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The Importance of Individual Differences in Grapheme-Color Synesthesia

In this issue of *Neuron*, Hubbard et al. show individual differences in how grapheme-color synesthetes perform on cognitive tasks. Importantly, these behavioral differences were correlated with fMRI measures. Such individual differences have important ramifications for synesthesia research. If individual differences are ignored, then synesthesia research will be characterized by erroneous conclusions and failures to replicate.

When a person with grapheme-color synesthesia views a black digit or letter, he or she sees the black graphemes just as we do but also experiences highly specific colors (Dixon et al., 2000; Mattingley et al., 2001; Grossenbacher and Lovelace, 2001; Smilek and Dixon, 2002). For example, when the synesthete J looks at different letters such as S, A, and E, she knows the letters are in black, but viewing the S leads to an experience of "medium-dark green," viewing the A leads to an experience of "slightly dark red," and viewing the E leads to an experience of "brown with a reddish orange tint." In a website documenting her synesthetic experiences, J relates, "I actually see these colors projected onto each of the letters when I look at them" (Emerson, 2005). The synesthete C describes her synesthetic colors in a similar fashion. Although she has different colors for these particular letters, her colors are just as specific, and when describing how she experiences these colors she tells us that her colors are experienced "out there on the page." We call these synesthetes *projectors*—a label that alludes to their photisms being perceived in external space (see also Cytowic, 2002). In their article, Hubbard, Arman, Ramachandran, and Boynton refer to these synesthetes as "lower" synesthetes.

The subjective reports of synesthetes whom we have interviewed, however, suggest that not all grapheme-color synesthetes experience synesthetic colors in the same way. In fact, only a minority of synesthetes (approximately 10%) experience their synesthetic colors in external space. The majority of synesthetes whom we have interviewed use phrases like "in my mind's eye" or "in my head" to convey how (and where) they experience their synesthetic colors. For these synesthetes, their colors are perceived internally with no hint of the projected quality of the colors that C and J perceive. Their experience can be likened, at least in part, to that of a nonsynesthete viewing a black and white photograph of a spruce tree. We "know" that the needles of a spruce tree are a highly specific shade of dark green and can readily form an image of this color in our mind's eye, but we do not project this color onto the photograph. We call these synesthetes *associators*, because their descriptions of their experiences reflect a strong association between graphemes and specific colors. In their article, Hubbard et al. (2005) refer to these synesthetes as "higher" synesthetes.

Although individual differences among synesthetes had been acknowledged in the literature, there has been little systematic study of these differences. In fact, there has only been one empirical study that has systematically documented these differences (Dixon et al., 2004). In general, studies of synesthesia are based on the assumption that synesthetes are a homogenous group of individuals. This is what makes the Hubbard et al. study so timely and important. By combining behavioral and neuroimaging techniques, Hubbard et al. provide strong evidence in support of the idea that there are important and stable individual differences among synesthetes. In order to fully understand the importance of this study, one needs to briefly survey where recent research on grapheme-color synesthesia has come from, and where it is heading.

Synesthesia has a long research history. Many papers were published in the 1920s, when introspection was an accepted and popular method of enquiry. With the rise of behaviorism, came the decline of synesthesia research. In the 1990s, and especially since the turn of the century, there has been a renaissance of research on synesthesia, with many high-profile researchers publishing their data in the very best journals. Arguably, much of this recent work was devoted to establishing that grapheme-color synesthesia is a "real" phenomenon that is perceptual in nature, not simply a memory association between graphemes and colors. A survey of recent titles clearly reveals this general theme (e.g., "The perceptual reality of synesthetic color" [Palmeri et al., 2002]; "Synesthetic photisms influence visual perception" [Smilek et al., 2001]; "Psychophysical investigations into the neural basis of synesthesia" [Ramachandran and Hubbard, 2001]).

Ramachandran and Hubbard (2001), for example, published a study showing that synesthetes could perceptually group graphemes according to their synesthetic colors. Smilek et al. (2001) and Palmeri et al. (2002) demonstrated that synesthetic colors could influence the ease with which targets could be found in visual search. Blake et al. (2005) even showed that achromatic graphemes can trigger colored, orientationcontingent afterimages known as the *McCullough effect*. One of the central objectives of all of this research was to demonstrate that synesthetes performed cognitive tasks with black and white stimuli in much the same way that nonsynesthetes performed these same tasks using colored stimuli. The conclusions were therefore that synesthesia was a "perceptual" phenomenon.

