August 2015

The Effects of Color in Recognition of Images in Multiple-Choice Displays By People with and Without Aphasia

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THE EFFECTS OF COLOR IN RECOGNITION OF IMAGES IN MULTIPLE-CHOICE DISPLAYS BY PEOPLE WITH AND WITHOUT APHASIA

by

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A Thesis Submitted in

Partial Fulfillment of the

Requirements for the Degree of

Master of Science

in Communication Sciences and Disorders

at

University of Wisconsin-Milwaukee

August 2015

ABSTRACT

THE EFFECTS OF COLOR IN RECOGNITION OF IMAGES IN MULTIPLE-CHOICE DISPLAYS BY PEOPLE WITH AND WITHOUT APHASIA

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The University of Wisconsin-Milwaukee, 2015
Under the Supervision of Dr. Sabine Heuer

Language assessments for people with aphasia often rely on the use of images. Images are presented together with a verbal stimulus and participants are asked to choose the image that corresponds to the verbal stimulus. It is assumed that if a person chooses an incorrect image, he or she has language comprehension deficits. However, other non-linguistic factors can influence image recognition processes, such as stimulus characteristics and verbal or motoric response requirements associated with target selection. Color has been shown to facilitate image recognition in language-normal individuals and in people with aphasia. However, traditional tasks to assess the influence of color on image recognition rely on verbal responses, which pose serious response confounds in individuals with aphasia. This study utilized eye-tracking to capture individuals' responses, avoiding response confounds associated with traditional assessment methods.

The overall goal of the present study was to determine the role of color in multiple-choice image displays on language-mediated eye movements in individuals with and without aphasia. Specifically, it was determined if people with and without aphasia

would recognize color images more easily compared to black-and-white line drawing images that correspond to a verbal stimulus in multiple-choice image displays. It was also determined if individuals with aphasia would fixate longer on images that share the same conceptual color as the verbal stimulus in color and black-and white images.

A group of ten language-normal participants and five participants with aphasia viewed 40 multiple-choice image displays containing color images and black-and white images which were presented together with a verbal stimulus under two conditions. In the target condition, the verbal stimulus corresponded to one of the images in the display. In the competitor condition, the target image was replaced with a color competitor image while the same single-word verbal stimulus was presented as before. Eye movements were recorded as individuals looked at a computer screen and listened to words. The eye-movement measures proportion of fixation duration on the target image (PFDT) and first pass gaze duration on the images (FPGD) served as the dependent measures. A pointing version of the task served as a control measure and validation that individuals indeed understood the verbal stimulus and identified the image correctly.

Surprisingly, FPGD and PFDT of color images were not found to have a significant advantage over FPGD and PFDT allocated to black-and-white images. In fact, FPGD for black-and-white target images was significantly greater than FPGD allocated to color images. No significant group differences were found in the target condition. In the competitor condition, participants fixated disproportionately longer on both color and black-and-white competitor images compared to the other images in the display, but no significant difference was found between the color images and the black-and-white competitor images. A significantly greater disproportionate allocation of fixation duration allocated to competitor images that were related semantically to the verbal stimulus compared to those who were not semantically related was observed. This result highlights the need to carefully control for semantic association between verbal stimuli and competitor image in addition to physical stimulus characteristics. In conclusion, based on the current findings, color did not facilitate image recognition in people with aphasia or control participants and a semantic competitor effect was observed rather than a color competitor effect.

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LIST OF ABBREVIATIONS

Aphasia Quotient .... AQ

First Pass Gaze Duration .... FPGD

Forward Strength .... FSG

Mini Mental State Examination .... MMSE

Proportion of Fixation Duration .... PFD

Proportion of Fixation Duration on the Target .... PFDT

Western Aphasia Battery-Revised .... WAB-R

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Sabine Heuer, for her guidance and support during this research project. In addition, I would like to thank members of my committee, Dr. Carol Seery and Dr. Shelley Lund, for their contributions to the work. I would also like to acknowledge the College of Health Sciences SRGA at the University of Wisconsin-Milwaukee for awarding me with a research grant that helped make this study possible.

INTRODUCTION

Aphasia is an acquired neurogenic communication disorder that may affect speaking, comprehension, reading, and writing. It is not a sensory or general intellectual deficit, or psychiatric disorder (Hallowell & Chapey, 2008).

Language assessments of individuals with neurogenic language impairment often rely on the use of images. Participants hear a word or sentence and have to choose a corresponding image. It is assumed that failure to choose the correct image represents language comprehension deficits. However, this may not be the only cause for failure to select the correct image. Individuals with brain injury frequently have concomitant motor deficits, such as paralysis and apraxia, which may impair his or her ability to correctly point to the target image. Additionally, visuoperceptual deficits are also common in individuals with neurogenic deficits, affecting accurate perception of stimuli and hand-eye coordination.

In addition to those response selection confounds, stimulus-driven influences are another source that might affect a participant's choices. Physical stimulus characteristics can guide visual attention, and thus cognitive resource allocation in cognitive-linguistic tasks (Huettig & Altmann, 2011). Individuals with deficits in attention allocation might be distracted by image displays that are not carefully controlled for stimulus characteristics such as color, size and orientation (Heuer & Hallowell, 2007, 2009).

Some image characteristics, including color, have been shown to influence cognitive processes of image recognition and naming accuracy in language-normal participants. There is a need to study the role of stimulus characteristics on image recognition in people with aphasia to ensure the validity of assessments of linguistic functions. The purpose of this study is to investigate the effects of color on image recognition in multiple-choice image displays in participants with aphasia.

The role of color in image recognition

Image recognition relies on different stages (Humphreys, Price & Riddoch, 1999). Initially, physical image characteristics such as color and edges are encoded. Next, the encoded visual information is matched against previously stored information in ones' long-term memory. Once a match is found, the name of the associated object or image is retrieved (Humphreys, Price & Riddoch, 1999). The authors suggest that these three stages can overlap, meaning that activation of one stage might begin before the previous stage has completely finished (Humphreys et al., 1999).

The role of color in image recognition has been studied extensively in language-normal adults. It is believed that color may aid in image recognition through two distinctly different processes. First, color aids in discriminating the target image from its background in visual scenes, making it easier to identify the target image. For example, if one is looking for an apple, one would look for the color red in a visual scene in order to locate the target. In order to differentiate a target from its background, one must be able to focus visual attention on the target and not its background. Thus, salient color information can help capture ones attention while searching for a certain targets in visual scenes (Rossion & Pourtois, 2004; Uttl et al., 2006; Therriault, Yaxley & Zwaan, 2009; Bramão, Inácio, Faísca, Reis & Petersson, 2010; Mohr, 2010). The surface color of an image is color information that is present when viewing a picture and may aid in image recognition (Rossion & Pourtois, 2004).

A second process through which color may facilitate image recognition is the elicitation of associations with the image in our memory, which in turn might facilitate lexical access. Natural images tend to have a higher color diagnosticity compared to images of man-made objects (e.g, car, tools or furniture). Color diagnosticity refers to how prototypical the color of an image is. For instance, *lemons* are always yellow. Thus, if one sees a yellow image, it is likely that *lemon* will be activated in the mental lexicon because of the highly diagnostic color while *car* will not receive the same amount of activation because yellow is a possible color but not a diagnostic color for car. Thus, recognition of high-color diagnostic images might be facilitated because color serves as a semantic feature in those images (Mohr, 2010; Bramão et al., 2010; Therriault et al., 2009; Tanaka, Weiskopf and Williams, 2001; Wurm, Legge, Isenberg & Luebker, 1993). The conceptual color of an object is the color of one's mental representation of an object.

The effect of color on image recognition in language-normal adults

It has been reported in multiple studies that color facilitates image recognition in language-normal participants. In a study by Rossion and Pourtois (2004), sixty college-age language-normal adults were asked to name black-and-white, gray-scale, and colored line drawings as quickly as possible. The participants were given 3000 ms to verbally respond to each picture. The Snodgrass and Vanderwart (1980) black-and-white line drawings were used. In the gray-scale images, surface information was added to the original black-and-white line drawings. A colored version of the same line drawings was also created. The presentation of the gray-scale, black-and-white and color versions of the drawings was randomized, and each participant only saw one version of the line drawings.

Colored line drawings were named significantly more accurately compared to black-and-white line drawings. The mean rate of naming accuracy for the black-and-white line drawings was 88.2%, the mean rate of naming accuracy for the grayscale drawings was 89.2%, and the mean rate of naming accuracy for the colorized drawings was 90.3%. Additionally, participants named the colored drawings significantly faster than the grayscale and black-and-white images Participants named the black-and-white line drawings at a mean rate of 882 ms, the gray-scale drawings at a mean rate of 883 ms and the color line drawings at a mean rate of 804 ms. No significant difference was found between the black-and-white drawings and the grayscale drawings, meaning that the grayscale versions with added surface detail such as shading and surface texture did not improve response times. Shape was controlled in this study because the same images were presented in 3 different conditions, indicating that the significant difference s in naming latencies and accuracies are contributed to the influence of color only. In summary, color facilitated naming accuracy and reduced response times over black-and-white line drawings and gray scale line drawings.

Results of this study indicated that language-normal participants produced more naming errors for black-and-white line drawings compared to colored versions of the line drawings. And, while naming accuracy was overall high, the difference was significant. If color influences naming accuracy in language-normal participants, its influence on individuals with neurogenic deficits needs to be explored, as color could also potentially facilitate naming in people with aphasia or people with other cognitive-linguistic deficits. A limitation of the study is that it focused on line drawings, carefully controlled for color diagnosticity, but semantic category was not controlled, which could have led to semantic associating aiding in recognition as well as or instead of color.

Uttl, Graf and Santacruz (2006) conducted a study to determine if color facilitated image recognition in man-made and natural images. The authors also aimed to determine the influence of 1) repeated viewing of man-made and natural images 2) the degree of color complexity, and 3) the degree of color diagnosticity on image recognition. The images were presented using a fade-in procedure in which image content, quantified through number of pixels, was gradually faded in.

The experiment included two components. During the first part, one hundred and forty language-normal participants were presented with seventy two colored and black-and-white photographs and were asked to determine, on a one-to-three scale, how recognizable each photograph was. During the second half of the experiment, participants saw the same photographs that they were shown in the first half of the experiment, along with seventy two new color and black-and-white photographs. The participants were asked to verbalize the names of each of the photographs as fast as they could. Images were validated by two different groups of participants. Each group was comprised of fifteen participants each and they were asked to rate the photographs' color diagnosticity and color complexity using a one-to-five scale.

