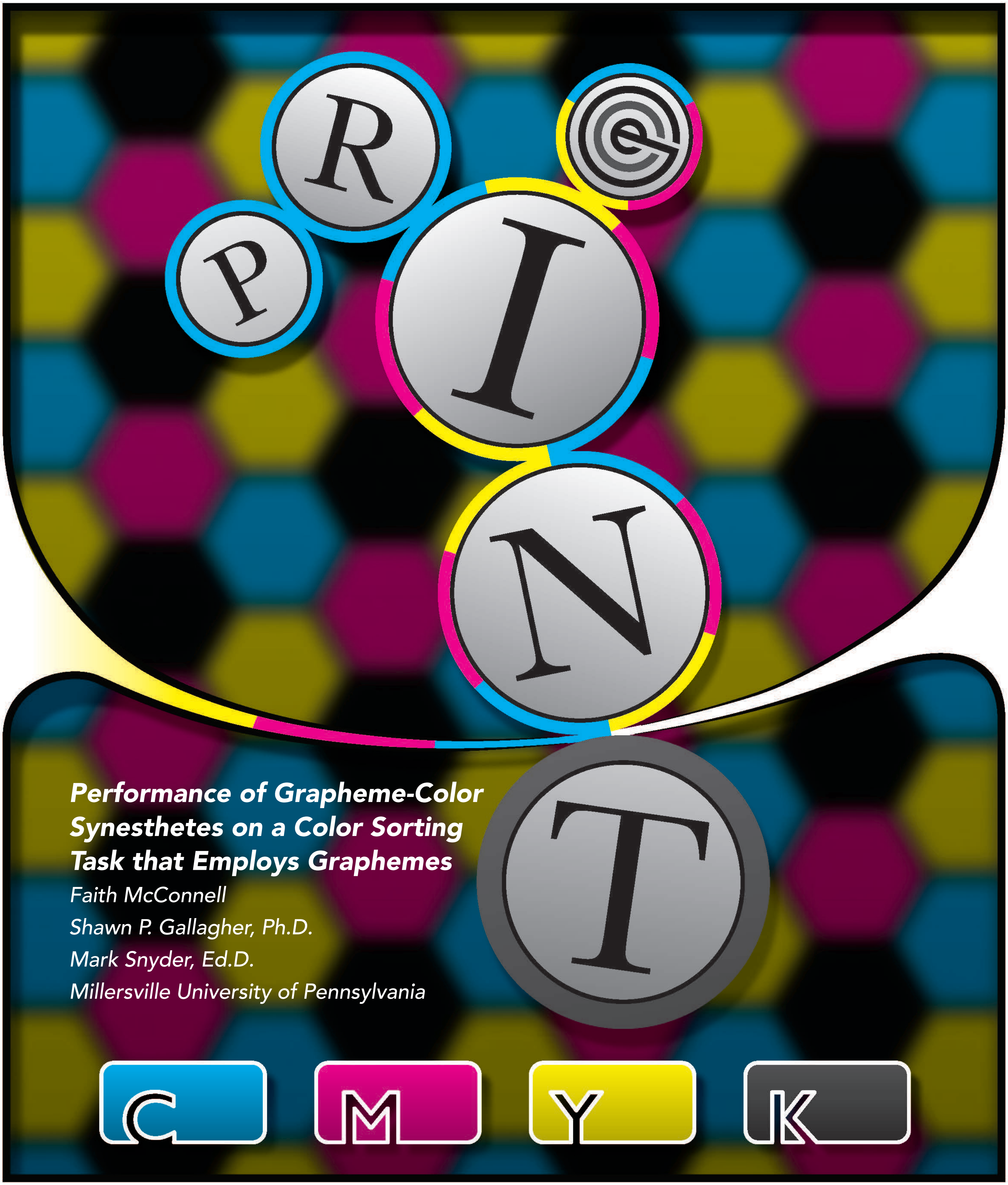
Visual Communications Journal

Fall 2017 Volume 53 Number 2



Performance of Grapheme-Color Synesthetes on a Color Sorting Task that Employs Graphemes

Faith McConnell

Shawn P. Gallagher, Ph.D.

Mark Snyder, Ed.D.

