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Color synesthesia improves color but impairs motion perception

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Abstract

A recent study showed that color synesthetes have increased color sensitivity but impaired motion perception. This is exciting because little research examines how synesthesia affects basic perceptual processes outside the context of the synesthetic experiences. The results suggest that synesthesia broadly impacts perception with greater neural implications than previously considered.

In a recent paper, Banissy and colleagues [1] examined whether color synesthesia influences basic feature level perception in the absence of inducing stimuli. They found that synesthetes who experience color as their evoked sensation (concurrent) are better at discriminating color than non-synesthetes. Interestingly, this improved color perception comes at the expense of impaired motion perception: synesthetes have elevated motion coherence thresholds compared to non-synesthetes. By independently investigating the three dimensions of color, Banissy and colleagues provide a strong replication of their previous finding of enhanced hue perception in color synesthetes and extend it to saturation and luminance [2]. The novel result is that synesthetes have impaired motion perception. These findings are interesting because much extant research on synesthesia has focused on validating the phenomenon, investigating its origins or examining how synesthetic experiences interact with other perceptual and cognitive functions [3]. In contrast, few studies have examined how mechanisms underlying synesthesia may influence basic visual processes [1] let alone those unrelated to the synesthesia.

To measure basic color perception, Banissy and colleagues tested groups of color synesthetes and non-synesthete controls on a visual search task in which targets and distracters differed along a single color dimension in each trial: hue, saturation or luminance (Figure 1A). Similar to their past findings [2], the color synesthetes were able to discriminate colors of different hue as well as saturation and luminance better than the non-synesthete controls (Figure 1B). This group difference was not due to a generalized task-advantage as the synesthetes did not differ from controls when discriminating line-orientation. Surprisingly, when measured using random-dot-kinematograms (Figure 1C), the synesthetes had elevated motion coherence thresholds (i.e. reduced performance) compared to the neurotypicals (Figure 1D).

One common model posits that synesthetic experiences arise due to increased connectivity between cortical regions that process the inducing and concurrent features [4]. For example, it has been argued that grapheme-color synesthesia arises due to excess connectivity between regions of the brain that subserve form and color processing. For color synesthesia, it is not unreasonable to conclude that such excess connectivity could lead to finer-scale color representations [2]. However, this idea does not explain why color synesthetes would have impaired motion perception, which is largely mediated by cortical regions distinct from those that process either form and color. Research applying transcranial magnetic stimulation in neurotypicals suggests that brain regions involved in motion and color processing (i.e., hMT+ and hV4, respectively) can mutually inhibit one another [5]. Banissy and colleagues reason that the impaired motion perception observed in the color synesthetes may be an indirect consequence of a synesthesia-induced bias towards color in the interaction between color and motion processes [1]. A similar argument was used to explain the authors' recent finding that form and color-processing areas (i.e., hV4) in the brains of color synesthetes had increased gray-matter volume compared to non-synesthetes. Moreover, an area central to motion perception (i.e., hMT+) had decreased gray-matter volume compared to non-synesthetes [6]. We find it entertaining that the motivation for investigating a seemingly unlikely interaction between color-synesthesia and motion was drawn from this volumetric finding in hMT+. This is a relatively rare example of neuroimaging observations being used to formulate testable predictions about behavior that are then empirically validated. The most common use of MRI in cognitive neuroscience research instead focuses on identifying neural correlates of known perceptual or cognitive behaviors.

Looking forward, the current study brings several unanswered questions to mind. Is the push-pull relationship between color and motion perception specific to color synesthetes? If the current results indeed arise due to a competition between brain regions that process color and motion, then the same logic may predict anyone with particularly good color perception to have somewhat impaired motion perception. For example, their Table 1 shows that 'Controls 6, 9 and 10' have relatively high motion-coherence thresholds, on par with those in the synesthete group [1]. Do these non-synesthetes also have particularly good color perception—on par with that of the synesthetes? If this were the case, it would be a clear and important demonstration that the study of synesthesia can directly inform normal visual processes. If this is not the case, an explanation must ultimately be found for why this observation is only found in synesthetes. Alas, the same participants were not used across their color and motion experiments so a direct examination of this possibility cannot be drawn from the data.

Increasing evidence suggests that synesthetic experiences can be bi-directional in nature. For example, we recently demonstrated that grapheme-color synesthetes can solve simple math equations using only colors, as accurately as if they are defined with graphemes [7]. Might the same mechanisms that lead to improved perception within a synesthete's concurrent feature-domain (i.e. color) also lead to improved perception with the domain of the inducing feature (i.e. form)? Intriguingly, the stimuli used to measure motion coherence thresholds are necessarily devoid of form information (Figure 1C). Not only does form processing play an important role in grapheme-color synesthesia, but it also contributes to many aspects of motion perception [8]. For example, the size and shape of an object can greatly influence the way it is perceived to move [9] and conversely, the motion of an object can influence its perceived shape. Could it be the case that the color-form and color-motion mechanisms that manifest in color synesthesia mediate interactions between form and motion?

When one begins to consider how interconnected different feature domains can be, it is natural to wonder the degree to which color synesthesia may influence basic perceptual processing beyond color and motion. Recent work has shown that individual differences in the anatomical structure and functional connectivity within visual cortex can influence a host of perceptual domains including size perception [10] and a range of contextual illusions. Having demonstrated that at least one seemingly unrelated perceptual process can be influenced by synesthesia, the current research opens the door to the possibility that the generalized perceptual consequences of synesthesia may be wide ranging indeed.

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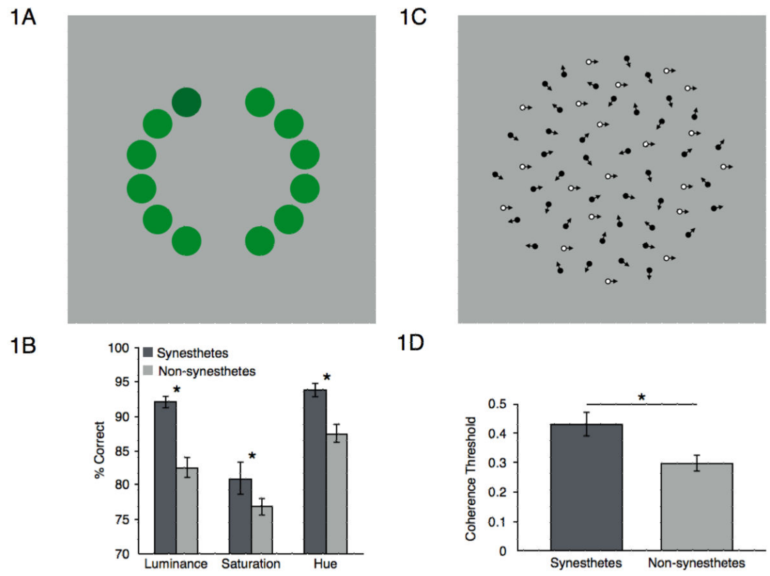

Figure 1.

Stimuli and results from Banissy et al. (2013). A) An example of the color visual search task. B) Mean accuracy across each color dimension for synesthetes and controls in the visual search task. The synesthetes preformed better than non-synesthetes in all color tasks. C) A sample random-dot-kinematogram display. Dots are randomly positioned within a circular array and move in different directions. The example shown here illustrates 33% coherence—the highlighted dots (33% of total) all move in the same direction. D) Mean motion coherence thresholds for synesthetes and non-synesthetes. The data indicate that synesthetes had reduced motion sensitivity (i.e., higher coherence thresholds) compared to non-synesthetes. A, B & D: adapted with permission [1].