Images were identified as natural or human-made. Participants identified color photographs with a fewer number of pixels than black-and-white photographs. Inaccurate responses were excluded from the data analysis. The authors reported an error rate of 3.5% of test trials. Participants required 35.7% of pixels to identify color images as opposed to 44.6% of pixels to identify black-and-white images. Color was beneficial for identifying both natural and man-made images equally, for high and low color diagnostic images, as well as high and low color complex images. The study also found that the number of pixels necessary for identifying the images seen previously was lower (29.7%) than the pixels required to identify new images (40.2%). A significant difference was found for study-test color, meaning that the participants needed fewer pixels to identify images that they had previously seen in the same color condition compared to images that they had previously seen in a different color condition. Images that were presented in color during both conditions were recognized faster than those that were presented in black-and-white during both conditions. The authors used the amount of pixels necessary for naming each photograph as the means of analyzing the results. When the photographs were shown to the participants for the first time, data revealed that the participants needed fewer pixels to name the colored photographs than they needed to name the black-and-white photographs. Participants needed a significantly smaller percentage of pixels in order to name the familiar photographs than the previously unseen photographs, and participants needed fewer pixels to identify the colored photographs than the black-and-white photographs during the second showing. Color was beneficial for identifying natural and man-made images, and color was equally beneficial for participants when naming both high and low color diagnostic images. The study highlights that the presence of surface color has a stronger influence than degree of color diagnosticity and type of object (natural vs. man-made) of presented images on image recognition.

Limitations include that it was not well defined what constituted a “color complex” photograph. The scale provided in the article describes this as a one-to-five scale, but complexity could mean different things to different raters.

As with previous studies, this study indicated that color facilitated image recognition in language-normal participants. Color facilitated image recognition also during repeated presentation of the same image. This result warrants further research to determine if people with aphasia would benefit from repeated exposure to color images more than to black-and-white images, for lexical retrieval assessment and treatment.

Additional evidence for the influence of color on image recognition was provided by Therriault, Yaxley and Zwaan (2009), who investigated the extent to which color influenced image recognition and image naming by manipulating the color of photographs. Images were presented in their typical color, in an atypical color, and in grayscale. Therriault et al. (2009) hypothesized that the typically colored images would evoke fastest responses, assuming that color facilitated image recognition. Conversely, the authors hypothesized that the atypically colored images would evoke the slowest response times.

All photographs were highly color-diagnostic. In the first part of the experiment, eighty four language-normal college aged participants were shown single images on a computer screen and were asked to name the image displayed. Results revealed that participants named the typically colored photos significantly faster than the gray-scale photographs, and the grayscale photographs were named significantly faster than the atypically colored photographs. These findings support the argument that color facilitates naming for typically colored images and inhibits naming for atypically colored images.

For the second part of the experiment, participants first heard a word and then a photograph appeared on the computer screen. Participants were instructed to respond by pressing “Y” or “N” on a computer keyboard to indicate if the photograph did or did not match the word. As in the first part of the experiment, results showed that the participants verified the name of the typically colored photographs significantly faster than the grayscale photographs, and the participants verified the name of the grayscale photographs significantly faster than the atypically colored photographs. The results of the second experiment once again support the claim that color modulates image recognition. The authors further argued that if color was not being utilized to recognize images, then gray scale photographs should have been named as quickly as the typically colored photographs, which was not the case.

A limitation of this study is that the authors failed to control for other image characteristics such as shape, and that the study only included high color-diagnostic photographs. This makes it difficult to determine if there is a difference between color diagnostic and non-color diagnostic images.

Bramão, Inácio, Faísca, Reis and Petersson (2010) explored the effect of color on image recognition with high and low color diagnostic images. The experimenters developed a set of stimuli each containing a black-and-white photograph, a colored photograph, a black-and-white line drawing and a colored line drawing for seventy two high and low color diagnostic images. One hundred and forty-four college-age language-normal participants were asked to verify the names of the images as quickly as possible utilizing two separate buttons: one for "yes" and one for "no." Response times and percentage of correct responses for both color and black-and-white images were reported separately for high and low color diagnostic images.

Results indicated faster reaction times for colored high color diagnostic images (mean reaction time of 521 ms) compared to black-and-white high color diagnostic images (mean reaction time of 551 ms) supporting the notion that presence of color facilitates image recognition in language-normal adults. Participants identified both high-color diagnostic (mean reaction time of 521 ms) and low-color diagnostic images (mean reaction time of 532 ms) equally quickly when the colored pictures were presented indicating that surface color did supersede effects of color diagnosticity. No significant difference was found when comparing photographs to line drawings.

However, stimulus characteristics other than color and color diagnosticity (e.g. shape, size) were poorly controlled. The photographs were matched to line drawings that closely resembled the photographs but were not derived from the exact same images, resulting in poor control of surface detail, visual angle, prototypicality of the depicted image and shape. Thus, any of these characteristics could also affect the process of image recognition.

In summary, image recognition was facilitated through the presence of color in language-normal adults in line drawings (Bramão et al., 2010; Rossion & Pourtois, 2004) and photographs (Bramão et al., 2010; Therriault et al., 2009, Uttl et al., 2006).

Additional factors, such as repeated exposure, were found to shape the facilitating effect of color (Uttl et al., 2006). Rossion and Pourtois (2004) pointed out that color did not just facilitate recognition, but also increased accuracy of image naming in language-normal adults. Therriault et al. (2009) found that incongruent color inhibited image recognition, as indicated by increased response times.

Common limitations of all studies include limited control of image characteristics that were not studied, including poor definition of color diagnosticity and color complexity, and lack of control of shape and surface detail. This was particularly problematic for the Bramão et al. study (2010), which compared line drawings directly to photographs without using the same images, but only the same depicted concepts in photographs and line drawings.

See Table 1 for a summary of all reviewed studies with language-normal adults.

Table 1

Summary of studies for language-normal adults

Authors	Participants	Stimuli	Purpose	Results
Rossion & Pourtois, 2004	60 language-normal participants	Black-and-white line drawings, color line drawings, gray line drawings	Compare naming speed and accuracy of color, black-and-white and gray scale drawings	Color line drawings named significantly more accurately and 100 ms faster than black-and-white and gray scale drawings
Uttl, Graf & Santacruz, 2006	140 participants identified objects in photos;	Colored and black-and-white photos	Explore role of repeated exposure, color complexity and diagnosticity on image recognition using a fade-in method	Fewer pixels required to recognize color than black-and-white photos, significantly fewer pixels to recognize images previously seen in the same color condition than in black-and-white. Fewer pixels to recognize previously seen compared to new images.
Therriault, Yaxley & Zwaan, 2009	84 language-normal participants	Congruent, incongruent and gray colored high diagnostic photographs	Compare naming and verification of congruently, incongruently and gray colored photos	Naming task: Congruently colored photos were named the quickest; Verification task: Congruently colored photos verified the quickest
Bramão, Inácio, Faísca, Reis & Petersson, 2010	144 language-normal college-age participants	High color and low color diagnostic color and black-and-white line drawings and photos.	Explore role of color in image recognition with high and how color diagnostic images	Color images were recognized faster than black-and-white images. Image type did not affect recognition

The role of stimulus characteristics in image recognition and naming in individuals with aphasia

Very few studies to date were conducted to explore the role of physical stimulus characteristics on image recognition and image naming in people with aphasia. Bisiach (1966) conducted a study in which he investigated the effects of color on naming in people with aphasia. Nine participants with aphasia were asked to name three different sets of line drawings. The study utilized thirty colored line drawings, thirty black-and-white line drawings and thirty black-and-white line drawings distorted with lines going across the image. The drawings were presented in sets of ten and their presentation was counterbalanced so that no participant saw the same image twice to avoid practice effects. Participants were given fifteen seconds to name each drawing. Out of a total of 90 images, participants recognized 84 colored line drawings, 81 black-and-white line drawings and only 61 distorted line drawings. Results show that saliency of the visual stimulus influenced image recognition. Within the correctly recognized images, no significant differences were observed in terms of naming accuracy among the three types of line drawings. Bisiach (1966) concluded that color facilitated recognition of line drawings in people with aphasia because color provided additional semantic information about the images and facilitated lexical access. He also stated that if any part of one's visual processing system is impaired (which is particularly prevalent in individuals who have had a stroke), a reduced amount of visual information is likely to be processed. Thus, color could potentially enhance stimulus saliency and improve information processing in people with neurogenic deficits.

Benton, Smith and Lang (1972) explored the role of stimulus characteristics on confrontation naming in 18 people with aphasia using three types of stimuli: real objects, a small line drawing of the object and a large line drawing of the same object. The authors controlled for anomia severity by excluding any participant who was unable to correctly name at least four out of sixty six items and participants who made less than three errors. The results indicated that participants named real objects significantly more accurately compared to the small version of the line drawings. No significant differences were found between objects and large line drawings or small and large line drawings. Thus, the type of stimulus presented affected the performance on object naming in people with aphasia.

Major limitations of the two studies reported above include poor stimulus control in terms of physical characteristics (e.g., color or color diagnosticity of the images and objects was not controlled) as well as linguistic properties (e.g., word frequency of the stimuli did not seem to be controlled but could have an impact on naming performance). Further, participant characteristics that could have impacted performance such as apraxia of speech, aphasia severity or type of aphasia were not described or controlled. Finally, only naming accuracy served as the dependent measure but no reaction time data was reported for the study by Benton et al. (1972). These methodological limitations make it difficult to interpret the results of these studies.

In a more recent study, Mohr (2010) explored the influence of color, semantic category and color diagnosticity on naming accuracy in people with aphasia. Twenty-nine individuals who were either in the post-acute or chronic aphasia stage participated. All participants exhibited mild to moderately severe anomia as measured with the Aachen Aphasia Test (AAT) (Huber et al., 1983). Participants who were unable to name less than half of the photographs in the stimulus set were excluded from the study. Seventy language-normal individuals served as control participants. Half of the one hundred forty-four photographs depicted living things and half represented man-made objects. Eighty-seven photographs were high color diagnostic objects and fifty-three were low color diagnostic objects. Images were presented in black-and-white or in color, on neutral grey or colored background. Participants were asked to name the objects in the photographs as quickly and accurately as possible. The participants named seventy photographs during in the initial session. Twenty-four of the participants with aphasia came back after a seven to seventeen day time span and were shown the photographs again. Participants were asked to name the same seventy photographs along with an additional seventy photographs.