Millersville University of Pennsylvania

VISUAL COMMUNICATIONS JOURNAL

VCJ

VOLUME 53 • NUMBER 2 FALL 2017

GRAPHIC COMMUNICATIONS EDUCATION ASSOCIATION

Acknowledgements

About the Journal

The Visual Communications Journal serves as the official journal of the Graphic Communications Education Association, and provides a professional communicative link for educators and industry personnel associated with design, presentation, management, and reproduction of graphic forms of communication. Manuscripts submitted for publication are subject to peer review. The views and opinions expressed herein are those of authors and do not necessarily reflect the policy or the views of the GCEA.

Article Submission

Please follow the guidelines provided at the back of this *Journal.*

Membership and Subscription Information

Information about membership in the Association or subscription to the *Journal* should be directed to the GCEA First Vice-President.

Reference Sources

The *Visual Communications Journal* can be found on EBSCOHost databases.
ISSN: Print: 0507-1658 Web: 2155-2428

GCEA Board of Directors

Performance of Grapheme-Color Synesthetes on a Color Sorting Task that Employs Graphemes

Faith McConnell • Shawn P. Gallagher, Ph.D. • Mark Snyder, Ed.D. • Millersville University of Pennsylvania

Introduction

Color perception is not universal and, for the people who do have color vision, it still may vary. As many as 8% of men have an inherited deficiency in color perception and a small fraction of women (less than 1%) have the ability to see an unusually wide variety of colors (Gegenfurtner & Sharpe, 1999). This variation is often due to differences in the anatomy of the human eye (e.g. *photoreceptor* deficiencies) but some of it is due to how the brain processes color. Some people even experience specific, vivid colors when viewing particular printed letters, regardless of the text's color. These people have one form of an unusual condition called *synesthesia.* Brain scientists believe that these strange experiences are due to "crossed wires" in the brain that activate color detecting parts of the brain whenever specific letters or numbers are viewed (Ramachandran & Hubbard, 2001). Although unusual, synesthesia is not rare and may affect as many as 1 in 200 people (Ramachandran & Hubbard, 2001). Few of these people (called *synesthetes*), however, realize that their experiences are atypical, but some know that they are unusually particular about color choices and select font colors that "fit" the characters and symbols in their creative works (unpublished observations). For example, one of our student synesthetes printed his resume using only dark green and brown text because, according to him, these colors "matched" his two initials which appeared in bold capitalized text at the top of the document.

Our aim is to draw attention to this fascinating phenomenon and determine if synesthesia shapes the perception of text, or if it is an intermittent experience that can be "tuned out" when, for example, the demands of a printing project contradict a synesthete's perception of congruence. We believe that our findings shed light on a little-known phenomenon that may be affecting the subjective nature of design and experience.

Testing Color Vision

The human eye contains two kinds of light-sensitive cells that convert light to a neural message that the brain can process. Rods are cells that operate in low light conditions and provide no color information; cones function when light is abundant and create the foundation for color vision. Color perception, therefore, starts with the cones in our eyes which respond best to short (usually seen as blue), medium (usually seen as green or orange), and long-wavelength (usually seen as red) light. Fewer than five percent of people have atypical color vision due to non-functioning cones and, at least in the United States, these people are often diagnosed as children during routine eye exams. Other differences in color perception are more difficult to identify. Although most people see color using the same three cones, the cortical (or brain-based) part of color perception is equally important. Cortical processing, like image processing software, may compromise or enhance color vision in ways that are more difficult to detect.

The Farnsworth-Munsell 100 Hue Test (100 Hue Test, X-Rite, Grand Rapids MI) uses color-sorting to measure color discrimination ability (Figure 1). The test can, of course, diagnose typical forms of color blindness, but it can also be used to monitor slow changes in color perception caused by eye diseases. The test consists of four trays of 85 sortable colored caps that span the visible spectrum and the objective is to arrange the caps into a spectrum of hues that varies progressively from one color to the next. Interested readers can explore a publicly available version of the task by Daniel Flück (www.color-blindness.com). This computer-based test is automatically administered and scored but is otherwise like the original. Instead of manually sorting disks on a table, participants use a computer mouse to sort colored tiles displayed on a monitor (Figure 1).

