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Article Addendum

The Whorfian mind

Electrophysiological evidence that language shapes perception

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Color perception has been a traditional test-case of the idea that the language we speak affects our perception of the world.[1] It is now established that categorical perception of color is verbally mediated and varies with culture and language.[2] However, it is unknown whether the well-demonstrated language effects on color discrimination really reach down to the level of visual perception, or whether they only reflect post-perceptual cognitive processes. Using brain potentials in a color oddball detection task with Greek and English speakers, we demonstrate that language effects may exist at a level that is literally perceptual, suggesting that speakers of different languages have differently structured minds.

Categorical perception is a term used to describe people's tendency to perceive perceptual continua such as color as discontinuous discrete categories, resulting in finer discriminations across category boundaries than within category boundaries.[3,4] It is now widely accepted that categorical perception of color is constrained by language. Whether comparing populations from traditional remote cultures[5-7] or populations matched for technological sophistication and education,[8,9] the findings unequivocally show a discrimination advantage for cross-category over within-category stimuli consistent with the individual's linguistic partition of the color spectrum. This has been shown in both offline similarity judgment tasks[10] as well as in online perceptual matching tasks.[11]

However, although these studies suggest that we perceive color categorically, it has been argued that the term Categorical "Perception" is a misnomer as it is not clear whether response patterns reflect low-level perceptual processes rather than higher-level post-perceptual memory or language processes.[12-14] Thus we cannot dismiss the assumption of a set of universal color categories, which are hard-wired in the human visual system.[15-17]

In Thierry, Athanasopoulos, Wiggett, Dering and Kuipers,[18] we measured brain potentials in Greek and English speakers to test the extent to which pre-attentive and unconscious aspects of perception are affected by an individual's native language. Greek differentiates between a light (ghalazio) and a dark (ble) shade of blue.[19] In two experimental blocks, all stimuli were light or dark blue and in the other two blocks the stimuli were light or dark green. We instructed participants to press a button when and only when they saw a square shape (target, probability 20%) within a regularly paced stream of circles (probability 80%). Within one block the most frequent stimulus was a light or dark circle (standard, probability 70%) and the remaining stimuli were circles of the same hue with a contrasting luminance (deviant, probability 10%), i.e., dark if the standard was light or vice versa.

Crucially, in this study we analyzed brain wave patterns only for deviance in the color of the circles, not the shape of the stimulus, which was the focus of attention. We expected luminance deviants to elicit visual mismatch negativity (vMMN) in all blocks, indexing pre-attentive change detection, which requires no active response on the part of the participants.[20-22] The vMMN is elicited by deviant (rare) stimuli in visual oddball paradigms, independently of the direction of focused attention[22] and is therefore considered automatic and pre-attentive.[21,22]

Consistent with our predictions, we found a vMMN effect of similar magnitude for blue and green contrasts in native speakers of English, but Greek participants perceived luminance deviants as more different in the blue than in the green blocks, which led to a greater vMMN effect for blues. We subsequently explored differences at earlier latencies, focusing on the so-called P1, that is, the first positive peak elicited by visual stimuli over parietooccipital regions of the scalp, to test for potential differences between participant groups in a time frame associated with activity in the primary and secondary visual cortices.[23] To our surprise, analysis of mean peak latencies and mean signal amplitudes between 100 and 130 ms revealed that the P1 peak followed a pattern of differences

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compatible with—and possibly underlying—the differences found in the vMMN. Indeed, P1 latencies and amplitudes elicited by light and dark stimuli were generally overlapped for blues and greens in English speakers, but again they were different for blues and greens in Greek speakers.

These results show for the first time a true perceptual effect of language. This effect is unconscious because color was task-irrelevant, and pre-attentive because the differences between Greek and English speakers occurred too early in the visual processing stream to be the result of assigning and comparing color names on a given trial. This strongly suggests that our findings reflect biases introduced into the color perception system itself. Below, we discuss further two critical aspects of our work. The first concerns the possibility that the observed differences in visual processing are caused by differences in visual diet instead of language. The second relates to the nature of the influence of language on perception.

It is possible that exposure to shades of blue in the natural environment may account for greater sensitivity to differences in luminance in Greek speakers. We believe that the visual diet hypothesis cannot adequately explain our results for the following reasons. Firstly, it would be difficult to account for the fact that the deviancy effect observed was very similar in blue and green contexts in English-native participants who are arguably exposed to many shades of green, and certainly more so than shades of blue. Indeed, the vMMN effect was highly comparable for blue and green in the English participants, and the P1 amplitude/latency patterns were remarkably overlapped for blue and green standard stimuli. Secondly, behavioral studies reveal robust categorical perception effects along the lightness dimension of the blue area of color space in populations with diverse cultural backgrounds and natural environments but who all have two terms to distinguish between a darker and a lighter shade of blue in their respective language, e.g., Greek,[19] Turkish,[24] Russian[8] and Japanese.[25] Thirdly, studies have shown that the categorizations of the Berinmo tribe inhabiting a dense rainforest environment[6] are remarkably similar to the categorizations of the Himba tribe inhabiting a desert savannah environment,[26] thus differences in color vision between populations may be too subtle to affect the normal range of human performance.[27]

Nevertheless we do not wish to discount completely visual diet considerations, as effects of visual diet on color perception still remain an empirical question. One way to further investigate this issue is to look at early stages of visual processing in populations who speak the same language (e.g., English) but who inhabit distinct visual environments, e.g., British vs. Australian populations. Another way would be to keep the visual environment constant and examine speakers of different languages, e.g., Welsh and English speakers residing in Wales.

We now turn to the extent of linguistic influence on visual perception. Based on our and recent studies, we may entertain two alternative scenarios. One possibility is that language is accessed online even as early as 100 ms. This would mean that traditional assumptions about the cognitive impenetrability of primary and secondary visual cortices would need to be revisited. It would also mean that Greek and English speakers perceive the spectrum in a similar fashion at some very early stage of visual processing. Studies show that when participants rehearse a string of digits language-induced CP effects disappear.[8] Therefore it would be highly desirable to repeat our task with a verbal interference manipulation, however this is not currently possible in an ERP setting due to movement artifacts produced by such an interference task when performed overtly.

The alternative possibility is that there is some kind of permanent restructuring of visual cortex in relation to the visual distinctions highlighted by one's native language. If such were the case, it would mean that information from the retina is perceived differently by native speakers of Greek and English at the level of the primary visual cortex, i.e., at no stage of visual perception would Greek and English speakers perceive the color spectrum similarly.

Both possibilities are compatible with our claim that language shapes color perception. In the first instance, the shaping is online, automatic and unconscious, and we cannot help but let language invade our visual perception. In the second case, the shaping occurs gradually during the first few years of life, and results in permanent physiological differences between populations in the structure of the visual cortex. In either case, our data strongly suggest for the first time that language may indeed have an impermeable grip on color perception, radically reshaping it either online or during the course of one's lifetime.

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