Results indicated that color facilitated naming of photographs for both groups of participants. All participants named the black-and-white photographs significantly slower than the color photographs. The language normal group exhibited faster response times than the group with aphasia. When analyzing photographs of living objects versus man-made objects, the language-normal group named man-made objects slower than living objects. However, no difference was found for the group of participants with aphasia. Color diagnosticity did not affect the naming performance of either group of participants. The study revealed that repeated exposure facilitated photograph naming in both. The response times when seeing the photograph for a second time seven to seventeen days later were significantly faster than during the first exposure to the photograph regardless of presence or absence of color. See Table 2 for a summary of the reviewed studies with people with aphasia.

Table 2

Summary of studies with individuals with aphasia

Authors	Participants	Stimuli	Purpose	Results
Bisiach, 1966	9 participants with aphasia	Colored, black-and-white & distorted line drawings	Explored the effects of color on image recognition and naming	Colored line drawings were more often recognized compared to other image types. No significant difference in naming accuracy for the recognized images by image type.
Benton, Smith & Lang, 1972	18 participants with aphasia	Real objects and small and large line-drawings of those objects	Explored the effects of size, and on naming	Real objects were named significantly more accurately than small line drawings
Mohr, 2010	29 participants with aphasia and 70 language-normal participants	Colored and black-and-white photographs of living and man-made objects. 87 were high-color diagnostic and 53 were low-color diagnostic.	Explored the effects of color, semantic category, color diagnosticity and priming on naming	all participants named black-and-white significantly slower than colored photographs. Color diagnosticity did not influence naming. Controls named man-made objects slower than living objects.

The results of these studies implicate that specific image characteristics have an influence on a participants' performance on recognition and naming tasks. Bisiach (1966) found that participants recognized colored line drawings better than black-and-white and distorted line drawings. Benton, Smith and Lang (1972) found that participants were able to name objects significantly more accurately than small line drawings of those same objects, meaning that stimulus type influences a participant's performance. Mohr (2010) found that color facilitated naming in photograph. However a common limitation of these studies was that they failed to accommodate for verbal response confounds due to apraxia of speech (AOS) and other concomitant deficits of stroke frequently present in people with aphasia. It is difficult to determine whether differences in naming accuracy of images were due to modified image characteristics, due to anomia or due to concomitant deficits related to stroke. In order to better control for response confounds, a different response method that does not rely on verbal responses is needed to explore the influence of stimulus-driven characteristics on language comprehension processes.

Eye tracking studies

Eye tracking is ideally suited to study the interaction of stimulus-driven influences on language comprehension in individuals with aphasia because participants do not need to respond verbally, with gestures, in writing or by manipulating devices such as a computer keyboard, computer mouse or joystick. This allows for the inclusion of participants with expressive language deficits, concomitant motor deficits such as AOS or impaired eye-hand coordination to participate in assessments, and potentially increases the validity of assessments of stimulus-driven influences on image recognition in individuals with aphasia.

Eye-tracking and language comprehension

It is well established that participants look at images that correspond to verbal stimuli regardless of explicit instructions to do so or not (Cooper, 1974; Hallowell, 1999, 2012; Hallowell et al., 2002; Heuer & Hallowell, 2009, Henderson, Shinkareva, Wang, Luke, & Olejarczyk, 2013; Huettig & Altmann, 2011). Eye-tracking has been shown to validly index language comprehension in individuals with and without aphasia (Hallowell, 1999, 2012; Hallowell et al., 2002; Tanenhaus, Magnuson, Dahan, & Chambers, 2000; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). Further, aphasia severity has been shown to correlate significantly with eye-tracking measures of language comprehension (Hallowell et al., 2002; Heuer & Hallowell, 2015).

Eye-tracking and stimulus or stimulus characteristics

There is a growing body of literature demonstrating that eye tracking-validly measures the influence of stimulus-driven processes on visual attention in language-normal adults (Dahan & Tanenhaus, 2005; Heuer & Hallowell, 2009; Huettig & Altmann, 2004, 2005, 2011). Huettig and Altmann (2004, 2011) specifically studied the role of color on language-mediated eye movements in multiple-choice image displays. The authors (2004) explored the role of color in multiple-choice image displays on eye movements in the presence of a verbal stimulus. Participants were presented with multiple-choice image displays containing four colored line drawings and heard a sentence corresponding to one image in the display (the target image). An example of a verbal stimulus that the participants heard was “The man thought about it for a while and then he looked at the frog and decided to release it back into the wild" (Huettig & Altmann, 2004, p. 127). Each display contained a target image (e.g. frog) and three unrelated distractor images. Participants were told to listen to the verbal stimuli and to look anywhere they wanted on the computer screen. Participants were found to fixate the target image significantly more often in response to the verbal stimulus compared to the distractor images. In a second condition, the competitor condition, the previous target image (e.g., frog) was replaced by a target competitor drawing of an image that had the same color as the target image (e.g. spinach). The same verbal stimulus as before, with reference to *frog* was presented. Results indicated that participants fixated on the competitor image significantly more frequently than any other images in the display. Thus, color was found to influence language-mediated eye movements in multiple-choice image displays with colored line drawings.

In a follow-up study, Huettig and Altmann (2011) determined whether the color influence was perceptual due to presence of color in displays, or whether color influenced eye fixations also in black-and–white images, relying on the viewers' knowledge of the typical color associated with depicted objects. During the first experiment, sixty language-normal participants viewed multiple-choice image displays containing four black-and white line drawings. They were presented simultaneously with a sentence that contained the name of one of the line drawings in the display. During the target condition, they heard a sentence which included the name of one of the line drawings that was displayed (e.g. grasshopper). During the competitor condition, they saw the same image displays but the sentence included a word that had the same conceptual color (e.g.

broccoli) as the original target (e.g. grasshopper). The participants were instructed to listen to the sentences and to look at whichever line drawing they wanted. During the target condition, participants fixated more often on the target (e.g. grasshopper) when hearing the target word (e.g., grasshopper) compared to the distractor images (e.g. broccoli). During the competitor condition, participants allocated eye movements equally across the target (e.g. grasshopper) and the distractors when hearing the word broccoli. Thus, in black-and white line drawing displays there was no color competitor effect observed, in contrast to the 2004 study in which colored line drawings were used. This discrepancy in results suggests that color only mediates eye movements when it is present in image displays.

During the second experiment, participants heard the same sentences as during experiment one. Instead of line drawings, photographs were used. Participants were split into two groups. One group saw black-and-white photographs and the other group saw color photograph displays. However, the color photographs were presented in an atypical color so that the photographs did not hint at the typical color of that particular image (e.g, a yellow frog instead of a green frog). The same procedure was used as in experiment one. Results indicated a small color competitor effect for the color photographs, but no significant difference for the black-and-white photographs. Like in experiment one, no significant difference was found between color competitor and distractor images in black-and-white photographs. As in experiment 1, the lack of a color competitor effect in the black-and-white images suggests that color only influences language-mediated eye movements when it is present in the displays.

Heuer and Hallowell (2009) studied the influence of objectively controlled image characteristics (color, orientation, size and luminance) and their effects on participants' visual attention using eye-tracking. Multiple-choice image displays containing three images were presented to forty language-normal participants. Within each image display, two images shared the same image characteristics (majority images) and one image differed in terms of one characteristic (singleton image). During the nonverbal condition, participants were asked to look wherever they wanted at the computer screen. During the verbal condition, participants were told to direct their attention to the image on the screen that corresponded to a single-word verbal stimulus (e.g., small, large, dark, bright, red, and green). During the singleton condition, the verbal stimulus corresponded to the one image that differed in terms of a specific image characteristic, while during the majority condition the verbal stimulus corresponded to a target image that shared that image characteristic with one other (non-target) image within the display. The verbal stimuli elicited a greater disproportionate allocation of visual attention than the same images during the non-verbal condition, Results also indicated greater disproportionate allocation of visual attention to the singleton images than the majority images in both verbal and nonverbal conditions. Thus, visual salience had a significant influence on visual attention, even when a verbal stimulus was given.

These results indicate that image characteristics have an influence on visual attention and that stimulus-driven influences must be carefully controlled when using images to study cognitive-linguistic processes. See Table 3 for a summary of the eye-tracking studies.

Table 3

Summary of eye-tracking studies on the influence of color in multiple-choice displays

Study	Participants	Stimuli	Purpose	Results
Huettig & Altmann, 2004	language-normal participants	Displays of multiple-choice image displays with four colored line drawings, each containing a target or a color competitor and three unrelated distractor images. Sentences corresponded to the target line drawings.	Explored role of color in multiple-choice image displays on eye movements in presence of verbal stimulus.	Participants fixated on target images and color competitor images significantly more often compared to distractor images.
Huettig & Altmann, 2011	60 language-normal participants	Condition 1: Four black-and-white line drawings containing a target or color competitor and three foils presented with sentences corresponding to the target or a color competitor	Determined whether color influence is perceptual due to surface color in displays or conceptual due to stored color knowledge.	Condition 1: No color competitor effect observed as participants fixated equally among 4 line drawings.
		Condition 2: Four black-and-white or atypically colored photographs, containing a target or color competitor three foil images presented with sentences corresponding to the target or the color competitor		Condition 2: No color competitor effect for black-and-white photos.
Heuer & Hallowell, 2009	40 language-normal participants	Displays of three images, two identical images (majority images) and one differing in terms of one of image characteristic (singleton image) presented under nonverbal and verbal conditions	Explore the influence of objectively controlled image on visual attention with and without verbal stimulus	Greater allocation of visual attention to singleton image than majority images in both conditions.

Eye-tracking measures

Huettig and Altmann (2004, 2005, 2011) and Heuer and Hallowell (2009) used proportion of fixation duration (PFD) on target images as a dependent measure. The proportion of fixation duration on targets is defined as the total duration of fixations on a particular image, divided by the total fixation durations on all images in a multiple-choice image display. A high value close to one indicates that the participant allocated a larger amount of fixation duration on that image compared to the other images in the display. The higher the number, the greater the amount of time was spent looking at a specific image. The lower the number, the more equally the fixations were distributed across images in the display. PFD has been used extensively in eye-tracking studies to index language comprehension processes and stimulus-driven influences on visual attention (Huettig & Altmann, 2004, 2005, 2011, Heuer & Hallowell, 2007, 2009).

