Consciousness and Cognition 22 (2013) 245–260

Contents lists available at SciVerse ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Review

How automatic are crossmodal correspondences?

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A R T I C L E I N F O

Article history:
Received 18 August 2012
Available online 29 January 2013

Keywords:
Crossmodal correspondence
Automaticity
Strategic
Voluntary
Stimulus-driven
Synaesthesia

A B S T R A C T

The last couple of years have seen a rapid growth of interest (especially amongst cognitive psychologists, cognitive neuroscientists, and developmental researchers) in the study of crossmodal correspondences – the tendency for our brains (not to mention the brains of other species) to preferentially associate certain features or dimensions of stimuli across the senses. By now, robust empirical evidence supports the existence of numerous crossmodal correspondences, affecting people's performance across a wide range of psychological tasks – in everything from the redundant target effect paradigm through to studies of the Implicit Association Test, and from speeded discrimination/classification tasks through to unspeeded spatial localisation and temporal order judgment tasks. However, one question that has yet to receive a satisfactory answer is whether crossmodal correspondences automatically affect people's performance (in all, or at least in a subset of tasks), as opposed to reflecting more of a strategic, or top-down, phenomenon. Here, we review the latest research on the topic of crossmodal correspondences to have addressed this issue. We argue that answering the question will require researchers to be more precise in terms of defining what exactly automaticity entails. Furthermore, one's answer to the automaticity question may also hinge on the answer to a second question: Namely, whether crossmodal correspondences are all 'of a kind', or whether instead there may be several different kinds of crossmodal mapping (e.g., statistical, structural, and semantic). Different answers to the automaticity question may then be revealed depending on the type of correspondence under consideration. We make a number of suggestions for future research that might help to determine just how automatic crossmodal correspondences really are.

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1053-8100/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.concog.2012.12.006

1. Introduction

The term "crossmodal correspondences" is but one of a range of terms that has been used over the years by researchers in order to refer to our brain's tendency to systematically associate certain features or dimensions of stimuli across the senses (see Marks, 2004; Spence, 2011, for reviews). Crossmodal correspondences have now been documented between many different pairs of stimulus dimensions: So, for example, auditory pitch has been shown to map onto visual elevation (see Ben-Artzi & Marks, 1995; Bernstein & Edelstein, 1971; Evans & Treisman, 2010; Melara & O'Brien, 1987; Miller, 1991; Patching & Quinlan, 2002; Proctor & Cho, 2006; Rusconi, Kwan, Giordano, Umiltà, & Butterworth, 2006), brightness and lightness (Hubbard, 1996; Ludwig, Adachi, & Matzuzawa, 2011; Marks, 1987; Martino & Marks, 1999; Melara, 1989; Mondloch & Maurer, 2004), size (Bien, ten Oever, Goebel, & Sack, 2012; Evans & Treisman, 2010; Gallace & Spence, 2006; Mondloch & Maurer, 2004; Parise & Spence, 2009, 2012), angularity of shape (Marks, 1987; Parise & Spence, in press), direction of movement (Clark & Brownell, 1976; Maeda, Kanai, & Shimojo, 2004; Sadaghiani, Maier, & Noppeney, 2009), and even spatial frequency (Evans & Treisman, 2010; Heron, Roach, Hanson, McGraw, & Whitaker, 2012).

The majority of the studies of crossmodal correspondences that have been published to date have involved the presentation of auditory and visual stimuli. That said, similar crossmodal correspondences also exist between auditory pitch and the elevation of tactile stimuli (Occelli, Spence, & Zampini, 2009), not to mention the size of objects experienced haptically (Walker & Smith, 1985),[1] and between tastes/odours and the angularity of visual stimuli or the pitch of auditory stimuli (Belkin, Martin, Kemp, & Gilbert, 1997; Crisinel & Spence, 2010, 2011, 2012; Deroy & Valentin, 2011; Hanson-Vaux, Crisinel, & Spence, 2013; see Deroy, Crisinel, & Spence, in press; Spence & Ngo, 2012a, for reviews).

One important, but as yet unconvincingly answered question in the area of crossmodal correspondences research, concerns whether they affect performance (in tasks involving, for example, participants having to make speeded responses) in an automatic manner, or whether instead they affect performance in more of a strategic manner, emerging only as a function of the specific task demands and instructions imposed on the participant by the experimenter. Addressing the issue of the automaticity of crossmodal correspondences means, however, breaking the notion of automaticity down into a number of distinct sub-components (see Section 2) and then trying to make sense of the apparently contradictory results that have been published in the area recently (see Section 3). This exercise will further help to draw attention to the differences that exist between synaesthesia and crossmodal correspondences (see Section 4) while agreeing that, as there certainly are various types of crossmodal correspondence, one perhaps needs to accept that one's answer to the automaticity question might vary as a function of the type of crossmodal correspondence under consideration. This said, the review of the literature relevant to the automaticity claim outlined here leads to the generation of a number of specific hypotheses that deserve further testing in future research on crossmodal correspondences (see Section 5).

The original evidence that prompted researchers to make the automaticity claim came from the many speeded classification studies demonstrating that the speeded discrimination of target stimuli in one modality (e.g., discriminating larger vs. smaller circles, for visual stimuli presented on a monitor) was affected by the presentation of a completely task-irrelevant auditory stimulus that varied randomly on a trial-by-trial basis between high and low pitch (see Marks, 2004; Spence, 2011, for reviews). However, the suggested automaticity of crossmodal correspondences has been questioned by a series of negative results from studies that have sometimes failed to show any difference in behaviour between those conditions in which congruent vs. incongruent pairs of visual and auditory stimuli have been presented (see also Chiou & Rich, 2012a; Heron et al., 2012; Klapetek, Ngo, & Spence, 2012; Klein, Brennan, D'Aloisio, D'Entremont, & Gilani, 1987; Klein, Brennan, & Gilani, 1987; Sweeny, Guzman-Martinez, Ortega, Grabowecky, & Suzuki, 2012). Explaining why such differences between studies have been obtained represents a worthwhile endeavour: And, what is more, in answering the question of the degree of automaticity of crossmodal correspondences, two further related questions also come to the fore, as detailed below.

The first question concerns the link between crossmodal correspondences and other phenomena such as coloured-hearing synaesthesia,[2] where the presence, or experience, of a stimulus in one modality (for instance, audition) induces a conscious concurrent in another, unstimulated modality (for instance, vision). Crossmodal 'mappings' or 'correspondences' between say, pitch and brightness can, at first, sometimes appear just as surprising as synaesthesia. In particular, it may not always be immediately obvious whether (or that) they are tracking, or picking-up on, some statistical regularity of the environment (see Spence & Deroy, 2012). The initially unexplainable nature of at least certain crossmodal correspondences has led to their being

[1] Here it is worth noting that auditory stimuli tend to be assigned to specific elevations even in the absence of any stimuli being presented in another sensory modality (e.g., see Cabrera & Morimoto, 2007; Pedley & Harper, 1959; Pratt, 1930; Roffler & Butler, 1968; Trimble, 1934). The matching of auditory pitch to elevation has also been demonstrated under those conditions in which the participants have to respond to (i.e., discriminate) a centrally-presented visual target by pressing one of two vertically-arrayed buttons, while the pitch of an accessory sound is varied (see Keller & Koch, 2006).

[2] Canonical cases of synaesthesia include such examples as coloured-hearing, tasted shapes, etc. (see Ward, 2012, for a recent review).

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