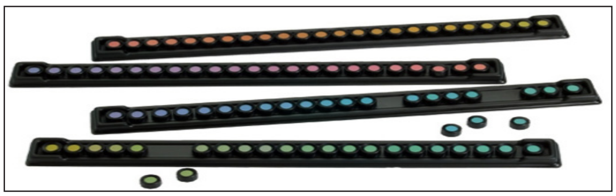
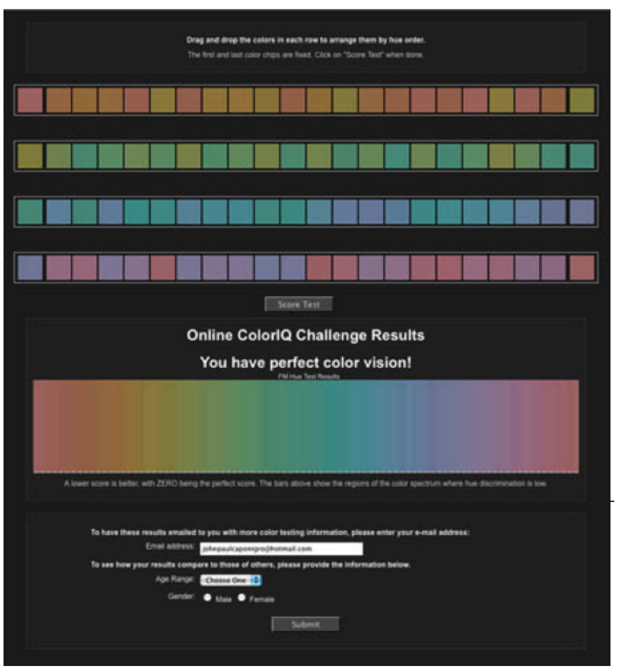


Figure 1: (Above) The Farnsworth-Munsell 100 Hue Test (100 Hue Test, X-Rite, Grand Rapids MI) uses color-sorting to measure color discrimination ability. (Below) The participants use a computer mouse to sort colored tiles displayed on a monitor This computer-based test is automatically administered and scored but is otherwise like the original.



Synesthesia

Synesthesia is a perceptual phenomenon in which stimuli in one sensory modality evoke experiences in another. For example, some people experience specific colors when they hear specific notes played on a piano; others associate tastes with shapes. Grapheme-color synesthesia may be the most common and easiest to objectively verify and, like color blindness, is often heritable (Ramachandran & Hubbard, 2001).

When an individual has grapheme-color synesthesia, they experience color when viewing certain, but not necessarily all, graphemes (letters, numbers, or other printed symbols) even when they are printed in black on white paper. For example, if a grapheme-color synesthete is shown the letter "A" they may experience a red glow, or *photism*, around the letter but fully realize that the color they "see" is in their mind, not on the paper. Synesthesia has been recognized for more than a century (Galton, 1880), but only recently have scientists been able to validate these experiences by showing synesthetes perform exceptionally well on tasks that involve visually searching for specific letters that "pop-out in color" when printed in black and white (Ramachandran & Hubbard, 2001). For example, finding a letter "F" in a sheet full of "Es" is difficult for most people, but if a synesthete associates "F" with red and "E" with green, the task is as easy as spotting the only ripe apple in a tree.

Eagleman, Kagan, Nelson and Sarma (2007) have demonstrated that the strength of synesthetic experiences can be measured with computerized tests that repeatedly present participants with graphemes while asking them to choose the associated color from an enormous array of hues. The strength of the synesthetic association is quantified from the consistency in color choices across multiple presentations (Figure 2). Synesthetes find such tasks easy and are reliable in the way they match specific letters with specific colors; non-synesthetes find these tasks impossible.

One proposed reason as to why synesthetes see colors when looking at graphemes might be that stray neural connections are linking and accidentally activating neighboring brain regions (Ramachandran & Hubbard, 2001). Two brain regions believed to play a role in synesthesia are the V4 color center (so called because it is the *fourth* in a group of visual processing areas) and the nearby posterior temporal grapheme area (PTGA), which is active when people view numbers and text. Neurons in the V4 color center are commonly activated in response to color but stray connections from the PTGA might reach V4 and trigger the sensation of color when colorless letters are viewed (Nunn, Gregory, Brammer, Williams, Parslow, Morgan & Gray, 2002).