First-pass gaze duration (FPGD) measures the duration of all fixations on an image from first entry to first exit in that image. A longer first-pass gaze duration on the target has been associated with images that were semantically related to a target word compared to unrelated foil images (Odekar, Hallowell, Kruse, Moates & Lee, 2009), and has been found to be longer for semantically informative objects, such as target objects in scene perception tasks (Henderson & Hollingworth, 1998).

In summary, color has been found to influence language-mediated eye movements in language normal adults (Huettig and Altmann, 2004, 2011; Heuer & Hallowell, 2009). As demonstrated by Huettig and Altmann (2004, 2011), when shown colored line drawings, participants fixated on target and color competitor images significantly more than the distractor images. The color competitor effect was only observed in color images, which suggests that color mediates eye movements only when it is present in the displays. However, there is a need to clarify the color competitor effects on language-mediated eye movements. While Huettig and Altmann (2004) used different images and the same verbal stimuli for target and color competitor conditions, they used the same images and different verbal stimuli in the follow-up study (Huettig & Altmann, 2011). There is a need to confirm that effect using the same procedure consistently with the colored and black-and-white line drawings. Findings to date highlight a need for careful control of image characteristics when studying cognitive-linguistic processes.

PURPOSE

Exploring the role of stimulus-driven influences during cognitive-linguistic tasks is clinically highly relevant in order to interpret client's performance on multiple-choice tasks that involve images. While the results of previous studies with individuals with aphasia indicated stimulus-driven influences, verbal response confounds might have affected results. Eye-tracking has the potential to eliminate those confounding factors because participants do not need to respond verbally, in writing, or with gestures; their response involves looking at a computer screen. In addition to reduced response confounds and the fact that participants tend to look at images that correspond to verbal stimuli, eye-tracking has been found to be sensitive to the presence and absence of color when presented with a verbal stimulus in multiple-choice image displays in language-normal adults. The goal of the present study was to determine the role of color in multiple-choice image displays on language-mediated eye movements in individuals with aphasia. Multiple-choice image displays containing color images or black-and white images were presented together with a verbal stimulus under two conditions. In the first condition, the verbal stimulus corresponded to one of the images in the display. In the second condition, the target image was replaced with a color competitor image while the same verbal stimulus was presented as in the first condition. The goal of the study is two-fold. First, it helped to determine if people with aphasia will identify color images more easily compared to line drawing images that correspond to the verbal stimulus in multiple-choice image displays. Second, it helped to determine if the color competitor effect was observed in people with aphasia, as it was with language-normal adults as discovered by Huettig and Altmann (2004).

Research Questions

Target Image Condition

1. Will both groups of participants allocate greater proportion of fixation duration (PFD) and longer first pass gaze duration (FPGD) to color target images compared to black-and-white target line drawings that correspond to a verbal stimulus in multiple-choice image displays?

2. Will group differences be observed across all image displays, in that people with aphasia will allocate lower PFD and shorter FPGD to target images across black-and-white and color image displays compared to language-normal adults?

Color Competitor Condition

3. Within the color image displays, will both groups of participants allocate greater PFD to color competitor images that share the same typical color as the image represented by the verbal stimulus compared to unrelated images in the multiple-choice display?

4. Within black-and-white line drawing displays, will there be a difference in PFD allocated to the color competitor image (the image that shares the conceptual color with the image presented in the verbal stimulus) compared to unrelated images in the multiple-choice display?

Expected outcomes

Target image condition

1. All participants will allocate significantly greater proportion of fixation duration (PFD) and longer first pass gaze duration (FPGD) to color target images compared to black-and-white line drawings that correspond to a verbal stimulus in multiple-choice image displays.
2. Language-normal individuals will allocate greater PFD and longer FPGD to target images in color and black-and-white image displays compared to individuals with aphasia.

Color competitor condition

3. Within the color image displays, participants will allocate significantly greater PFD to color competitor images that share the same typical color as the image represented by the verbal stimulus compared to unrelated images in the multiple-choice display.
4. Within black-and-white line drawing displays, participants will allocate PFD and equally across the color competitor images and the foils.

METHODS

Approval for this research was granted by the Institutional Review Board at The University of Wisconsin-Milwaukee. Prior to participation in the study, each participant provided written consent. See the Appendix A for the consent forms.

Participants with aphasia

Participants with aphasia were recruited in the Milwaukee area in aphasia and stroke support groups and at University Speech and Language clinics. Five participants with aphasia were recruited. Aphasia was defined as acquired neurogenic communication disorder that may affect all communication modalities but is not a disorder of general intellectual abilities, sensory deficits or psychiatric disorder (Hallowell & Chapey, 2008). Inclusion criteria were (a) native speaker of English; (b) presence of aphasia (confirmed aphasia diagnosis from a certified SLP, and confirmed by participants, caused by a lesion to the left hemisphere as verified through medical records); c) passing a vision screening to ensure that the participants were able to see the line drawings that they were shown in the study, to ensure that the participant had sufficient visual acuity to identify images on the computer screen and to ensure that the participant did not have an impairment to his or her central vision. For the vision screening, participants were asked to complete the Lea Symbols Line Test, the Amsler grid and the Color Vision Testing Made Easy test by Waggoner (1994). These three vision exams screened participants for central and peripheral visual acuity, and color vision. While completing the Lea Symbols Line Test, the participant was asked to sit at a distance of .6 meters from the stimuli while identifying five symbols. This ensured that the participant had sufficient visual acuity to identify images on the computer screen. Next, the participant was shown the Amsler grid, which tested for impairment of the participant's central vision due to macular degeneration. The participant was shown the grid, which consists of vertical and horizontal lines, and was asked questions about what they see. Last, the participants were shown four colored images from Waggoner's (1994) "Color Vision Testing Made Easy." The participants were required to identify all four colored images correctly to pass the color vision screening. A quick physical examination of the participants' eyes to check for swelling or redness was also conducted. Participants with aphasia were also required to complete a visual neglect screening using a line cancellation task to ensure that there is no neglect that could impact the participant's ability to see all four line drawings. All participants passed the vision screening procedures.

Each participant also completed a hearing screening to ensure that he or she was able to comfortably hear the verbal stimuli that was presented in the study. Participants were presented with tones at 1000, 2000 and 4000 Hz through supra-aural headphones at 25 dB HL (American Speech-Language-Hearing Association, 1997). If a participant was unable to identify when a tone was presented to them, a note was made and accommodations occurred to ensure that the participant was able to adequately hear the verbal stimuli. Four participants with aphasia were able to hear all of the tones when presented at 25 dB HL, and one participant with aphasia needed an adjustment in volume for both ears. There were two male and three female participants with aphasia. The ages of the participants with aphasia ranged from 50 to 72, with 62.8 being the mean age. The years of education of the participants with aphasia ranged from 12 years to 18 years, with an average of 15.2 years. The time post-onset of stroke ranged from 13 months to 468 months, with an average of 131.4 months. Language abilities were assessed with the revised Western Aphasia Battery (WAB-R, Kertesz, 2006). This comprehensive test battery assesses different communication and language skills including spontaneous speech, auditory verbal comprehension, repetition, naming and word finding. Participants were not excluded from the study based on his or her WAB-R results. See Table 4 for a summary of participants' performance on the WAB. Due to recording difficulties, data for one participant could not be analyzed. That participant's data was excluded from the study.

Table 4

Participant Performance on the Western Aphasia Battery

Participant	Spontaneous Speech Score	Auditory Verbal Score	Repetition	Naming/Word Finding	Aphasia Quotient	Aphasia Type
1	18	9.15	8.8	9.4	90.7	Transcortical Sensory
3	17	9.35	9.8	9.9	92.1	Anomic
4	20	10	10	10	100	Anomic
5	4	7.7	.02	4.2	31.84	Broca's

Based on the test performance, the participant's type of aphasia was computed. One participant had transcortical sensory aphasia, one participant had conduction aphasia, two participants had anomic aphasia and one participant had Broca's aphasia. The WAB-R also allows for calculation of an Aphasia Quotient (AQ). The AQ suggests the aphasia severity of each participant. According to the authors of the WAB-R, a very severe aphasia would fall into a score of 0-25, a severe aphasia would fall into a score range of 26-50, a moderate form of aphasia would fall into a score range of 51-75 and a mild severity rating would be a score of 76 or higher (Kertesz, 2006). The participants had the respective aphasia quotients: 90.7, 38.1, 92.1, 100 and 31.84. Out of this group, two participants were considered to have severe aphasia (38.1, 31.84), while three participants exhibited mild aphasia.

Participants without aphasia

Ten language-normal participants, self reportedly without neurogenic impairment, were recruited for the study as control participants. The language-normal participants were recruited from the Milwaukee community. Their ages ranged from 55-86, with an average age of 66.8. Years of education ranged from 12 years to 18 years, with a mean of 16.65 years. Control participants underwent a cognitive screening, the Mini Mental State Examination (MMSE) (Folstein, Folstein & McHugh, 1975) to assure absence of mild cognitive impairment or dementia. All participants had to obtain a score of at least 23 out of 30. The average score on the MMSE was 29.6, and the scores ranged from 29 to 30. There were two male and eight female language-normal participants. A Mann-Whitney U test was conducted to determine if there was a significant difference in age and in education between the group of people with aphasia and the language-normal group of participants. The test revealed no significant differences between the groups for age, U = -.49, p = .68, nor for education, U = -1.28, p = .25. The language-normal participants had a mean rank of 8.4 for age, while the participants with aphasia had a mean rank of 7.2. The language-normal participants had a mean rank of 9 for years of education, while the participants with aphasia had a mean rank of 6.

Control participants underwent the same vision and hearing screening procedures as people with aphasia, except for the neglect screening. All ten participants passed the vision screenings, and no accommodations were necessary.

For the hearing screening, three of the control participants were able to hear all of the tones when presented at 25 dB HL. One participant required a slight adjustment for one ear, and six participants required slight volume adjustments due to inability to hear at the 25 dB HL at one or more frequencies in both ears.

Stimuli

Image displays

A series of multiple-choice image displays were created in both black-and-white and color. Four line drawings were presented in each image display. One image was presented in each corner of the display. A total of twenty multiple-choice image displays of black-and-white line drawings and twenty displays including colored line drawings were used in the experiment. Each display contained a target image (that corresponded to a verbal stimulus) and three unrelated line drawings. Two naïve viewers were asked to look at the image displays without any verbal stimuli presented. The viewer was asked to select, based upon his or her own personal judgment, any displays that seem unbalanced (e.g. one of the images stands out to him or her more than the other images in regards to shape, color, size etc.) Any images that were judged to be unbalanced within a display were replaced with a different foil image.

