USING OBJECT COLOR DIAGNOSTICITY TO INFLUENCE ACCESS TO SEMANTIC INFORMATION IN A BOUNDARY EXTENSION PARADIGM

by

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(Under the Direction of James M. Brown)

ABSTRACT

Individuals consistently remember seeing wider-angle versions of previously viewed scenes than actually existed. The multi-source model of boundary extension (BE) suggests many sources of information contribute to this visual memory error. Color diagnosticity is known to affect object recognition with poorer recognition for atypically vs. typically colored objects. If atypically colored objects lead to poorer recognition then, according to the multi-source model, a less precise initial encoding should lead to greater BE. Low color diagnostic stimuli and two versions of high color diagnostic scenes were tested (i.e., typically and atypically colored). Scenes were presented for 46 or 250 ms followed by a mask, and then immediately presented again for test. Observers first identified the central object, then gave a BE rating. Our findings suggest reduced availability of semantic information leads to increased boundary extension. This provides further insight into the role of object recognition and semantic information on boundary extension.

INDEX WORDS: Boundary extension, color diagnosticity

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CHAPTER 1

INTRODUCTION

The speed by which someone can recognize an object or scene can be aided or impeded depending on the method of presentation. There are many scenarios that could affect recognition performance and ability. For instance, simply rotating an image of a human face 180° can drastically decrease recognition ability (Van Belle, Graef, Verfaillie, Rossion, & Lefevre, 2010). One way to aid object recognition is to use high color diagnostic (HCD) images that are typically colored (Tanaka & Presnell, 1999). Color diagnosticity is the level to which an object or scene is identified by its constituent colors (Tanaka, Weiskopf, & Williams, 2001). HCD objects or scenes contain colors with which they are commonly associated. For example, all drivers should know brake lights, stop lights, and stop signs are red. When a driver perceives the color red ahead of them, they are likely to slow down and prepare to stop. This realization could occur moments before he or she precisely realizes the identity of the perceived "red" in his or her field of view. Another example of HCD objects can be imagined in the context of shopping for fruit at the grocery store. Bananas can be found with ease by doing a quick visual scan of the produce section searching for the canonical bright yellow hue commonly associated with them. Interestingly, many fruits and vegetables are HCD suggesting perhaps that color diagnosticity was enormously advantageous in hominid evolution.

The "color advantage" seen in these examples can become a "color disadvantage" if atypically colored versions of these HCD images are used. In other words, replacing the canonical colors for a particular HCD object or scene with unlikely or incorrect colors (e.g., a purple banana) can actually impede or reduce the speed of recognition (Nagai & Yokosawa, 2003; Tanaka & Presnell, 1999). Using the previous HCD real world examples, a stop sign that has faded to silver and a banana that is green (under ripe) or brown (over ripe) could initially cause a slight “color disadvantage” due to the discrepancy between color expectation and reality. This conflict would soon be resolved by a combination of top-down and bottom-up processes allowing object recognition to occur despite the unusual coloration. If altering the canonical colors of HCD objects or scenes can temporarily inhibit or interfere with recognition abilities, then typically colored versions should be more quickly recognized than atypically colored versions. The literature tends to support this (e.g., Bramao, Faisca, Petersson, & Reis, 2010).

Manipulating semantic access

This difference in ability to recognize objects due to color diagnosticity is a potentially useful tool in studying boundary extension. Boundary extension is an error of commission in which observers confidently remember more information from a scene than was present in the studied view (Intraub & Richardson, 1989). Intraub’s (Intraub, 2010, 2012) multisource model of scene perception suggests boundary extension arises due to a combination of information from such sources as the visual input, semantic information, amodal perception at the view boundaries (Hale, Brown, McDunn, & Siddiqui, 2014), and associations between the main objects and depicted scene location (McDunn, Siddiqui, & Brown, 2014). Recent research indicates semantic information may not be necessary for boundary extension to occur. For example, boundary extension is still present when semantic information is reduced by using “scenes” of monochromatic abstract shapes on random dot backgrounds (Hale et al., 2014; Siddiqui, McDunn, & Brown, 2012).