Currently, researchers and vision scientists still do not know if this miswiring offers synesthetes an advantage or disadvantage. Bannissy et al. (2009) found that, when graphemes were not involved, synesthetes demonstrated enhanced color discrimination abilities as measured by the Farnsworth-Munsell 100 Hue Test. The researchers used the cap-sorting task in the typical fashion and found that grapheme-color synesthetes have unusually good color discrimination skills, perhaps as a result of having more brain regions involved in color processing.

Although synesthesia might improve color discrimination when graphemes are not involved, it might create a disadvantage when synesthetes must sort or arrange colored text. Smilek, Dixon, Cudahy, and Merikle (2001) showed how synesthesia can lead to confusion in some specific situations. They instructed synesthetes to find specific characters, or "targets," presented against backgrounds that were either congruent or incongruent with the color of the target's photism. They found that, for example, if a synesthete experienced the digit "5" as red, it was easy for them to spot it among other digits that evoked the experience of green, provided the digits were displayed on a white background. However, they also found that the same task was difficult when the digits were presented on a background that was congruent with the color of the target's photism; the same red photism that made the digit "pop out" on a white background could camouflage it on a red background.

Purpose of the Study

Color-grapheme synesthetes are good at color sorting tasks, but certain graphemes might confuse their perceptual abilities in specific situations. The purpose of this study was to determine if photisms can affect a synesthete's performance on a color discrimination task when it involves sorting colored graphemes, rather than caps or blocks. Synesthesia may give graphic designers better color discrimination skills when they are sorting and arranging non-grapheme objects, however, graphemes might evoke photisms that can confuse a synesthete's ability to discriminate or match colors. This effect could have tremendous implications each time a synesthetic designer choses a font color for either print or video display. The current study combined themes from the previously mentioned research and examined grapheme-color synesthetes' performances on color hue sorting tests that used graphemes chosen to minimize and maximize the odds of color confusion.

Our first task was to develop a computerized Grapheme Hue Test so our participants would be able to sort colored "A"s and "B"s or "4"s and "5"s instead of colored disks (as in the original 100 Hue Test) or colored square tiles (as in the computer-based version of the 100 Hue Test). If the synesthetes had great difficulty sorting, for example, an array of "A"s that were displayed in shades of green, it could be because the actual printed colors don't match the color of the letter's associated photism. If a particular grapheme was among those that did not generate a specific colored photism, we would expect the synesthete to have no difficulty in sorting colored letters. Such findings would support the theory that synesthesia can affect color perception and discrimination skills when the affected individual is manipulating colored graphemes. We predicted that synesthetes would commit more errors and require more time when sorting colored graphemes that generate photisms than when sorting colored graphemes that do not.

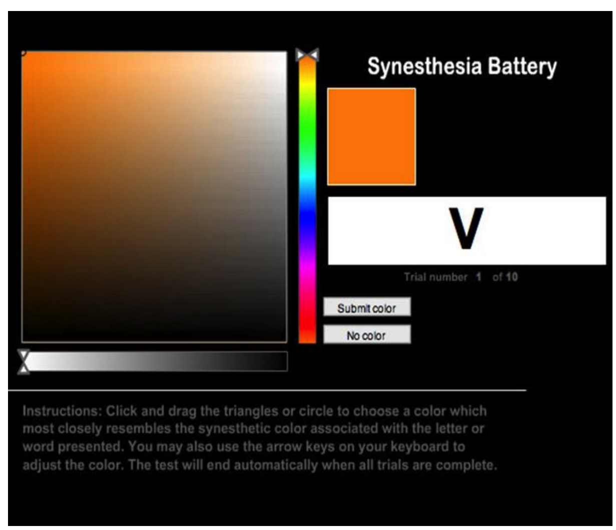


Figure 2: Screenshot from the Synesthesia Battery (Eagleman et al., 2007).