Image selection criteria

The images' size, color and color diagnosticity were controlled, as well as the linguistic properties of the corresponding verbal stimulus. The color and black-and-white images were derived from the colored line drawing set created by Rossion and Pourtois (2004). Different color and black-and-white line drawings were used to avoid any order effects. The target images were selected based on a high color diagnosticity rating from the Rossion and Pourtois (2004) study. Twenty high-color diagnostic images that received a rating of 4.0 or higher on a 5-point scale, as reported by Rossion and Pourtois (2004) were selected as target images. Then, target images were paired with twenty color competitor images based on their common typical color, color diagnosticity rating and FSG rating. The FSG (forward strength) values were developed by Nelson, McEvoy and Schreiber (1998) and represent "forward cue to target strength association." This value provides the probability that a certain word (e.g., strawberry) is associated with the word 'red.' A low FSG rating (ratings closer to zero) signifies that there is a low correlation between two words. The higher the FSG rating is between two words, the higher is the strength of the word association between the target word and its color. FSG norms are available only for some of the items. Images were matched for word length of corresponding image name as indexed by number of letter and syllables, and the word frequency indexed as LOG frequency derived from the CELEX index (Baayen, Piepenbrock and Van Rijn, 1993). The LOG frequency of a word shows how frequently a particular word occurs in the English language (in log 10 format). The semantic relationship between the target and the color competitor word was also controlled. The pairs of target image and color competitor image were randomly assigned to a color or a black-and-white condition. Paired-samples t-tests comparing controlled variables and ratings between target images and color competitor match revealed no significant differences in any of the controlled variables, except for numbers of letters. See Table 5 for descriptive statistics and Table 6 for t-test results. Independent samples t-tests comparing black-and-white to color images also revealed non-significant differences in controlled variables across images, except for number of syllables. See Table 7 for descriptive statistics and Table 8 for t-test results.

Table 5

Means and Standard Deviations for Controlled Variables of Target Images and Matched Color Competitor Images.

	Target		Color Competitor		
Variables	*Mean*	*SD*	*Mean*	*SD*	*N*
Diagnosticity	4.498	.31	4.56	.30	20
Frequency	1.14	.46	.88	.55	20
Syllables	1.70	.92	2.05	.68	20
Letters	5.35	1.87	6.35	1.63	20

Table 6

Comparison of Controlled Variables of Target and Color Competitor Images Using Paired Samples t-tests

Stimulus Characteristic	*t*	*df*	Significance (2-tailed)
Color Diagnosticity	-.97	19	.34
Word Frequency	1.98	19	.06
Syllables	-1.79	19	.09
Letters	-2.15	19	.02*

Table 7

Means and Standard Deviations for Controlled Variables of Color and Back-and-white Images

	Target		Color Competitor		
Variables	*Mean*	*SD*	*Mean*	*SD*	*N*
Diagnosticity	4.49	.31	4.56	.31	20
Frequency	1.13	.10	.89	.50	20
Syllables	1.60	.68	2.10	.88	20
Letters	5.40	1.60	6.30	1.92	20

Table 8

Comparison of Color and Black-and-white Images using Independent t-tests

Stimulus Characteristic	*t*	*df*	Significance (2-tailed)
Color diagnosticity	-.70	38	.49
Log Frequency	1.46	38	.15
Syllables	-2.22	38	.03*
Letters	-.1.61	38	.12

Three foil images for each image display were selected based on two criteria: the foil image was a different color than the target word and the foil image was from a different semantic category than the target word. See Appendix B for image controlled variables and groups. Color images derived from the Rossion & Pourtois study (2004) were converted into black-and-white images. The same procedure was followed to convert each image into a black-and-white line drawing. The images were saved as JPEG images, with an image quality of "12 Maximum" and a format option of "Baseline (Standard)." Each image has a pixel size of 144x144 and 71.958 pixels per inch (PPI). Image size is 2 x 2 inches.

Verbal stimuli

Twenty verbal stimuli, corresponding to the name of each of the twenty target images, to be presented were recorded in a soundproof booth with an adult male speaker.

Procedure

Eye tracking procedures

Participants were seated at a distance of .6 meters away from a twenty-four inch computer screen. The height of the computer was adjusted so that each participant was at eye-level with the upper one-third of the computer monitor. Prior to viewing the image displays, all participants completed a brief, automatic nine-point calibration. Participants were asked to look at the computer screen and track a yellow dot with their eyes while keeping their head as still as possible. After the calibration procedures were completed, participants were able to move their heads freely. Participants viewed the image displays while their eye movements were recorded using the LC Technologies EyeFollower, a remote, binocular infrared eye-tracking system that records eye movements at 120 Hz. Images were presented for 4000 ms, followed by a black screen with a fixation icon in the center, presented for 500 ms.

For the experimental task, participants were instructed to look at the images and listen to the words and that there are no correct or incorrect answers. Results of previous studies have demonstrated that no explicit instructions are required when using a multiple-choice image display and a corresponding verbal referent in eye-tracking protocols to index comprehension (Heuer & Hallowell, 2009; Henderson, Shinkareva, Wang, Luke, & Olejarczyk, 2013; Huettig & Altmann, 2011). Thus, when presented with a verbal stimulus and corresponding visual stimuli, participants tend to allocate greater proportions of total fixation time to the image that corresponds to the verbal stimulus.

The sequence of presentation of the competitor condition and the target condition was counterbalanced. Participants were presented with either the target or competitor condition before being presented with the other condition. The black-and-white line drawings and the color line drawings were randomized within each of the conditions.

Target condition

Participants looked at a computer screen and listened to a word presented through loudspeakers while their eye movements were recorded. The participants were shown ten multiple-choice displays in color and ten multiple-choice displays in black-and-white in random order. Each display was accompanied by a verbal stimulus corresponding to one image in the display. Image displays were presented for four seconds.

Competitor condition

During the competitor condition, participants received the same instructions. They were presented with twenty image displays, half in black-and white and half in color. The same verbal stimuli as during the target condition were presented. The color competitor image in these displays had the same diagnostic color as the verbal stimulus. For example, if the target image and corresponding verbal stimulus in the target condition were “carrot”, the carrot remained the verbal stimuli but a different line drawing was presented (pumpkin) in the competitor condition. Thus, an image “pumpkin” was presented with the verbal stimulus “carrot,” that shared the same diagnostic color.

Pointing version

All participants were asked to complete a pointing version with the 40 image displays. Participants were presented with the forty image displays (all displays from the target and color competitor condition) and a verbal stimulus that corresponded to one of the images in the multiple-choice display. Twenty verbal stimuli were repeated from the eye-tracking task (the target condition) and twenty new verbal stimuli were presented corresponding to an image that was present in the multiple-choice display of the color competitor condition. The participants were asked to point to the line drawing that corresponded to the verbal stimulus. The line drawings that were presented in black-and-white in the pointing task were also presented in black-and-white in the eye-tracking task, as were the colored versions.

The purpose of this task was twofold. First, for people with aphasia, identification of the target image verified that they understood the verbal stimulus. Eye-movement data for one particular image for each participant was included only if the participant identified the target image during the pointing version. Second, for language-normal adults, identification of the target images served as a validation procedure that the images in fact conveyed the content that was intended. Only image displays, for which all ten participants identified the target with 100% accuracy, were included as items in the final analyses.

ANALYSIS

NYAN 2 Professional Edition software (Joos & Weber, 2011) was used to present and extract the data. Fixations were defined as having relative stability within 1.4 degrees of visual angle, vertically and horizontally (LC Technologies, 2011) for a minimum duration 100 ms. (Manor & Gordon, 2003). Only fixations allocated to target images were included in the analysis.

A preliminary statistical power analysis was performed for an estimation of effect size based on data from a previous study (Heuer & Hallowell, 2015) (N= 40), using PFDT measures to index differences in performance of a visual search task between people with and without aphasia. To obtain an effect size d of 1.2, with an alpha = .05 and power = 0.95, (GPower 3.1.9.2; Faul, Erdfelder, Lang & Buchner, 2007), 12 participants are required per group. Thus, the originally targeted sample size of n = 20 might have been slightly too small. However, the actually collected sample of n=15 with five participants with aphasia and 10 control participants was most likely too small to detect statistical effects.

Due to the small and uneven sample size, nonparametric statistics were used to address hypothesis 1 and 2. To address hypothesis 1, a nonparametric Wilcoxon test was conducted to compare PFDT and FPGD allocated to target images in the color and black-and-white image displays. To address hypothesis 2, a Mann-Whitney U test was conducted to determine whether significant differences were indexed for the dependent measures PFDT and FPGDT between the two groups.

Hypothesis 3 and 4 were addressed with a pop-out statistic (Heuer & Hallowell, 2009). A parametric statistical analysis is inappropriate for the comparison of PFD of target and foils within a display because the observations between targets and foils are not independent. If one allocates greater PFD to one image in the display, it results automatically in lower PFD allocated to other images in the display. Thus a non-parametric statistical procedure to evaluate whether significantly greater PFD have been allocated to the targets as opposed to the foils within the image displays was conducted. A pop-out effect was defined as disproportionate allocation of fixation duration on one image within an image display. For each image display viewed by each participant, an average pop-out score (Hallowell & Kim, 2006) was calculated. The pop-out score lies between 0 and 1. A score with a value close to 0 indicates equally distributed eye fixation duration over all four images. A value close to 1 indicates a high degree of disproportionate allocation of fixations. The pop-out equation is as follows:

$$\text{Pop-out eye movement score} = \frac{\text{PFDT} - (1/\ \#\text{ of images})}{1 - (1/\#\text{images})}$$

In this equation, ‘‘# images’’ refers to the number of images within the display (four for all trials in the current study). Single sample t-test statistic were calculated to investigate whether eye movement pop-out scores were significantly different from 0 (representing a perfectly proportionate distribution of fixation durations) for hypothesis 3 and 4. A significant t-test was anticipated for the color image displays in hypothesis 3, while a nonsignificant t-test was anticipated for the black-and-white line drawing displays in hypothesis 4.