Another way to manipulate the availability of semantic information is to present a scene in which the observer is restricted from easily recognizing this scene or its constituent objects (i.e., the observer has limited access to the semantic information within the scene). One way this can be achieved is by presenting scenes for a short duration with atypically colored HCD objects. Scenes containing typically rather than atypically colored HCD objects are identified more quickly suggesting semantic information is available sooner and more readily in these (Bramao et al., 2010). Low color diagnostic (LCD) objects should not differ significantly in recognition ability from typically colored HCD objects because no advantage or disadvantage of color related to these objects exists (Nagai & Yokosawa, 2003). We constructed a boundary extension paradigm implementing this method of semantic access restriction.

Pilot experiments

To select our stimuli we trained a group of participants to be able to categorize objects based on color diagnosticity by giving precise definitions of color diagnosticity, providing an example of a HCD (i.e., a Smurf) and a LCD (i.e., a balloon) object not from the potential stimulus set, and answering any questions. The participants ranked objects for color diagnosticity on a Likert scale from 0-10 where 0 was very LCD and 10 was very HCD. Objects with an average ranking of 0-2 or 8-10 defined our LCD and HCD stimuli objects, respectively. Any object that did not fall into one of these ranges was excluded from the study.

To ensure our stimuli would impact recognition ability as expected, another pilot experiment was conducted in which a group of participants were shown a series of scenes for 46 ms each followed by a colored noise mask and then an identification response. Each stimulus contained a central object that was typically colored HCD, atypically colored HCD, or LCD. As expected, identification ability of atypically colored HCD objects was inferior to typically colored HCD objects (*t* (14) = 3.212, p < .01) and LCD objects (*t* (14) = -2.934, p < .05; see Figure 1).

The current study

From the perspective of Intraub's multi-source model, a less precise initial encoding should lead to greater boundary extension (Courtney & Hubbard, 2004; Intraub, Daniels, Horowitz, & Wolfe, 2008). Therefore boundary extension should be greater in this study when semantic access is restricted using atypically colored HCD objects verses typically colored HCD or LCD objects. A recognition deficit should exist for atypically colored HCD objects displayed for a brief duration (e.g., 46 ms). At a longer stimulus duration however (e.g., 250 ms), semantic information should be equally available across the three types of colored scenes leading to consistent (i.e., not statistically different) identification performance and boundary extension ratings.

CHAPTER 2

EXPERIMENT

Method

Subjects. Participants were 70 undergraduate students from the University of Georgia research pool (43 female; 27 male). All participants had normal or corrected-to-normal vision, normal color vision (verified by pseudoisochromatic plates), no history of an attention deficit disorder, no history of epilepsy, and a dominant right hand (i.e., “right-handed”). Participants were also either at least 18 years old at the time of the experiment or had signed consent from their parent or guardian. All research was conducted in accordance with the Declaration of Helsinki and under the approval of University of Georgia Institutional Review Board (IRB) ethical guidelines for research involving human participants. Participants received partial course credit as compensation for their participation in this study.

Stimuli. The experiment stimulus set consists of 20 images with HCD central objects (i.e., half typically colored and half atypically colored) and 10 images with LCD central objects. To create atypically colored objects, typically colored objects were modified in Adobe Photoshop CS6 by adjusting hue and color balance (see Figure 2).[1] Two color noise masks were created using Paint, each consisting of overlapping blocks filled with one of twelve solid colors.[2] All stimuli have an 800 x 600 pixel resolution that encompasses the entire screen. Images were presented on a monitor operating at an 85 Hz refresh rate using E-Prime v2 software. Participants viewed the monitor from 181.4 cm with overhead lights on. Responses were recorded using the computer keyboard. A chin rest was used to ensure participants focused centrally on the screen during each trial.

Procedure. Participants were read the instructions by the experimenter. The instructions were also displayed on the computer monitor. Participants were given one practice trial followed by 30 experimental trials. Experimental trials were presented randomly between the three viewing conditions (i.e., typically colored HCD, atypically colored HCD, and LCD). Each trial consisted of 7 parts: (1) a fixation stimulus displayed until the participant began the trial by pressing the spacebar, (2) a test stimulus displayed for either 46ms or 250ms depending on condition, (3) two color noise masks displayed for 100 ms each, (4) an object identification response prompt for this stimulus which was entered using the keyboard, (5) a confidence rating in the participant's identification response, (6) the same test stimulus with a boundary extension rating response prompt, and (7) a confidence response prompt for this boundary extension rating (see Figure 3). The boundary extension rating was given on a 5-point Likert scale indicating whether the test stimulus appeared much closer (1) or much farther away (5) than the previous image. A response of 3 indicates the image at test appeared identical to the image seen at study. Boundary extension ratings were later adjusted from a range of 1 to 5 to a range of -2 to +2 for the purposes of analysis. Both confidence level ratings were given on a 4-point Likert scale ranging from sure (1) to not sure (3) in which a response of 4 indicated no memory of the study image for that trial. Trials in which a confidence rating of 4 was given for the participant's boundary extension rating were removed from the analyses.