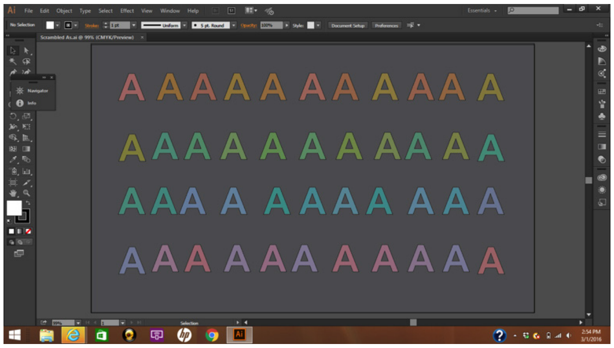


Figure 3: Grapheme Hue Test modelled on the computer-based Farnsworth-Munsell Color Hue Test.

Method

Participants

This study was conducted with the approval of the Institutional Review Board. Candidate synesthetes were recruited from a population of undergraduates and classified using the system developed by Eagleman et al. (2007) through the Synesthesia Battery that is publicly available at www.synesthete.org (Figure 2). Six confirmed synesthetes performed the full battery of tests and received $25 gift cards for their time.

Procedures

We used Adobe Illustrator (Adobe Systems, San Jose CA) to create the Grapheme Hue Test which generated grapheme arrays in colors that matched those used in the computer-based 100 Hue Test (Figure 3). We also made our test shorter than the original by increasing the step increments and employing 36 sortable elements, rather than 85. Finally, we validated our test by administering it to eight participants who had also taken the computer-based 100 Hue Test. Participant scores on the original 100 Hue test were highly correlated with scores on our Grapheme Hue Test, $r(6) = .97$, $p < 0.01$.

Figure 3 shows one unsorted set of graphemes in the Grapheme Hue Test. The synesthetes had four grapheme sets to sort; first, they sorted two scrambled sets of graphemes for which they had no photisms, these were control trials, and then two for which they did, these were photism trials.

To score performance on the Grapheme Hue Tests, we assigned each grapheme a number (not visible to the participant) that represented where it should fall in a perfectly sorted array. We then calculated a deviation

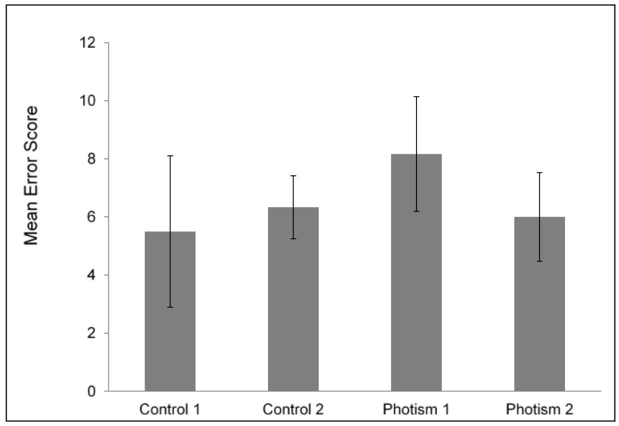


Figure 4: Mean deviation scores for participants in each phase of the grapheme sorting task. A one-way ANOVA demonstrated no significant difference across conditions, $F(3, 20) = .38$, $p > 0.05$.

scores for each trial per the methods described by Banissy et al. (2009). Lower scores indicated fewer errors and a score of 0 indicated that all graphemes had been perfectly sorted. We recorded times and deviation scores for each trial.

Results

We hypothesized that synesthesia could create confusion in a color sorting task and that synesthetes would have higher deviation scores in the photism trials than the control trials. A one-way ANOVA demonstrated no significant differences in mean deviation scores across the four trials, $F(3,20)=.38$, $p >.05$ (Figure 4).

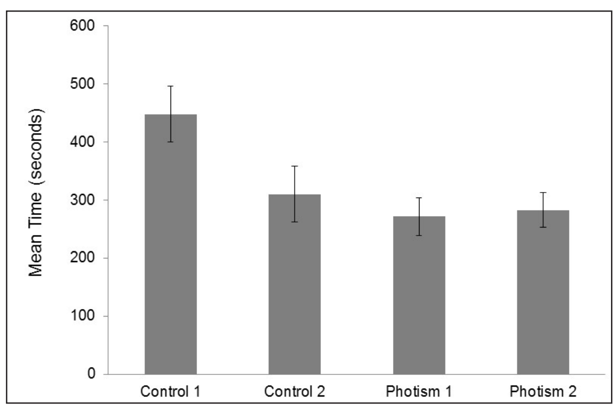


Figure 5: Mean time required for participants to complete each phase of the grapheme sorting tasks. Although a one-way ANOVA demonstrated a significant difference across the four conditions, $F(3, 20) = 4.00$, $p < 0.05$, a post-hoc Tukey test showed no significant differences among Control 2 and the Photism 1 and Photism 2 conditions ($HSD = 161.29$ sec).

