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Title	Can we explain cross-modal representation with neural algorithms alone?: Commentary on Paillard
Author(s)	Elliott, Mark
Publication Date	1999
Publication Information	Elliott, M. A., Gisa Aschersleben, T. B., & Jochen, M. (1999). Can we explain cross-modal representation with neural algorithms alone?: Commentary on Paillard <i>Advances in Psychology</i> (Vol. Volume 129, pp. 117-119): North-Holland.
Publisher	North-Holland
Link to publisher's version	http://linkinghub.elsevier.com/retrieve/pii/S0166411599800132
Item record	http://hdl.handle.net/10379/1579

Downloaded 2020-01-21T12:06:19Z

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**Can we explain cross-modal representation with neural algorithms
alone? – a remark on Paillard.**

Mark A. Elliott

Institut für Allgemeine Psychologie, Universität Leipzig, Leipzig, Germany

Correspondence to:

Mark. A. Elliott
Institut für Allgemeine Psychologie,
Universität Leipzig
Seeburgstr. 14/20
D-04103 Leipzig
Germany

Tel: ++49 (0)341 973 5962
Fax: ++49 (0)341 973 5969
Email: elliott@uni-leipzig.de

Paillard's chapter "Motor determinants of a unified perceived world" highlights a set of intriguing possibilities: firstly there are constraints on the quality of visual (and one might also assume auditory) perception that are imposed by somatosensory and positive/negative taxic experiences in the environment. In addition, and by extension, Paillard cites research by Collins and Bach-y-Rita, (1973), which indicates that, for at least one level of description, stimulus representations may be 'qualitatively identical' irrespective to the sensory modality through which the stimulus was processed. Thus, and as Paillard describes, the sensation derived from 'feeling' the representation of a visual image is able to guide definition of the figural properties of the image, the level of 'representational commonality' being the representation of the spatial configuration of the image. Recent research in both psychophysics and electrophysiology has revealed a number of examples in which behaviour is guided by (i.e. Spence & Driver, 1996), and brain activity has been argued to correlate with, the formation of a multimodal representation (although accounts are not in agreement as to the cortical origin of this activity: see Giard & Peronnet, 1998; Hackley & Valle-Incián, 1998; Schröger & Widmann, 1998). However the question remains as to the best level of description for this representation. Phillips and Singer (1997) consider this point in some depth: the formation of representations which may be described in terms of a common cortical algorithm (for example the commonality of certain neuronal firing frequencies during auditory or visual stimulus coding), are not sufficiently described by appeal to that same neuronal algorithm. Thus, even if we assume that a given representational state (for example, that which results from slowly increasing the temperature of a thermoconductive pad attached to the skin) correlates with some definable property of neural activity (such as the corresponding increase in 40-Hz activity across the somatosensory cortex [Chen & Herrmann, in progress, Herrmann,

personal communication]), the statistical relationship between the 40-Hz activity and the associated representation of 'heat' is unlikely to completely describe the experience of 'hotness', i.e. the 'qualia' associated both with the representation and the 40-Hz activity in the brain.

In addition, the idea that multi-modal representations may include common property states (that contribute to the specification of the quale) also bears relation to the 'context' of a given representation (i.e. in what circumstances does a given representation become manifest and for what reasons do we have representations with specific or shared properties in the first place). The question of context is most certainly not trivial and is as broad as it is complex. For example, one could ask an ethologist about the origin of associated representations such as 'stripes', the colours 'yellow' and 'black' with the behaviour schema 'don't eat this one it's poisonous' (i.e. amongst some birds), and the relationship of such representations with the (desired) existential context 'I'm poisonous therefore not edible' (i.e. amongst some bees). It is unlikely that either the common association or common context shared by these representations can be explained simply in terms of one or a number of neural algorithms, or for that matter, exclusively in terms of the representations themselves. The ethologist might argue that these associations, the consequent behaviour, behavioural context and the selection of the gene that produces this colouration have resulted from innumerable interactions of predator and prey during the process of evolution. In addition, and given that the collection of representations (above) instantiated within the bird brain are, to some extent, responsible for the peaceful co-existence of the birds and the bees, the 'fitness' potential of black and yellow stripes has been exploited to full potential by certain species of 'non-poisonous' flying

insects. On this basis, one is forced to ask whether the environment itself (i.e. the amount of 'bogus' black and yellow striped insects) is subject to alteration by virtue of some statistical structure that is best understood at the level of the representation and of the reciprocity of this relationship. Clearly, the cortical algorithm alone is not sufficient to describe a pattern of commonality (or identity) between the qualitative content of two or more representations, or to sufficiently explain the 'contexts' of that commonality. Thus, a coherent description, with explanatory power, is neither the exclusive province of a single level of analysis and almost certainly not the ultimate result of reducing the overall level of analysis to that of systems neuroscience.

However, for current purposes, it is of principal importance that a level of representational commonality exists, which might be adequately described in terms of the statistical structure adopted by patterns of activity in the nervous system. The importance of this possibility relates to the possibility that a psychophysical description of the common property states of a 'representation' might also be obtained in terms of statistical structures that emerge from careful and complementary experimentation involving both psychophysical and electrophysiological methods. Penultimately, and as Phillips and Singer (1997) argue (and I agree) both the neurophysical and psychophysical structures evolved directly from, and as natural adaptations to, the statistical structure of the environment and thus we have a third dimension for consideration, namely the information properties of stimuli in the environment. By Paillard's account extraction of these statistical properties may be conceived of in terms of a common cortical algorithm that generates a representation, independent of the sensory system from which it was derived and which maintains a high level of informational content relatively independently of the modality by which

it was encoded. Thus, and on the basis of this notion of representational commonality, Paillard's account introduces the basis for a prospective methodology, which would certainly permit a direct comparison (or bridging law) to be established between complementary levels of description, the results of which could only advance our current thinking about what a 'representation' may or may not be.

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