RESULTS

During the pointing task, all participants from the language-normal group and the group with aphasia correctly pointed to each picture corresponding to a verbal stimulus. Therefore, it was assumed that participants understood the verbal stimuli and recognized all target images correctly. No image displays were excluded from the subsequent eye-tracking data analysis. Preliminary analysis of the eye tracking data revealed that one trial did not include any data due to equipment failure. That trial was removed from the analysis. Zero of these trials occurred within the group of people with aphasia, and one trial occurred with the language-normal group. Inaccurate trials, meaning that the participant looked at the screen during a trial, but never fixated on the target image were also removed from the analysis. Surprisingly, this occurred only with the language-normal participants. Of the inaccurate trials, twenty four occurred for black-and-white images in the competitor condition, thirty six for color images in the competitor condition, five for black-and-white images in the target condition, and five for color images in the target condition. See Table 9 for a summary of excluded trials.

Table 9

Number of Excluded Trials

Condition and Image Type	Invalid Trials: People with aphasia (N = 4)	Invalid Trials: Controls (N = 10)	Inaccurate Trials: People with aphasia (N = 5)	Inaccurate Trials: Controls (N = 10)	Total: People with aphasia (N = 5)	Total: Controls (N = 10)
Competitor (20 trials)	0	1/200	0	60/200	0/80	61/200
B&W (10)	0	1/50	0	24/100	0/400	25/100
Color (10)	0	0	0	36/100	0/40	36/100
Target (20 trials)	0	0	0	10/200	0/80	10/200
B & W (10)	0	0	0	5/100	0/40	5/100
Color (10)	0	0	0	5/100	0/40	5/100
Total	0/160	1/400	0/160	70/400	0/160	71/400

Hypothesis 1

A Wilcoxon test was conducted to evaluate hypothesis 1, comparing the difference between FPGD and PFD allocated to color target images (Md = 1.52) and black-and-white target images (Md = 1.49). The test revealed a significant difference between FPGD allocated to color target images compared to the black-and-white images

(Z = -2.23, *p* =.026). The mean of the ranks in favor of the black-and-white images was 8.80, and the mean of the ranks in favor of the color images was 4.25. Thus, black-and-white target images received significantly greater FPGD compared to color target images. For PFDT, the test revealed no significant difference between color (Md = .76) and black-and-white target images (Md = .76) (Z = -.09, *p* = .925). The mean of the ranks in favor of the black-and-white images was 7.29, and the mean of the ranks in favor of the color images was 7.71.

Hypothesis 2

A Mann-Whitney U test was conducted to test hypothesis 2, that language-normal individuals would allocate greater FPGD and PFD to both the color and black-and-white target images than the people with aphasia. For FPGD the test revealed no significant differences between the groups for color images, *U* = 22, *p* = .77, nor for black-and-white images, *U* = 22, *p* = .77. The language-normal participants had a mean rank of 8.3 for color (Md = 1.67), while the participants with aphasia had a mean rank of 7.4 (Md = 1.21). For PFDT, the test also revealed no significant differences between the groups for color, *U* = -.86, *p* = .46, or for black-and-white, U= -.55, *p* = .66. The language-normal participants had an average rank of 7.0 for color (Md = .72), while the participants with aphasia had an average rank of 9.33 (Md = .78). The language-normal participants had an average rank of 7.18 for black-and-white images (Md = .70), while the participants with aphasia had an average rank of 8.67 (Md = .83).

For hypotheses 3 and 4, pop-out scores were computed for every image display in the competitor condition. A mean pop-out score was computed for color and for black-and-white displays. See Table 10 for mean and standard deviation of the mean pop-out scores.

Table 10

Means and Standard Deviations of Mean Pop Out Scores

Pop-out scores	Mean	Standard Deviation	***N***
Competitor color	.21	.27	15
Competitor B&W	.21	.27	15

Hypothesis 3

To evaluate hypothesis 3, whether color images in the color competitor condition were fixated for disproportionately greater amounts of time compared to distractor images within the displays a single sample t-test was conducted on the pop out score for color competitor images. The mean pop-out scores of the color competitor images was significantly different from zero, $t(13) = 2.90$, $p = .01$. The 95% confidence interval for the pop out score mean ranged from .05 to .36. Results indicated that color competitor images were fixated disproportionately longer than distractor images in the display.

Hypothesis 4

To evaluate hypothesis 4, whether black-and-white color competitor images were fixated for disproportionately greater amounts of time compared to distractor images within the displays a single sample t-test was conducted on the pop out score for black-and-white competitor images. The sample mean of .21 (SD = .27) was significantly different from 0, *t*(13) = 2.83, *p* =.01. The 95% confidence interval for the pop-out score mean ranged from .05 to .36.

Exploratory analyses

Two exploratory analyses were conducted. First, a paired-samples t-test was conducted to evaluate whether the mean pop out score for color images was statistically different from the black-and-white pop out scores. The results indicated that the mean score for color pop out scores (*M* = .21, *SD* = .27) was not statistically different from the mean black-and-white pop out scores (*M* = .21, *SD* = .27), *t*(13) = -.04, *p* = .97. The 95% confidence interval for the mean differences between the color and black-and-white pop out scores was -.18 to .18.

Second, in the color competitor condition, the color association between the color competitor image and the color of the object conveyed in the verbal stimulus were carefully controlled (e.g., carrot-pumpkin or cherry-tomato). However, the semantic relationship between image and verbal stimulus was not as stringently controlled, resulting in different degrees of semantic associations between images and verbal stimuli (e.g., cherry – tomato versus moon-lemon). A paired-samples t-test was conducted to compare the pop-out score of color competitor images that were semantically related to the verbal stimulus to those that were not. The goal of this analysis was to determine whether images that shared a semantic association with the verbal stimulus would have greater pop-out scores than semantically unrelated images. The test revealed a significant difference between the semantically related images (*M* = .18, *SD* = .16) compared to the unrelated images, (*M* = .06, *SD* = .09) $t(12) = -3.98$, $p = .002$) Please see Appendix B for the semantically related and unrelated pairs that were compared.

DISCUSSION

The purpose of the study was to determine whether color would facilitate image recognition for people with and without aphasia in multiple-choice image displays, and, whether people would fixate on color competitor images longer than other images in the display when the images were presented in color. Results did not confirm the hypotheses.

The first hypothesis, that participants would allocate greater PFD and FPGD to the color images compared to the black-and-white images, was not confirmed. This results was surprising, given the large amount of evidence that color facilitates image recognition in traditional studies (Bramáo, Inácio, Faísca, Reis & Petersson, 2010; Rossion & Pourtois, 2004; Therriault, Yaxley & Zwaan, 2009, Uttl, Graf & Santacruz, 2006) and eye tracking studies (Huettig & Altmann, 2004, 2005, 2011). The Wilcoxon test revealed no significant differences between color and black-and-white images for PFD, and a significant difference indicating significantly greater FPGD for black-and-white images compared to color images, which was opposite to the hypothesized result. One possible reason for these results is that no specific instructions were given to the participants telling them to direct their attention to the line drawing that matched the verbal stimulus. Potentially, participants just scanned the image displays. The preliminary data analyses revealed that language-normal adults did not fixate on the target image in 5 individual trials when hearing the corresponding verbal stimulus, suggesting that they might not always have paid attention to the verbal stimulus. However, this result is in contrast to a large body of eye-tracking literature, reporting that people will fixate on an image that corresponds to a verbal stimulus regardless of the nature of instruction

(Cooper, 1974; Hallowell, 1999, 2012; Hallowell et al., 2002; Heuer & Hallowell, 2009, Henderson, Shinkareva, Wang, Luke, & Olejarczyk, 2013; Huettig & Altmann, 2004; 2011). Most likely, the sample size of fifteen participants was too small to replicate the results of previous studies. For comparison, Huettig and Altman's (2011) sample included sixty participants and Heuer and Hallowell (2009) included forty participants.

The fact that FPGD was significantly longer for black-and-white images compared to color target images might indicate a difference in ease of visual information processing. Longer FPGD was hypothesized based on evidence from eye-tracking studies that used the measure in semantic priming (Odekar et al., 2009) and viewing complex visual scenes (Henderson & Hollingworth, 1998) with language-normal adults. Longer FPGD were associated with images that were semantically related to a prime (Odekar et al., 2009) and with informative objects (e.g, humans) in visual scenes (Henderson & Hollingworth, 1998). However, Heuer & Pinke (2015) observed longer FPGD for more complex compared to simple attention switching tasks in language-normal adults. Alternatively, longer FPGD might indicate a greater information processing effort for black-and-white compared to colored line drawings, which would support the hypothesis. However, limited evidence on the sensitivity of FPGD to index differences in cognitive processing effort exists to date, to support such an interpretation.

The second hypothesis, that language-normal individuals would allocate greater PFD and FPGD to target images in both conditions when compared to individuals with aphasia, was not confirmed. No significant difference was observed between the language-normal group and the group of people with aphasia for PFD and FPGD allocated to color and the black-and-white target images. It is possible that the present study failed to detect significant differences between the two groups due to uneven and small participant groups. With a larger n it is more likely to detect differences in fixation allocation between people with and without aphasia.

The third hypothesis, that within the color image displays, participants would allocate significantly greater PFD to color competitor images than to the other images in the displays was confirmed. Participants allocated disproportionately greater fixation duration to the color competitor images than the other unrelated images in the display. This finding appears to be in line with Huettig and Altmann (2004), who found that participants fixated on the color competitor image significantly more frequently than any other images in the display, meaning that color influenced language-mediated eye movements with colored line drawings.

However, the fourth hypothesis that within the black-and-white color competitor image displays, participants would allocate PFD equally between target and foil images was not confirmed, as indexed by a significant one-sample t-test. These findings did not coincide with the findings by Huettig & Altmann in 2011, where no difference in distribution fixation allocation between target and foil images during the black-and-white condition was observed. In fact, when the black-and-white and color pop-out scores were compared, no significant difference between the two was observed. Interpretation of this result is challenging. On one hand, a disproportionate allocation of fixation duration to the color competitor images was observed when colored line drawings were displayed but black-and-white color competitor images received the same amount of disproportionate visual attention. The question is what made people allocate disproportionate attention to the color competitor images if color was not the cause? The exploratory analysis of the presence and absence of a semantic association between the color competitor images and the corresponding verbal stimuli suggested that color competitor images that shared a semantic association with the verbal stimulus were fixated longer than those images that only shared the conceptual color with the verbal stimulus. There is evidence in the eye-tracking literature that people will fixate on images that are semantically related to a verbal stimulus (Huettig & Altmann, 2005; Odekar et al., 2009; Yee & Sedivy, 2006; Yee, Blumstein, & Sedivy, 2008). Thus, it is possible that the semantic relationship between image and verbal stimulus influenced allocation of eye fixation stronger than the shared color between image and verbal stimulus.