We also hypothesized that synesthetes would require more time to sort colors in the photism condition than they would for the control condition. This hypothesis could not be supported. A one-way ANOVA revealed a significant difference among the four conditions $F(3,20)=4.00$, $p<.05$, but a *post hoc* Tukey test revealed that the difference was only between the first control condition and each of the remaining three. This result was contrary to our expectations and most likely shows a practice effect; participants struggled a bit while learning the task during the first trial, but improved on subsequent trials (Figure 5). Switching the participants from the control to the photism trials did not lead to a sudden decrease in performance.

Discussion

We developed a grapheme sorting task that effectively tested color discrimination ability but, contrary to our expectations, synesthetes did not differ in their ability to sort photism and non-photism graphemes. The results of this study suggest that synesthetes quickly adapt to their photisms or that they can ignore them when necessary. Although we cannot conclude that synesthesia has *no* effect on one's ability to sort or discriminate printed graphemes, these effects are probably small and certainly would not preclude one from a career in graphic design. When one synesthete in this study was asked if our sorting tasks were difficult, he replied that he could "*eventually ignore the shape of the letters and only focus on the colors.*" Almost all of our participants reported a similar ability. Although synesthetes perceive photisms and associate specific graphemes with specific colors, our data give us no reason to suspect that synesthesia significantly compromises color discrimination skills.

References

Cytowic, R. E., & Eagleman, D. (2009). Wednesday is indigo blue: Discovering the brain of synesthesia. MIT Press.

Eagleman, D.M., Kagan, A.D., Nelson, S.S. Sagaram, D. & Sarma, A.K. (2007). A standardized test battery for the study of synesthesia. *Journal of Neuroscience Methods*. 5;159(1):139–145.

Galton, F. (1880), 'Visualised numerals', *Nature*, 22, pp. 252–256.

Gegenfurtner, K., & Sharpe, L. (1999). Color Vision: From genes to perception. Cambridge: Cambridge University Press.

Hupé, J., Bordier, C., & Dojat, M. (2012). The neural bases of grapheme-color synesthesia are not localized in real color-sensitive areas. *Cerebral Cortex*, 22(7), 1622-1633. doi:10.1093/cercor/bhr236

Nunn, J. A., Gregory, L. J., Brammer, M., Williams, S. C. R., Parslow, D. M., Morgan, M. J., & Gray, J. A. (2002). Functional magnetic resonance imaging of synesthesia: activation of V4/V8 by spoken words. *Nature Neuroscience*,5(4), 371–375.

Ramachandran, V.S. & Hubbard, E. M. (2001). Synaesthesia—A window into perception, thought and language. *Journal of Consciousness Studies*, 8(12), 3–34.

Smilek, D., Dixon, M. J., Cudahy, C., & Merikle, P. M. (2001). Synaesthetic photisms influence visual perception. *Journal of Cognitive Neuroscience*, 13(7), 930–936.

Glossary of Terms

Cortical — involving or resulting from the action or condition of the cerebral cortex— that part of the brain that functions chiefly in the coordination of sensory and motor information.

Grapheme — a unit within a writing system–such as letters and numbers.

Grapheme-color Synesthesia — a person with grapheme-color synesthesia will associate colors with letters and numbers involuntarily. For example, when shown the letter "A" they may sense red.

Photism — a synesthetic visual sensation. To synesthetes, it is an involuntary, consistent and memorable response.

Photoreceptors — a receptor for light stimuli. There are two types of photoreceptors in the human eye: rods and cones.

Synesthesia — a neurological phenomenon in which stimulation of one sensory or cognitive pathway leads to automatic, involuntary experiences in a second sensory or cognitive pathway. For example, it can involve associations between letters, shapes, colors, tastes, smells, etc. People who experience these crossover associations are known as synesthetes.

