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A deafening flash! Visual interference of auditory signal detection

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ABSTRACT

In some people, visual stimulation evokes auditory sensations. How prevalent and how perceptually real is this? 22% of our neurotypical adult participants responded 'Yes' when asked whether they heard faint sounds accompanying flash stimuli, and showed significantly better ability to discriminate visual 'Morse-code' sequences. This benefit might arise from an ability to recode visual signals as sounds, thus taking advantage of superior temporal acuity of audition. In support of this, those who showed better visual relative to auditory sequence discrimination also had poorer auditory detection in the presence of uninformative visual flashes, though this was independent of awareness of visually-evoked sounds. Thus a visually-evoked auditory representation may occur subliminally and disrupt detection of real auditory signals. The frequent natural correlation between visual and auditory stimuli might explain the surprising prevalence of this phenomenon. Overall, our results suggest that learned correspondences between strongly correlated modalities may provide a precursor for some synaesthetic abilities.

1. Introduction

In synaesthesia an inducing stimulus consistently and involuntarily evokes a consciously experienced concurrent sensation in a different sensory dimension or modality. Though there are many variants of synaesthesia, one feature they have in common is that they are rare: the most frequent types (e.g. grapheme and colour, or sound and shape) are found in only about 2–4% of the population (Simner et al., 2006; Ward, 2013). The low prevalence of cases is consistent with suggestions that synaesthesia represents an aberrant genotype (Brang, Williams, & Ramachandran, 2012; Tomson et al., 2011), which may result in unusual patterns of neural cross-wiring or cross-activation between adjacent cortical regions (Ramachandran & Hubbard, 2001; Rouw & Scholte, 2007). However, many researchers have argued that some forms of synaesthesia might be grounded on normal mechanisms involved in forming and reinforcing associations between different modalities and sensory dimensions (Brang et al., 2012; Cohen, 2013; Cohen Kadosh, Henik, Catena, Walsh, & Fuentes, 2009; Cytowic, 2003; Grossenbacher & Lovelace, 2001; Ramachandran & Hubbard, 2001; Ward, Huckstep, & Tsakanikos, 2006). On this latter view, the rarity of synaesthesia might be explained by the observation that the kinds of exotic associations that typify synaesthesia are very rarely found in nature. For example, grapheme-colour synaesthesia might be rare because consistent correspondences between letters and colours are themselves rare and thus do not typically reinforce strong associations, even though repeated exposure to consistent letter-colour pairings (found in fridge-magnets, educational materials,

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or experimental stimuli) might shape and reinforce grapheme-colour associations in individuals who are susceptible to them (Bor, Rothen, Schwartzman, Clayton, & Seth, 2014; Witthoft, Winawer, & Eagleman, 2015).

Such reasoning leads to the hypothesis that we might find synaesthetic associations more frequently when they occur between stimulus dimensions that are naturally correlated, so that their associations are regularly and consistently reinforced. For example, visual events naturally correlate very frequently with sounds, whenever two objects collide or a person speaks and their lips move. An opportunity to test this association frequency hypothesis is presented by a past report that transient visual stimulation such as flashes or moving dots can induce conscious concurrent auditory sensations in some individuals (Saenz & Koch, 2008). Saenz and Koch (2008) devised an elegant objective test of this phenomenon, where participants had to compare two paired 'Morse code' type sequences, presented both either as sounds or flashes. A small sample of participants self-identified as 'hearing-motion' synaesthetes showed relatively high performance for both auditory and visual stimuli, while control participants found the task significantly harder in the visual modality. This superior visual performance in synaesthetes was explained on the assumption that they were benefiting from additional temporal information provided by recoding the visual stimulation into the auditory modality (Glenberg, Mann, Altman, Forman, & Procise, 1989; Guttman, Gilroy, & Blake, 2006). Apart from other rare reports of individuals who hear distinct musical sounds associated with visual colours (Baron-Cohen, Burt, Smith-Laittan, Harrison, & Bolton, 1996; Goller, Otten, & Ward, 2009) there has been no other published research on this visual-to-auditory direction of association to our knowledge. Two unresolved questions are raised, which we consider here: how prevalent is this phenomenon, and is it perceptually real?

Prevalence cannot be assessed from Saenz and Koch's (2008) original study, as the few participants who were identified as synaesthetes were not randomly sampled but self-selected. Our first goal was therefore to make a tentative estimate of the prevalence of visually-evoked auditory sensations in a random sample, using a combination of subjective questioning and objective tests based on Saenz and Koch's (2008) paradigm. Our association frequency hypothesis predicts relatively high frequency of reports of visually-evoked sensations, in neurotypical individuals, along with task performance resembling that of Saenz & Koch's synaesthetes.

Though intended as an objective diagnostic of 'hearing-motion' synaesthesia, Saenz and Koch's (2008) sequence discrimination paradigm only provides an indirect test of the effects of visually-evoked auditory sensations on the visual modality, rather than on hearing. Our second goal was therefore to probe the effects of visual stimulation on actual auditory signal detection, and measure the correlation of such effects with performance on Saenz & Koch's sequence discrimination paradigm. We measured sensitivity for detecting a white-noise burst, in the presence of an irrelevant and temporally non-predictive visual event (a high-contrast drifting radial grating), compared to no visual stimulus (following Lovelace, Stein, & Wallace, 2003). We predicted that participants who benefitted from auditory-recoding of visual stimuli in the sequence discrimination task might be affected more by irrelevant flashes in the auditory signal detection task, because they would be experiencing concurrent visually-evoked auditory sensations. We also measured and controlled for individual biases in the dominance of the auditory modality relative to visual (Colavita, 1974; Koppen, Levitan, & Spence, 2009), in case this influenced our other objective measures.

2. Methods

2.1. Participants

A total of 40 naïve participants with normal hearing (by self-report) took part in the research and were paid for their participation. Two participants who did not have time to complete the debriefing questions were excluded from analysis, and a further participant was excluded because of chance performance in both auditory and visual sequence discrimination tasks. The final sample had 24 females, aged 19–36 (mean 24.24, standard deviation 4.68). One participant had an absolute auditory threshold of more than 3 standard deviations higher than the sample mean, but was included as performance on the main tasks was in the normal range and exclusion made no difference to the pattern of results. A subsample of 24 participants (18 female, mean age 23.8, SD 4.27) also performed an additional 'Colavita' test (see below). All participants had normal or corrected vision and reported normal hearing. All procedures were carried out with informed consent and were approved by the local Psychology ethics committee.

2.2. Apparatus and stimuli

The experimental procedure was conducted using an Apple Mac Mini connected to a 17″ Sony HMD-A420 cathode ray tube (CRT) display. Auditory stimuli were presented through two Labtec PC speakers both positioned next to each other directly in front of and below the centre of the monitor. Video mode was 800×600 pixels with a 120 Hz refresh rate and viewing distance was approximately 57 cm (controlled using a chin rest). A small white fixation point marked the centre of the display. Subject responses were collected using the arrow keys on a standard computer keyboard. Experimental procedures and stimuli were programmed using Psychtoolbox for Matlab.

Stimuli for each main task closely followed the methods described in the originating studies (Lovelace et al., 2003; Saenz & Koch, 2008). For the Sequence Discrimination task (Fig. 1a), visual stimuli consisted of white circular discs of luminance 81 cdm^{-2}, presented centrally on a black background. Disk diameter was 3 degrees of visual angle. Auditory stimuli were