynolds, B. S., Newsom, C. D., & Lovaas, O. I. (1974). Auditory overselectivity in autistic children. *Journal of Abnormal Child Psychology*, 2, 253-263.  
doi:10.1007/BF00919253
- Reynolds, G. (2012). *Processes and Mechanisms of Stimulus Over-Selectivity*. (Doctoral thesis). Swansea University, Wales, United Kingdom.
- Reynolds, G., & Reed, P. (2011a). Effects of schedule of reinforcement on over-selectivity. *Research in Developmental Disabilities*, 32, 2489-2501.  
doi:10.1016/j.ridd.2011.07.011
- Reynolds, G., & Reed, P. (2011b). The strength and generality of stimulus over-selectivity in simultaneous discrimination procedures. *Learning and Motivation*, 42, 113-122. doi:10.1016/j.lmot.2010.12.001
- Reynolds, G., Watts, J., & Reed, P. (2012). Lack of evidence for inhibitory processes in over-selectivity. *Behavioral Processes*, 89, 14-22.  
doi:10.1016/j.beproc.2011.09.008
- Rimland (1964) *Infantile Autism*. New York: Appleton Century Crofts
- Rincover, A., & Ducharme, J.M. (1987). Variables influencing stimulus overselectivity and “tunnel vision” in developmentally delayed children. *American Journal of Mental Deficiency*, 91, 422-430.
- Rincover, A., & Koegel, R. L. (1975). Setting generality and stimulus control in autistic children. *Journal of Applied Behavior Analysis*, 8, 235-246.  
doi:10.1901/jaba.1975.8-235
- Robbins, T. W. (1996). *Dissociating executive functions of the prefrontal cortex*. Philosophical Transactions of the Royal Society of London: Series B, 351, 1463-1471.
- Roberts, A. C., Robbins, T. W., & Weiskrantz, L. (1998). *The prefrontal cortex. executive and cognitive functions*. Oxford: Oxford University Press.
- Roid, G.H., & Miller, L.J. (1995, 1997). *Leiter International Performance Scale-Revised*. Wood Dale, IL: Stoelting Co.

- Roid, G.H., & Miller, L.J. (1997). *Leiter International Performance Scale-Revised: Examiner's Manual*. In G.H. Roid and L.J. Miller, *Leiter International Performance Scale-Revised*. Wood Dale, IL: Stoelting Co.
- Ross, A. (1976). *Psychological aspects of learning disabilities and reading disorders*. New York: Mc-Graw-Hill.
- Rumsey, J.M. (1985). Conceptual problem-solving in highly verbal, nonretarded autistic men. *Journal of Autism and Developmental Disorders*, 15, 23–36. doi:10.1007/BF01837896
- Scherf, K.S., Behrmann, M., Minshew, N., & Luna, B. (2008). Atypical development of face and greeble recognition in autism. *Journal of Child Psychology and Psychiatry*, 49 (8), 838–847. <http://dx.doi.org/10.1111/j.1469-7610.2008.01903.x>
- Schneider, W. X., & Deubel, H. (1995). Visual attention and saccadic eye movements: Evidence for obligatory and selective spatial coupling. In J. M. Findlay, R. K Kentridge, & R. Walker (Eds.), *Eye movement research: Mechanisms, processes, and applications* (pp. 317-324). New York: Elsevier.
- Schover, L. R., & Newsom, C. D. (1976). Overselectivity, developmental level, and overtraining in autistic and normal children. *Journal of Abnormal Child Psychology*, 4, 289–298. doi:10.1007/BF00917765
- Schrandt, J.A., Townsend, D.B., & Poulson, C.L. (2009). Teaching empathy skills to children with autism. *Journal of Applied Behavior Analysis*, 42 (1), 17-32. doi: 10.1901/jaba.42-17
- Schreibman, L. (1975). Effects of within-stimulus and extra-stimulus prompting on discrimination learning in autistic children. *Journal of Applied Behavior Analysis*, 8, 91-112. doi:10.1901/jaba.1975.8-91
- Schreibman, L., & Lovaas, O.I. (1973). Overselective response to social stimuli by autistic children. *Journal of Abnormal Child Psychology*, 1, 152-168. doi:10.1007/BF00916110
- Schreibman, L., Koegel, R. L., & Craig, M. S. (1977). Reducing over-selectivity in autistic children. *Journal of Abnormal Child Psychology*, 4: 425–436. doi:10.1007/BF00915090