Visual Communications Journal Submissions Guidelines

Manuscript Form and Style

» Prepare manuscripts according to the APA style, including the reference list.

» List your name and address on the first page only. Article text should begin on the second page.

» Provide a short biography for yourself that can be used if the article is accepted for publication.

» All articles must be submitted in electronic form on a CD-ROM or as an email attachment.

» Submit a Microsoft Word document, maximum of 10 pages (excluding figures, tables, illustrations, and photos). Do not submit documents created in page-layout programs.

» Word documents must have been proofread and be correct.

» Call out the approximate location of all tables and figures in the text. Use the default style "Normal" on these callouts. The call-outs will be removed by the designer.

» Use the default Word styles only. Our designer has set up the page layout program styles to correspond to those style names.

- Heading 1
- Heading 2
- Heading 3
- Normal

Graphics

» Be sure that submitted tables and other artwork are absolutely necessary for the article.

» Write a caption for each graphic, include captions in a list at the end of your Word document.

» Electronic artwork is preferred and should be in PDF or TIFF format.

» Send all artwork files and hard copies of these files with your submission.

Tables

» Set up tables in separate documents, one document for each table.

» Do not attempt to make it "pretty." Use the default Word style "Normal" for all table text. Do not use any other formatting.

» Do not use hard returns inside the table ("enter" or "return").

» Get the correct information into the correct cell and leave the formatting to the designer.

» Tables will be formatted by the designer to fit in one column (3.1667" wide) or across two columns (6.5" wide).

Artwork

» Scan photographs at 300 ppi resolution.

» Scan line drawings at 800 ppi resolution.

» Screen captures should be as large as possible.

» Graphics should be sized to fit in either one column or across two columns.

- One column is 3.1667" wide, two columns are 6.5" wide.
- Graphics may be larger than these dimensions, but must not be smaller.

Manuscript Guidelines

Eligibility for Publication

» Members of the Graphic Communications Education Association, or students of GCEA members, may publish in the *Visual Communications Journal*.

Audience

» Write articles for educators, students, graduates, industry representatives, and others interested in graphic arts, graphic communications, graphic design, commercial art, communications technology, visual communications, printing, photography, desktop publishing, or media arts. Present implications for the audience in the article.

Types of Articles

» The *Visual Communications Journal* accepts four levels of articles for publication:

» 1. Edited articles are accepted or rejected by the editor. The editor makes changes to the article as necessary to improve readability and/or grammar. These articles are not submitted to a panel of jurors. The decision of the editor is final.

» 2. Juried articles are submitted to the editor and are distributed to jurors for acceptance/rejection. Juried articles are typically reviews of the literature, state-of-the-art technical articles, and other nonempirical papers. Jurors make comments to the author, and the author makes required changes. The decision of the jurors is final.

» 3. Refereed articles are submitted to the editor and are distributed to jurors for acceptance/rejection. Refereed articles are original empirical research. Jurors make comments to the author and the author makes required changes. The decision of the jurors is final.

» 4. Student articles are submitted by GCEA members and are accepted/rejected by the editor. These articles are not submitted to a panel of jurors. The editor's decision is final. Please be aware that poorly written student papers will be rejected or returned for editing.

Submittal of Manuscripts

» All manuscripts must be received by the editor no later than December 15th to be considered for the spring Journal or by June 15th to be considered for the fall Journal. Include digital copies of all text and figures. Prepare text and artwork according to the instructions given in these guidelines. Be sure to include your name, mailing address, e-mail address, and daytime phone number with your materials. E-mail all materials to the editor (address shown below).

Acceptance and Publication

» If your article is accepted for publication, you will be notified by e-mail. The *Visual Communications Journal* is published and distributed twice a year, in the spring and in the fall. Printed copies are mailed to GCEA members. A PDF version of the *Journal* is published online at www.GCEAonline.org.

Notice

» Articles submitted to the *Journal* cannot be submitted to other publications while under review. Articles published in other copyrighted publications may not be submitted to the *Journal*, and articles published by the *Journal* may not be published in other publications without written permission of the *Journal.*

» Submit All Articles and Correspondence to:
Dan Wilson, dan.wilson@illinoisstate.edu
or check www.GCEAonline.org for contact information for the GCEA First Vice-President.

» See the previous page for style guidelines