Results

A 3 (Color Diagnosticity) x 2 (Duration) repeated measures ANOVA was calculated to look for main effects across conditions in object identification ability. Similarly, a repeated measures ANOVA was calculated to compare boundary extension ratings across conditions. Planned comparison *t*-tests were calculated to determine if atypically colored HCD objects at 46 ms differed from the other viewing conditions at that stimulus duration. The same *t*-tests were also calculated for the longer stimulus duration. Additionally, planned comparison *t*-tests were calculated to determine if boundary extension ratings significantly differed from zero (i.e., boundary extension is present if rating is significantly less than zero).

Results were consistent with the pilot data for object recognition at 46 ms. Participants accurately recognized fewer atypically colored HCD objects than typically colored HCD objects, *t* (34) = 2.680, p < .05 and LCD objects, *t* (34) = -2.973, p < .05 (see Figure 4). However, there was not a statistical difference between viewing conditions at 250 ms with atypically colored HCD objects being identified equally as well as typically colored HCD objects, *t* (34) = 1.368, p > .05 and LCD objects, *t* (34) = -1.696, p > .05 (see Figure 5).

In all three viewing conditions for short and long stimulus durations, boundary extension values were significantly less than zero (atypically colored HCD at 46 ms, *t* (34) = -9.865, p > .05; typically colored HCD at 46 ms, *t* (34) = -5.551, p > .05; LCD at 46 ms, t (34) = -5.022, p > .05; atypically colored HCD at 250 ms, t (34) = -6.275, p > .05; typically colored at 250 ms, t (34) = -5.662, p > .05; LCD at 250 ms, t (34) = -6.735, p > .05) suggesting that boundary extension was present in every condition.

For the 46 ms stimulus duration, there was increased boundary extension for atypically colored HCD objects compared to typically colored HCD objects, *t* (34) = 2.621, p < .05 and

LCD objects, *t* (34) = -3.547, $p < .05$ (see Figure 6). At 250 ms, atypically colored HCD objects demonstrated equal levels of boundary extension as typically colored HCD objects, *t* (34) = 0.231, $p > .05$ and LCD objects, *t* (34) = -0.790, $p > .05$ (see Figure 7).

As expected, there were no main effects of Color Diagnosticity or Duration for either of the repeated measures ANOVAs (i.e., identification or boundary extension). The only expected statistical difference in identification ability or boundary extension was for atypically colored HCD objects at the 46 ms duration when compared to the other viewing conditions at that duration.

CHAPTER 3

GENERAL DISCUSSION

Boundary extension occurs because individuals consistently recall seeing more information than was actually present in the original exposure (i.e., an error of commission; Intraub & Richardson, 1989). This visual error can be more or less severe depending on the circumstance. In the instance of a degraded mental representation perhaps due to a poor initial encoding, accurate information is sparsely available leading to greater reliance on extrapolation. As data from this experiment suggests, this is one circumstance that can lead to greater boundary extension.

In this experiment, participants could correctly identify typically colored HCD objects at a higher accuracy than atypically colored versions at the short (i.e., 46 ms) viewing duration. LCD objects did not differ significantly in recognition ability from typically colored HCD objects at this duration. The color information in the atypically colored stimuli likely interfered with the availability of semantic information enough to significantly affect recognition ability.

This reduction in semantic availability conceivably led to a poorer initial encoding resulting in greater boundary extension for these scenes than for typically colored or LCD versions. At the longer (i.e., 250 ms) viewing duration, this “color disadvantage” observed in the shorter duration for atypically colored HCD objects no longer exists. Participants could adequately identify objects in all viewing conditions at the longer duration. While boundary extension was present in all viewing conditions and at all stimulus durations, a significant difference did not exist in boundary extension ratings between viewing conditions at the longer viewing duration.