- Shaw, M. L. (1978). A capacity allocation model for reaction time. *Journal of Experimental Psychology. Human Perception and Performance*, 4, 586-598.
- Shepherd, M., Findlay, J. M., & Hockey, R. J. (1986). The relationship between eye movements and spatial attention. *Quarterly Journal of Experimental Psychology*, 38A, 475-491.
- Sidman, M. (1979). Remarks, *Behaviorism*, 7, 123-126.
- Sidman, M. (1980). A note on the measurement of conditional discrimination. *Journal of the Experimental Analysis of Behavior*, 33, 285-289.  
doi:10.1901/jeab.1980.33-285
- Sigman, M., Mundy, P., Sherman, T., & Ungerer, J. (1986). Social interactions of autistic, mentally retarded, and normal children and their caregivers. *Journal of Child Psychology and Psychiatry*, 27, 647-656.
- Silverstein, B. (1976). *Overselectivity, mental age and behavioural development: A comparison of normal and autistic children*. Doctoral dissertation, University of California, Los Angeles, Dissertation Abstracts International, 37, 2562B. (University Microfilm NO. 76-242).
- Smeets, P.M., Hooheveen, F.R., Striefel, S., & Lancioni, G.E. (1985). Stimulus o overselectivity in TMR children: Establishing functional control of simultaneous multiple stimuli. *Analysis and Intervention in Developmental Disabilities*, 5(3), 247-267. doi:10.1016/0270- 4684(85)90014-X
- Sohlberg, M.M., Johnson, L., Paule, L., Raskin, S.A., & Mateer, C.A. (2001). *Attention Process Training (APT)- II: A Program to Address Attentional Deficits for Persons with Mild Cognitive Dysfunctions*. Wake Forest, NC: Lash & Associates Publishing/Training Inc.
- Sokhadze, E., Baruth, J., Tasman, A., Sears, L., Mathai, G., El-Baz, A., et al. (2009). Event- related potential study of novelty processing abnormalities in Autism. *Applied Psychophysiological Biofeedback*, 34, 37-51.
- Sonoyama, S. & Kobayashi, S. (1986). Stimulus over selective in autistic and normal children. The effects of different visual stimulus complexes. *Japanese Journal of Behavior Therapy*, 12, 62-72.

- Stout, S., Arcediano, F., Escobar, M., & Miller, R.R. (2003). Overshadowing as a function of trial number: Dynamics of first- and second-order comparator effects. *Learning and Behavior*, 31, 85-97.
- Stuss, D. T., & Knight, R. T. (2002). *Principles of frontal lobe function*. Oxford: Oxford University Press.
- Sutherland, N.S., & Holgate, V. (1966). Two-cue discrimination learning in rats. *Journal of Comparative and Physiological Psychology*, 61(2), 198-207.
- Sutherland, N. S., & Mackintosh, N. J. (1971). *Mechanisms of animal discrimination learning*. New York: Academic Press.
- The Tova Company (2009). *Test of Variables of Attention* ®: California, USA.
- Trabasso, T., & Bower, G. (1968). *Attention in learning*. New York: Appleton Century Croft.
- Treisman, A. (1969). Strategies and models of selective attention. *Psychological Review*, 76, 282-299.
- Turner, M. (1997). Towards an executive dysfunction account of repetitive behavior in a autism. In J. Russell (Ed.), *Autism as an executive disorder* (pp. 57–100). New York: Oxford University Press.
- Van der Geest, J.N., Kemner, C., Camfferman, G., Verbaten, M.N., & Van Engeland, H. (2002). Looking at images with human figures: comparison between autistic and normal children. *Journal of Autism and Developmental Disorders*, 32, 69-75. doi:10.1023/A:1014832420206
- Varni, J. W., Lovaas, O., Koegel, R. L., & Everett, N. L. (1979). An analysis of observational learning in autistic and normal children. *Journal of Abnormal Child Psychology*, 7 (1), 31-43. doi:10.1007/BF00924508
- Vinogradova, O.S. (2001). Hippocampus as comparator: Role of the two input and two output systems of the hippocampus in selection and registration of information. *Hippocampus*, 11, 578-598.
- Volkmar, F.R., Paul, R., Klin, A., & Cohen, D.J. (2005). *Handbook of autism and pervasive developmental disorders*. John Wiley & Sons, Inc.: New Jersey.