Possible reasons why results of this study were in contrast to previous studies that explored the role of image characteristics on image recognition might be related to differences in measures selected in previous and the current study. FPGD reflects the fixation duration time from first entering to first exiting the target image. Similarly, PFD is a measure of fixation duration but reflects the proportion of fixation duration allocated to the target images compared to foil images in the displays. In previous studies, response latency measures were often reported (the time elapsed *until* a response was elicited rather than the actual processing duration). Thus, there might be a qualitative difference in the responses captured between response duration measures and response latency measures. In future studies, a corresponding eye movement latency response measure. Such as the Latency until First Fixation, should be considered as dependent measure.

A possible reason why no differences were observed between the group of language-normal participants and the group of participants with aphasia could be due to the observed severity levels of aphasia, as determined by the WAB. Three of four participants with aphasia presented with mild aphasia, while the remaining participant exhibited severe aphasia. Because the majority of the participants had mild aphasia their performance on the eye-tracking tasks might have been similar to that of language-normal control participants. Possibly, a greater discrepancy would have been observed with more participants with more severe aphasia.

Limitations and future studies

This study had several limitations. The lack of control of semantic association between competitor images and verbal stimulus was one of them. While word length and frequency were controlled in this study, semantic association was not well controlled. The finding associated with that lack of control highlights the need to carefully control semantic association in future studies of physical stimulus control and gives rise to research question to be addressed in a future study: If semantic association affects allocation of visual attention, would people with more severe comprehension deficits be more susceptible to color or semantic association compared to people with milder comprehension deficits?   Further, would people with more severe aphasia perform differently than language-normal control participants on the eye tracking target and competitor condition? Possible participants with mild aphasia exhibit much different results than participants with moderate or severe aphasia..

The instructions that were provided were purposefully nonspecific in order to obtain results based on spontaneous eye movements. While there is evidence that specific instructions are not required, especially for task such as presented in the target condition, potentially, more specific instructions might have encouraged participants more to listen to the words and allocate fixations to the target images. The color competitor condition is an especially unusual task. Participants are presented with images and a verbal stimulus that does not appear to relate to an image in the display. Thus in future studies more careful consideration will be paid to the wording of the instructions.

Finally, the sample size of people with aphasia and control participants was too small to draw meaningful conclusions. Initially, the goal was to recruit ten participants with aphasia and ten language-normal participants. For our recruitment process, we contacted Milwaukee-area hospitals and clinics that offered aphasia and stroke support groups, along with outpatient rehabilitation speech and language pathologists. We distributed flyers to the Speech and Language clinic at Marquette University as well as the UWM clinic. We visited support groups at Froedtert Hospital, St. Luke's Hospital, and Aurora West Allis Hospital to speak about our research study and to distribute flyers. We talked to outpatient speech-language pathologist and asked them kindly to share flyers with clients. Finally, we contacted Milwaukee skilled nursing home facilities with rehab units in order to recruit participants. Possibly, the flyers were not designed carefully enough and contained too much written information. This could be problematic because people with aphasia often have reading difficulties. Maybe we were not able to fully explain the purpose of our research study. It is possible that people with aphasia did not see how this study would contribute with assessment tools in the future, and the study was not perceived as meaningful. Very likely, the journey to UW-Milwaukee was too long or too difficult for certain participants. The hospitals where we recruited were not located near the UWM area. Participants might have had concerns about driving to an unfamiliar place, maneuvering parking, or not having transportation available to them. Although we did not recruit as many participants as we would have liked, we were able to nurture relationships with the participants that we did recruit, and we were able to build connections with local speech-language pathologists who may be able to help with recruitment in future studies. Suggestions for future recruitment include to reconsider the flyer design and to reach out to local neurologists in hopes that they may be able to help in the recruitment process. An additional suggestion is to offer to complete data collection at locations that are more accessible and easier to travel to than the UWM campus. One way to possibly increase participation in the study is to set up the eye-tracking equipment in locations that are more centrally located to the participants (such as at local libraries), or to offer to go to the participant's home to collect data.

Continuation of this research with a larger number of participants is needed to confirm or revise results. It is unlikely that participants with and without aphasia perform without significant differences on a task that relies on comprehension of the verbal stimulus. However, based on the preliminary results the following conclusions are drawn: Color did not facilitate image recognition in people with or without aphasia. No significant differences in eye fixation duration patterns were observed. Similarly, while participants fixated on the color competitor images disproportionately longer compared to foil images, semantic association, - not color - appeared to have a greater influence on allocation of fixation duration to the color competitor images.

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APPENDIX A

UNIVERSITY OF WISCONSIN – MILWAUKEE
CONSENT TO PARTICIPATE IN RESEARCH
CONSENT FOR PARTICIPANTS WITH APHASIA

THIS CONSENT FORM HAS BEEN APPROVED BY THE IRB FOR A ONE YEAR PERIOD]

1. General Information

Study title:
Improving the validity of cognitive-linguistic assessments for people with aphasia using eye-tracking methods

Person in Charge of Study (Principal Investigator):

- Kristin Zenz, Graduate student, Department of Communication Sciences and Disorders
- Sabine Heuer, Ph.D., Assistant Professor, Aphasia Lab director, Department of Communication Sciences and Disorders

2. Study Description

You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to.

Study description:
This study explores cognitive processes using traditional methods and eye-tracking methods. You will also be asked to complete a brief vision and hearing screening. You will be asked some questions about your health history. Then you will be asked to complete a language test, test that evaluates attention, and experimental tasks using eye tracking. You will see pictures on a computer screen and you will hear words. During the eye-tracking tasks your eye movements will be recorded. The study will take approximately 90 minutes.

3. Study Procedures

What will I be asked to do if I participate in the study?
If you agree to participate you will be asked to

- Complete a hearing screening to ensure that you can hear all words clearly. You will not be excluded from the study based upon your hearing screening results.
- Complete a vision screening to ensure that you will see all images clearly. You will be excluded from the study if you do not pass the vision screening
- Complete a language test to assess how well you speak and comprehend language. You will not be excluded from the study based upon these results

- **Calibration of eye-tracking device:**
  - Your eye movements will be recorded. Before the experiment takes place, we need to calibrate the device. This will allow us to monitor your eye movements. You will sit in front of a computer screen. You will be asked to look at the computer screen and follow a blinking yellow dot with your eyes. This procedure takes less than a minute. We will ask you to hold your head still during calibration. Afterward, you may move your head freely.
- **Experimental tasks:**
  - You will be asked to look at images and listen to words while we record your eye movements.
  - For the traditional attention test you will be asked to connect numbers and letters in a specific sequence as quickly as possible. The Comprehensive Trail Making Test includes five different trials.
  - You will be asked to listen to words and point to images on a computer screen.
- No audio/video/photographic recordings will be performed.

4. Risks and Minimizing Risks

What risks will I face by participating in this study?
There are no foreseeable risks for participating in this research study.

5. Benefits

Will I receive any benefit from my participation in this study?

You will receive free vision and hearing screenings. Your participation in the study provides support for the development of assessment for use with people with aphasia.

6. Study Costs and Compensation

Will I be charged anything for participating in this study?
You will not be responsible for any of the costs from taking part in this research study.

Are subjects paid or given anything for being in the study?
Each participant will receive $ 30 for completing the study. If a participant chooses to discontinue participation in study early, payment amount will be prorated depending upon the proportion of time actually spent engaged in the experiment. Participants will receive compensation after his or her participation in the experiment.

7. Confidentiality

What happens to the information collected?
Records obtained during the screening procedure and the standardized test record forms will be kept confidential and locked in filing cabinets within the secure UWM Aphasia Laboratory. No identifying information will be stored with the records. Only Principle Investigators and immediate study personnel will have access to raw data.

The payment forms, which will have your name on it, will be stored separately in a lockable filing cabinet. The payment form will not include your experiment ID number. Only Principle investigators will have access to the payment forms. They will be destroyed when the study is completed.

Only Principle Investigators and immediate study personnel will have access to raw data. Data will be stored and locked in the Aphasia laboratory at UWM at all times. However, the Department of Communication Sciences and Disorders and the Institutional Review Board at UW-Milwaukee, or appropriate federal agencies like the Office of Human Research Protections may review this study's records.

8. Alternatives

Are there alternatives to participating in the study?
There are no known alternatives available to you other than not taking part in this study.

9. Voluntary Participation and Withdrawal

What happens if I decide not to be in this study?
Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions or withdraw at any time. Your decision will not change any present or future relationships with the University of Wisconsin Milwaukee.

In the event that you are not eligible for participation, you will be excluded from the study and the screening data collected to this point will be destroyed. You will, however, be paid with the amount prorated according to the proportion of the study you have completed. The study is estimated to take 90 minutes; therefore, if you participated for 15 minutes, your prorated payment would be $5.00.

10. Questions

Who do I contact for questions about this study?
For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:

Sabine Heuer
Department of Communication Sciences and Disorders
Enderis Hall 859
P.O. Box 413
Milwaukee, WI 53201
(414) 229-0537

Who do I contact for questions about my rights or complaints towards my treatment as a research subject?
The Institutional Review Board may ask your name, but all complaints are kept in confidence.

Institutional Review Board
Human Research Protection Program
Department of University Safety and Assurances
University of Wisconsin – Milwaukee
P.O. Box 413
Milwaukee, WI 53201

(414) 229-3173

11. Signatures

Research Subject's Consent to Participate in Research:
To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.

____
Printed Name of Subject/ Legally Authorized Representative

____ ____________________
Signature of Subject/Legally Authorized Representative Date

Principal Investigator (or Designee)
I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.

____ ____________________
Printed Name of Person Obtaining Consent Study Role

____ ____________________
Signature of Person Obtaining Consent Date

UNIVERSITY OF WISCONSIN – MILWAUKEE
CONSENT TO PARTICIPATE IN RESEARCH
CONSENT FOR PARTICIPANTS WITHOUT APHASIA

THIS CONSENT FORM HAS BEEN APPROVED BY THE IRB FOR A ONE YEAR PERIOD]

1. General Information

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Study description:
You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to.