Conclusions

Based on these results, a few conclusions can be suggested. First, color information seems to be able to impact semantic access in an object recognition paradigm when objects are presented for a short duration and then color masked. Color information alone is not the cause of this impact however. Objects rated as having low color diagnosticity did not significantly differ from objects rated as having high color diagnosticity. By definition, objects that are LCD do not have a "typical" color. Therefore any alternate color versions of these LCD objects would not be expected to be impacted either. These objects seem to be unaffected by their constituent color information in the same way as atypically colored HCD objects.

Bramão, Reis, & Petersson (2011) suggest the main function of perceptual color in regards to color diagnosticity is to facilitate lexical access at the semantic level. Given this, participants possibly had difficulties in identifying the atypically colored HCD objects due to a momentary suppression of top-down processing (i.e., their ability to quickly access name information associated with known objects and their typical corresponding colors). The ability to associate color information with name information and object identity would only be advantageous when this color was nearly always associated with that object. This seems a likely explanation for the "color disadvantage" observed in atypically colored HCD objects.

Next we can conclude that a reduction in access to an object's semantic information, or arguably a reduction in semantic information across the scene as a whole, seems to increase boundary extension severity. This is likely due to the poorer quality of information available for recall. This supports previous research suggesting a degraded initial encoding of a scene can lead to increased boundary extension (Courtney & Hubbard, 2004; Intraub et al., 2008). By manipulating color typicality and viewing duration of HCD objects, we created a scenario (i.e., atypically colored HCD objects at the short viewing duration) by which only a degraded version of the image could be encoded. Therefore under these circumstances participants remembered a more extrapolative, wider angle version at recall.

Third, the “color disadvantage” in atypically colored HCD objects found in this experiment only persists momentarily (i.e., short rather than long stimulus duration). Once other features of the object (e.g., shape, structure, texture, even surrounding scene information) begin to resolve and override the atypical coloration, the objects were easily identified. Therefore in this paradigm boundary extension is only affected by color diagnosticity as long as this “color disadvantage” exists.

An explanation for this can be explained using current models in object recognition. Object structural information (e.g., shape) is believed to be the primary component of object recognition (Biederman, 1987; Biederman & Ju, 1988). However Biederman’s RBC (recognition-by-components) model (1987) does not incorporate color as a critical component in object recognition. The ‘Shape + Surface’ model (Tanaka et al., 2001) maintains that an object’s shape is the primary contributor to object recognition in a typical viewing scenario. However this model also takes into account color and other object features (e.g., texture) as contributing factors. The amount of contribution for each of these factors could arguably differ based on the components of a given scene and the scenario in which the scene was viewed. Furthermore, this model considers top-down factors such as object name, visual color knowledge, and verbal color knowledge. Combined, the bottom-up and top-down information leads to recognition of a particular object.

In the current study, the incorrect color information only negatively affected recognition at the short stimulus duration. Given slightly more time to view the stimuli, participants were able to use other perceptual inputs (e.g., shape, structure, texture) to identify the objects. Therefore it seems that a poor initial encoding (i.e., lack of necessary perceptual inputs, bottom-up information) and a reduction in lexical access at the semantic level (i.e., top-down information) could both contribute to the “color disadvantage” found in identification ability and boundary extension for atypically colored HCD objects.

This “color disadvantage” could likely be temporally extended or made more impactful if the accessibility to other perceptual inputs was reduced. For instance, if high spatial frequency information is removed from an image causing it to be blurry, the ability to recognize objects within the image is likely to be negatively impacted. Individuals with age related macular degeneration (AMD) have low visual acuity resulting in vision similar to the “blurry image” described above. Color information has been shown to facilitate object recognition in individuals with AMD (Boucart, Despretz, Hladiuk, & Desmettre, 2008). Facilitation of this kind is not found in individuals with normal visual acuity therefore supporting the theory that color can play a larger role in the absence or reduction of other inputs. The “color disadvantage” we observed could also be prolonged or amplified if any top-down processes are reduced. Alzheimer patients respond better to color cues than to shape cues regardless of visual acuity (Cernin, Keller, & Stoner, 2003). These individuals likely have difficulty accessing top-down components of an object or scene and therefore rely more heavily on basic perceptual inputs. For individuals with AMD and Alzheimer’s patients, the “color disadvantage” created in this study using atypically colored HCD objects presented at a short duration would likely be more severe due to a reduction in the bottom-up or top-down components of the object and surrounding scene. Based on our results, the “color disadvantage” not only reduces object recognition but also increases boundary extension. Alzheimer patients may not have increased boundary extension due to memory deficits; however, research in this particular area is sparse. Individuals with ALS or presumably individuals with poor visual acuity for any reason would most likely show increased boundary extension in this paradigm.