- Vollmer, T.R., Roane, H.S., Ringdahl, J.E. & Marcus, B.A. (1999). Evaluating treatment challenges with differential reinforcement of alternative behavior. *Journal of Applied Behavior Analysis*, 32, 9-23.
- Walpole, C.W., Roscoe, E.M., & Dube, W.V. (2007). Use of a differential observing response to expand restricted stimulus control. *Journal of Applied Behavior Analysis*, 40, 707-712.
- Walters, A. S., Barrett, R. P., & Feinstein, C. (1990). Social relatedness and autism: Current research, issues, directions. *Research in Developmental Disabilities*, 11, 303–326.
- Wayland, S., & Taplin, J.E. (1982). Nonverbal categorisation in fluent and non- fluent anomic aphasics. *Brain and Language*, 16, 87-108.
- Wechsler, D. (2008). *Wechsler Adult Intelligence Scale- Fourth Edition*. Pearson: San Antonio, Texas.
- Wehner, E., & Rogers, S. (1994). *Attachment relationships of autistic and developmentally delayed children*. Paper presented at the bi-monthly meeting of the Developmental Psychobiology Research Group, Denver, CO.
- White, K.G., & Ruske, A.C. (2002) Memory deficits in Alzheimer’s disease: the encoding hypothesis and cholinergic function. *Psychonomic Bulletin and Review*, 9, 426– 437.
- Wilhelm, H. & Lovaas, O.I. (1976). Stimulus over selectivity: a common feature in a autism and mental retardation. *American Journal of Mental Deficiency*, 81, 26-31.
- Wilkie, D.M., & Masson, M.E. (1976). Attention in the pigeon: A re-evaluation. *Journal of the Experimental Analysis of Behavior*, 26, 207-212.  
doi:10.1901/jeab.1976.26-207
- Wing,L., & Gould,J. (1979) Severe impairments of social interaction and associated abnormalities in children: empidemiology and classification *Journal of Autism and Developmental Disorders* 9,11-29.
- World Health Organization (1994). *International Statistical Classification of Diseases, 10th Revision, Second Edition*. Geneva: WHO.

- Wurtz, R.H., & Mohler, C.W. (1976). Enhancement of visual responses in monkey striate cortex and frontal eye fields. *Journal of Neurophysiology*, 39, 766-772.
- Wyckoff, L. B., Jr. (1969). The role of observing responses in discrimination learning. In D. P. Hendry (Ed.), *Conditioned reinforcement* (pp. 237-260). Homewood, IL: Dorsey Press.
- Yarczower, M., & Switalski, R. (1969). Stimulus control in the goldfish after massed extinction. *Journal of the Experimental Analysis of Behavior*, 12, 565-570.
- Yarbus, A. L. (1967). *Eye movements and vision*. New York: Plenum.
- Yerys, B.E., Wallace, G.L., Harrison, B., Celano, M.J., Giedd, J.N. & Kenworthy, L.E. (2009). Set-shifting in children with autism spectrum disorders: Reversal shifting deficits on the Intradimensional/Extradimensional Shift Test correlate with repetitive behaviour, *Autism*, 13, 523-539.