Study description:
This study explores cognitive processes using traditional methods and eye-tracking methods. You will also be asked to complete a brief vision and hearing screening. You will be asked some questions about your health history. Then you will be asked to complete 1) traditional test of attention and 2) experimental tasks using eye tracking. You will see pictures and you will hear words. During the eye-tracking tasks your eye movements will be recorded The study will take approximately 45-60 minutes.

3. Study Procedures

What will I be asked to do if I participate in the study?
If you agree to participate you will be asked to

- Complete a hearing screening to ensure that you can hear all words clearly. <u>You will not be excluded from the study based upon your hearing screening results.</u>
- Complete a vision screening to ensure that you will see all images clearly. <u>You will be excluded from the study if you do not pass the vision screening.</u>
- Complete a cognitive screening. <u>If you do not pass the cognitive screening, you will be excluded from the study.</u>

- **Calibration of eye-tracking device:**
    - Your eye movements will be recorded. Before the experiment takes place, we need to calibrate the device. This will allow us to monitor your eye movements. You will sit in front of a computer screen. You will be asked to look at the computer screen and follow a blinking yellow dot with your eyes. This procedure takes less than a minute. We will ask you to hold your head still during calibration. Afterward, you may move your head freely.
- **Experimental tasks:**
    - You will be asked to look at images and listen to words while we record your eye movements.
    - For the traditional attention test you will be asked to connect numbers and letters in a specific sequence as quickly as possible. The Comprehensive Trail Making Test includes five different trials.
    - You will be asked to listen to words and point to images on a computer screen.
- No audio/video/photographic recordings will be performed.

4. Risks and Minimizing Risks

What risks will I face by participating in this study?

- There are no foreseeable risks for participating in this research study.

5. Benefits

Will I receive any benefit from my participation in this study?
You will receive free vision and hearing screenings. Your participation in the study provides support for the development of assessment for use with people with aphasia.

6. Study Costs and Compensation

Will I be charged anything for participating in this study?
You will not be responsible for any of the costs from taking part in this research study.

Are subjects paid or given anything for being in the study?
Each participant will receive $ 15 for completing the study. If a participant chooses to discontinue participation in study early, payment amount will be prorated depending upon the proportion of time actually spent engaged in the experiment. Participants will receive compensation after his or her participation in the experiment.

7. Confidentiality

What happens to the information collected?
Records obtained during the screening procedure and the standardized test record forms will be kept confidential and locked in filing cabinets within the secure UWM Aphasia Laboratory. No identifying information will be stored with the records. Only Principle Investigators and immediate study personnel will have access to raw data.

The payment forms, which will have your name on it, will be stored separately in a lockable filing cabinet. The payment form will not include your experiment ID number. Only Principle investigators will have access to the payment forms. They will be destroyed when the study is completed.

Only Principle Investigators and immediate study personnel will have access to raw data. Data will be stored and locked in the Aphasia laboratory at UWM at all times. However, the Department of Communication Sciences and Disorders and the Institutional Review Board at UW-Milwaukee, or appropriate federal agencies like the Office of Human Research Protections may review this study's records.

8. Alternatives

Are there alternatives to participating in the study?
There are no alternatives available to you other than not taking part in this study.

9. Voluntary Participation and Withdrawal

What happens if I decide not to be in this study?
Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions or withdraw at any time. Your decision will not change any present or future relationships with the University of Wisconsin Milwaukee.

In the event that you are not eligible for participation, you will be excluded from the study and the screening data collected to this point will be destroyed. You will, however, be paid with the amount prorated according to the proportion of the study you have completed. The study is estimated to take 60 minutes, therefore, if you participated for 15 minutes, your prorated payment would be $3.75 .

10. Questions

Who do I contact for questions about this study?
For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:

Sabine Heuer
Department of Communication Sciences and Disorders
Enderis Hall 859
P.O. Box 413
Milwaukee, WI 53201
(414) 229-0537

Who do I contact for questions about my rights or complaints towards my treatment as a research subject?
The Institutional Review Board may ask your name, but all complaints are kept in confidence.

Institutional Review Board
Human Research Protection Program
Department of University Safety and Assurances
University of Wisconsin – Milwaukee
P.O. Box 413
Milwaukee, WI 53201
(414) 229-3173

11. Signatures

Research Subject's Consent to Participate in Research:

To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.

____
Printed Name of Subject/ Legally Authorized Representative

____ ____________________
Signature of Subject/Legally Authorized Representative Date

Principal Investigator (or Designee)
I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.

____ ____________________
Printed Name of Person Obtaining Consent Study Role

____ ____________________
Signature of Person Obtaining Consent Date

APPENDIX B

*Indicates the competitor stimulus
Pointing version: competitors

1.

Snowman*	Broom
Knife	Bell

2.

Guitar	Hat
Barn*	Jacket

3.

Horn	Well
Needle*	Ant

4.

Frog*	Pliers
Box	Wine glass

5.

Oven	Grapes
Asparagus	**Kangaroo***

6.

Rocking chair	Scissors
Lobster*	Belt

7.

Ball	Table
Caterpillar	**Anchor***

8.

Apple	Boot
Hammer	**Sheep***

9.

Donkey*	Bow
Paintbrush	Bread

10.

Clock	**Screw***
Button	Sun

11.

Zebra	Motorcycle
Cigar*	Rhino

12.

Pumpkin*	Harp
Working glove	Chair

13.

Bear	**Thimble***
Cow	Lips

14.

Chain	**Lettuce***
Sock	Candle

15.

Ax	**Lemon***
Saw	Gun

16.

Artichoke*	Iron
Dress	Beetle

17.

Spin wheel	Sweater
Arm	**Grasshopper***

18.

Purse	Dog
Tomato*	Butterfly

19.

Cloud	Whistle
Lamp	**Camel***

20.

Skunk	**Banana***
Bowl	Sled

*Indicates the target stimulus
Pointing version: Targets

1.

Swing	Wrench
Bottle	**Cherry***

2.

Foot	Pen
Alligator*	Onion

3.

Screwdriver	Vase
Record player	**Potato***

4.

Toaster	**Barrel***
Helicopter	Refrigerator

5.

Eagle	**Spoon***
Pig	Pineapple

6.

Dresser	**Celery***
Teacup	Bee

7.

Pear*	Frying pan
Kite	Necklace

8.

Tea kettle	Hanger
Accordion	**Star***

9.

Bat	Tie
Cake	**Swan***

10.

Desk	Horse
Fork*	Couch

11.

Stool	**Turtle***
Glasses	Balloon

12.

Heart*	Mushroom
Penguin	Salt

13.

Flag	**Moon***
Leg	Crown

14.

Strawberry*	Arrow
Bird	Church

15.

Ladder	Mitten
Nail*	Helmet

16.

Corn*	Doorknob
Book	car

17.

Football	**Key***
Spider	Leaf

18.

Deer*	Boat
Watermelon	Pants

19.

Wheel	Tree
Peanut	**Elephant***

20.

Lock	Seal
Carrot*	Nose

APPENDIX C

Pair	Target	Competitor	Verbal Stimuli	Conceptual Color	Condition	Color Diagnosticity	FSG	Log Frequency	Syllables	Letters
1	Strawberry*		Strawberry	Red	BW	4.64	0.1	0.78	3	10
		Lobster*	Strawberry	Red	BW	4.73	.08	.48	2	7
2	Carrot		Carrot	Orange	BW	5	.18	0.9	2	6
		Pumpkin	Carrot	Orange	BW	4.91	0.16	0.3	2	6
3	Nail		Nail	Silver	BW	4.46	n/a	1.4	1	4
		Screw	Nail	Silver	BW	4.46	n/a	1	1	5
4	Pear		Pear	Green	BW	4.18	.34	.78	1	4
		Lettuce	Pear	Green	BW	4.64	.06	.85	2	7
5	Key		Key	Silver	BW	4.27	n/a	1.93	1	3
		Anchor	Key	Silver	BW	4.46	n/a	.78	2	6
6	Star*		Star	Yellow	BW	4.18	n/a	2	1	4
		Lemon*	Star	Yellow	BW	4.55	.04	1.18	2	5
7	Heart*		Heart	Red	BW	5	n/a	2.21	1	5
		Barn*	Heart	Red	BW	4.09	.31	1.11	1	4
8	Cherry		Cherry	Red	BW	4.73	.21	.85	2	6
		Tomato	Cherry	Red	BW	4.64	.19	1.15	3	6

9	Moon*		Moon	White	BW	4.64	.024	1.77	1	4
		Sheep*	Moon	White	BW	4.09	.14	1.6	1	5
10	Turtle		Turtle	Green	BW	4.09	.03	.6	2	6
		Frog	Turtle	Green	BW	4.09	.07	.95	1	6
11	Celery		Celery	Green	Color	4.82	.06	.48	2	6
		Artichoke	Celery	Green	Color	4.82	n/a	.3	3	9
12	Potato*		Potato	Brown	Color	4.55	n/a	1.56	3	6
		Kangaroo*	Potato	Brown	Color	4.73	n/a	.48	3	8
13	Deer		Deer	Brown	Color	4.73	n/a	1.08	1	4
		Camel	Deer	Brown	Color	4.55	n/a	1.4	2	5
14	Spoon		Spoon	Silver	Color	4	.24	1.18	1	5
		Thimble	Spoon	Silver	Color	4	n/a	0	2	7
15	Elephant		Elephant	Gray	Color	4.73	.48	1.38	3	8
		Donkey	Elephant	Gray	Color	4.46	n/a	1.15	2	6
16	Alligator		Alligator	Green	Color	4.55	.16	.3	4	9
		Grasshopper	Alligator	Green	Color	4.46	.24	.48	3	11
17	Corn		Corn	Yellow	Color	4.91	.06	1.38	1	4
		Banana	Corn	Yellow	Color	4.82	.14	.9	3	6

18	Barrel*		Barrel	Brown	Color	4.36	n/a	1.32	2	6
		Cigar*	Barrel	Brown	Color	4.91	n/a	1.26	2	5
19	Swan*		Swan	White	Color	4.82	.86	.85	1	4
		Snowman*	Swan	White	Color	4.82	n/a	0	2	7
20	Fork		Fork	Silver	Color	4.09	n/a	1.18	1	4
		Needle	Fork	Silver	Color	4.09	n/a	1.2	2	6

Note: *Indicates a semantically unrelated word pair