Semantic information has already been shown to be an unnecessary source for boundary extension to occur (Hale et al., 2014; McDunn et al., 2014). However our current research demonstrates that semantic information may play a role in the magnitude of boundary extension. Limiting availability of semantic information by presenting atypically colored versions of HCD objects for a short viewing duration increased boundary extension ratings. In other words, participants confidently remembered a wider-angle version of these scenes than any of the others. These findings provide further insight into the role of object recognition and semantic information on boundary extension.

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Footnotes

[1] For atypically colored HCD objects, approximately 65% were complimentary or “near complimentary color versions of the originals (i.e., typically colored HCD objects). The remaining objects were changed to a color that was “most atypical” from the original color if the complimentary color did not meet this description.

[2] Each color noise mask contained black, white, grey, red, orange, yellow, dark green, light green, dark blue, light blue, and purple in an approximately equal and random distribution on the screen. These colors are representative of a large range of colors present in all stimulus viewing conditions. The second mask is a 180° rotated version of the first mask to further decrease the likelihood of any afterimage effects due to the location of a particular color within a stimulus.

Table 1. Identification values for both stimulus durations in all 3 viewing conditions (i.e., typically colored HCD, atypically colored HCD, and LCD). Values represent percent correct (1.0 = 100% correct) based on individual means.

	46 ms duration			250 ms duration		
Viewing Condition	HCD Typical	HCD Atypical	LCD	HCD Typical	HCD Atypical	LCD
Identification Percentage	.84	.59	.88	.9	.78	.93

Table 2. Boundary extension values for both stimulus durations in all 3 viewing conditions (i.e., typically colored HCD, atypically colored HCD, and LCD). A score of "0" indicates the recalled image from study and the viewed image at test are identical.

	46 ms duration			250 ms duration		
Viewing Condition	HCD Typical	HCD Atypical	LCD	HCD Typical	HCD Atypical	LCD
Identification Percentage	-0.4086	-0.6314	-0.3429	-0.3914	-0.4114	-0.3486

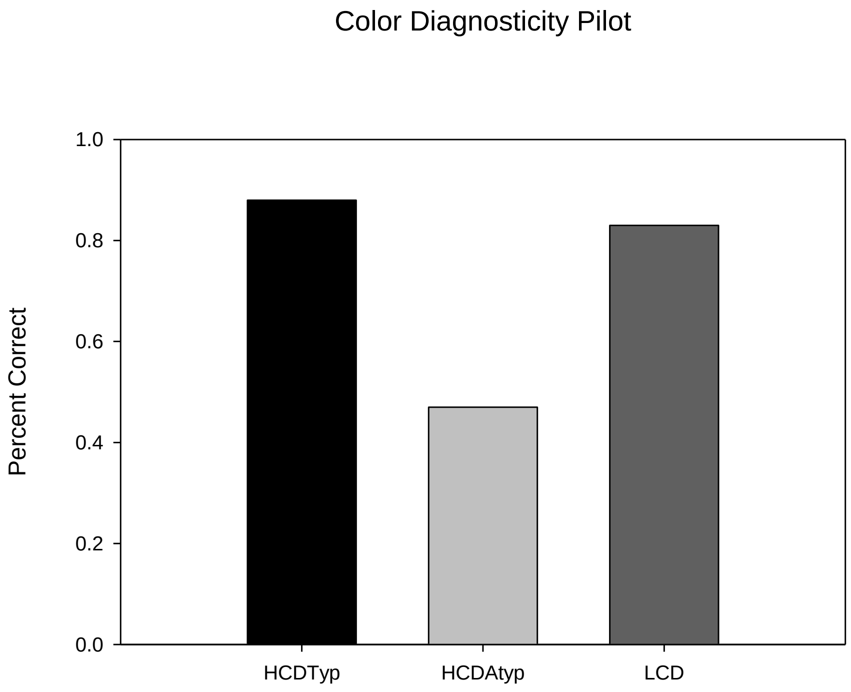

Figure 1. Pilot identification task results for typically colored HCD, atypically colored HCD, and LCD objects.