Interestingly, though, all of these studies were conducted on synesthetes who experience their colors in external space (synesthetes whom we would call projectors, and whom Hubbard et al. have referred to as lower synesthetes). A recurring question that was hinted at in the literature but never empirically addressed was whether all synesthetes would show these perceptual influences of synesthetic colors. One wonders whether or not there might be individual differences among synesthetes and, if there were individual differences among grapheme-color synesthetes, what the nature of these differences would be. For instance, would projectors differ from associators, and would some projectors even differ from other projectors?

The study by Hubbard et al. provides compelling evidence that one grapheme-color synesthete can be very different from another grapheme-color synesthete and that not all synesthetes will show these "perceptual" effects. These individual differences are most salient in the perceptual crowding experiment (experiment 2) reported by Hubbard et al. In that experiment, target digits were presented in the periphery and were flanked by other digits (e.g., a 4 surrounded by 2s). The idea was that for synesthetes the synesthetic color of the target would provide an extra cue as to its identity and circumvent the effects of perceptual crowding that would be experienced by the nonsynesthetes who did not have this extra color cue. The important finding was that not all synesthetes performed better than controls on this task. Analyses of individual synesthetes revealed that three of the synesthetes significantly outperformed controls on the perceptual crowding task, whereas the other three were indistinguishable from controls. Furthermore, the performance of the synesthetes on these perceptual tasks was correlated with fMRI responses in retinotopic visual areas showing that the individual differences in behavior were not simply an artifact of the behavioral task.

What does this mean for the study of grapheme-color synesthesia? First, in our view, failing to be cognizant of these individual differences will lead to synesthesia research being characterized by failures to replicate. For instance, consider again the perceptual crowding experiment reported by Hubbard et al. An inspection of their Figure 2 shows that the synesthete JAC performed much better than control participants, while the synesthete CHP performed nominally worse than control participants. Now imagine that JAC was tested by one laboratory and that these researchers published this interesting finding. Intrigued by this finding, a second laboratory might seek to replicate this experiment using the exact same task but a different synesthetic subject (synesthete CHP). Because CHP would not show the same effects as JAC, researchers could question the replicability of the initial finding. In reality, however, the difference in these hypothetical results would have occurred not because JAC's effects were not reliable, but because there are stable individual differences between synesthetes.

Second, the findings reported in the article by Hubbard et al. suggest that, if synesthetes of different subtypes are pooled, and their performance on certain tasks is evaluated in terms of group effects, the synesthetes as a group are going to have high variability, making it difficult to reject the null hypothesis when synesthetes are compared to controls. Highlighting this point, in the perceptual crowding experiment reported by Hubbard et al. only three of the six synesthetes performed significantly better than control participants, and when the data from all six synesthetes were pooled together and the synesthetes as a group were compared to controls, there was no significant difference between synesthetes and nonsynesthetes. Based on such a group comparison, one might conclude that synesthetes perform no differently on perceptual crowding tasks than do nonsynesthetes. The analysis of the individual data clearly shows, however, that such a conclusion would be incorrect, as there is clearly a subgroup of synesthetes who perform very differently than nonsynesthetes. Thus, the study nicely shows that relying on group analyses alone would lead researchers to potentially miss very important findings and draw erroneous conclusions.

In our view, the Hubbard et al. study is a fine illustration of how far synesthesia research has come. Research has moved beyond studies designed to demonstrate that synesthesia is a "real" phenomenon. The Hubbard et al. study is a cognitive neuroscience assay of synesthesia that uses converging evidence from both behavioral paradigms (performance on the textual grouping and perceptual crowding tasks) and fMRI to demonstrate that there are fine-grained individual differences in grapheme-color synesthesia. Their conclusions are important ones. Not all grapheme-color synesthetes are the same, and to treat them as though they come from a homogeneous group will lead to failures to replicate and erroneous conclusions.

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