Counting by Color: Event-Related Potentials in Grapheme-Color Synesthetes

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Grapheme-Color Synesthesia

Synesthesia is a neurological condition in which stimulation of one sensation triggers the automatic, involuntary experience of another sensation. For example, the most common form of synesthesia is grapheme-color, in which numbers and letters induce the perception of particular colors, called photisms.

This study examined EEG brain activity in synesthetes and non-synesthetes who were shown sentences about colors, in which the color word was replaced with a number that represented the synesthetes' photisms, creating a meaningful association (eg., "Apples are 5," when "5" is associated with red). Previous studies have shown that for synesthetes, the P2 EEG component is significantly greater in trials where the number is incongruent to the contextually primed-for color (Brang et al, 2010).

Figure 1: Sample Synesthete's Associations

0 1 2 3 4 5 6 7 8 9

Investigating P2 in Synesthetes

To further explore the significance of the P2 component in synesthetes, this study presented the graphemes in colored ink. In "congruent" cases, participants were shown sentences in which the final number elicited the correct color photism for the sentence, but the number was in the incorrect color ink. In other "incongruent" trials, the sentences ended with a number associated with a wrong photism, but it was shown in the correct color ink.

It was hypothesized that in EEG recordings, the mean P2 amplitude would be greater in synesthetes for incongruent conditions

Figure 2: Sample Stimuli (when 5=red)

Congruent Trial: "Apples are 5"

Incongruent Trial: "Apples are 7"

Participants

15 participants were involved in this study. Participants were between the ages of 16 and 22, and consisted of approximately equal numbers of men and women. They were divided into 3 groups of 5 people:

- Group 1: Grapheme-color synesthetes
- Group 2: Trained Non-synesthetes: were taught to know a particular synesthete's number-color associations
- Group 3: Naïve Non-synesthetes: were not familiar with a synesthete's associations in any way.

Materials and Instrumentation

EEG signals were recorded from 32 Ag/AgCl sintered electrodes which are embedded in an elastic Quik-cap, and referenced using both mastoid sites. EEG signals were acquired with Neuroscan's Synamps system.

Stimuli consisted of 150 sentences, presented on a computer screen using Superlab software. Sentences were borrowed from Brang, et al. (2010), but altered when appropriate.

Procedure

- Sentence stimuli were customized for each synesthete to match their personal number-color associations. The group of trained-non-synesthetes was taught to know these associations with a tutorial computer slideshow and testing. The naïve non-synesthetes had no exposure to the grapheme-color associations.
- Participants viewed a series of 150 sentences, each priming for a particular color. Sentences were presented one word at a time, and ended with one of 5 types of stimuli (either a color-patch, an achromatic word, a colored word, an achromatic number, or a colored number). In each of these conditions, half of the sentences ended in stimuli that was congruent to the primed-for color, and half were incongruent.
- As participants viewed the sentences, EEG data was collected. Recordings from electrode CZ during the colored-number conditions were analyzed.

EEG Elastic Cap and Electrodes

References

Brang, D. D., Kanai, S., Ramachandran, V. S., & Coulson, S. S. (2010). Contextual priming in grapheme-color synesthetes and yoked-controls: 400 msec in the life of a synesthete. *Journal of Cognitive Neuroscience.*

Results

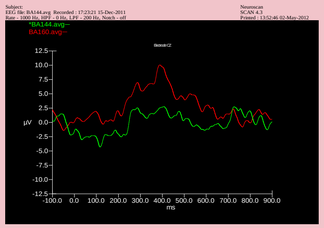
When comparing synesthetes' EEG data, mean voltage for P2 appeared to have greater amplitudes during "incongruent" color-number trials than during "congruent" trials, as was hypothesized. The difference in these P2 amplitudes were approaching (but did not reach) statistical significance [$t(4) = 2.49$, $p = .067$]. For both groups of non-synesthetes, there was no statistical difference at P2 in congruent vs. incongruent color-number conditions.

Comparing ERP's of Each Group for Both Conditions

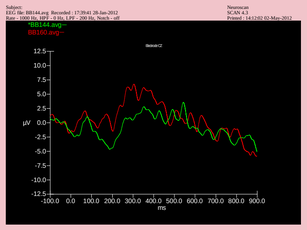
Red: Congruent Color-Number Condition

Green: Incongruent Color-Number Condition

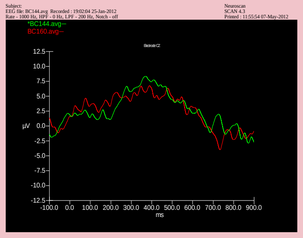
Graph 1: Synesthetes



Graph 2: Trained Non-synesthetes



Graph 3: Naïve Non-Synesthetes



Discussion

Although the mean difference in P2 did not reach our alpha level of $p = .05$, we believe this was due, in part, to low levels of statistical power associated with our small sample. Because it was approaching significance, we suggest that P2 was notably greater in synesthetes on trials in which the grapheme/photism was incongruent to the context, despite being written in the proper color ink. Previous research suggests that P2 is typically greater in synesthetes when elicited photisms are incongruent to the context, when the grapheme is achromatic (Brang et al, 2010). Our study shows that the effect persists even when the incorrect grapheme is written in the correct color ink, keeping it "incongruent" for the synesthete. This may indicate that, in a way, synesthetic color experience takes precedence over visual color perception when processing meaningful stimuli.