Figure 2. Example of a HCD object that has been transformed into an atypically colored HCD object.

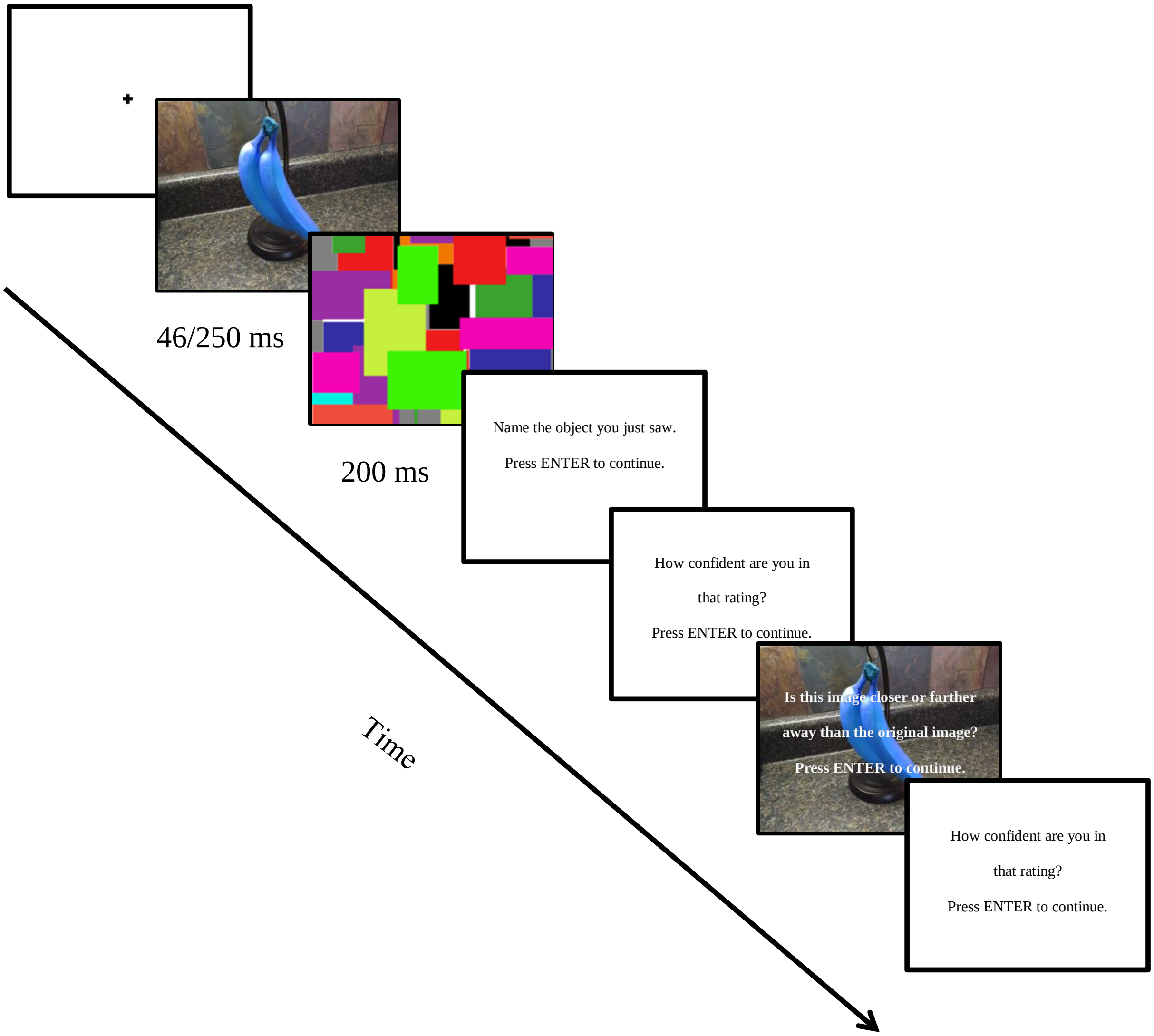

Figure 3. Individual trial breakdown over time. Components without a stimulus duration caption were terminated by participant response. Original stimulus was shown for either 46 or 250 ms depending on condition. Color noise mask was shown for 100 ms followed by 180° rotated version of this mask for 100 ms.

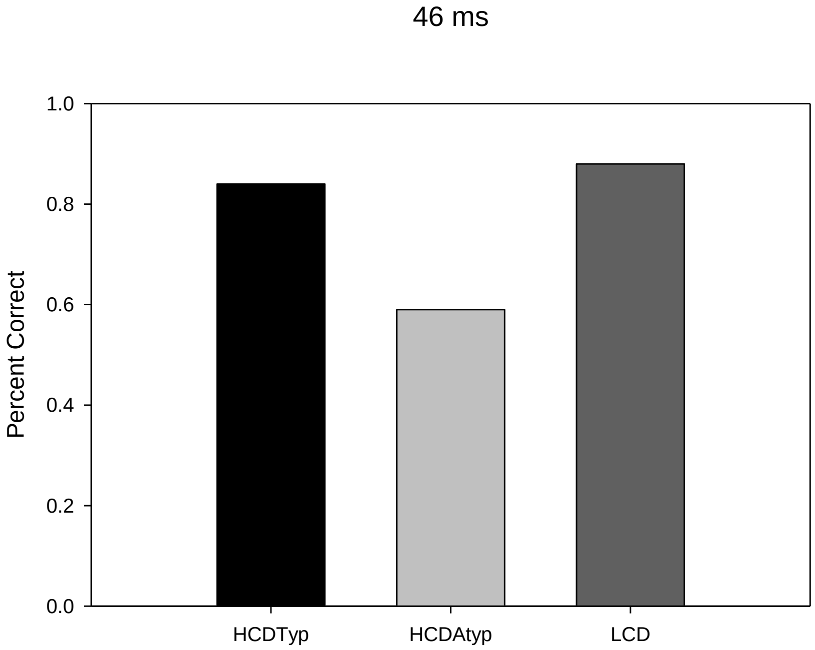

Figure 4. Identification task results for typically colored HCD, atypically colored HCD, and LCD objects at 46 ms stimulus duration.

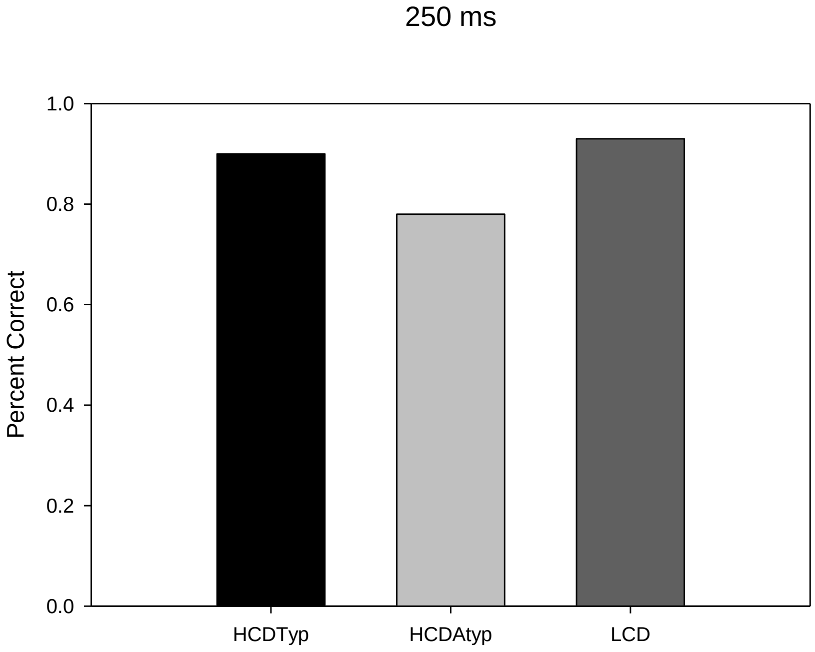

Figure 5. Identification task results for typically colored HCD, atypically colored HCD, and LCD objects at 250 ms stimulus duration.

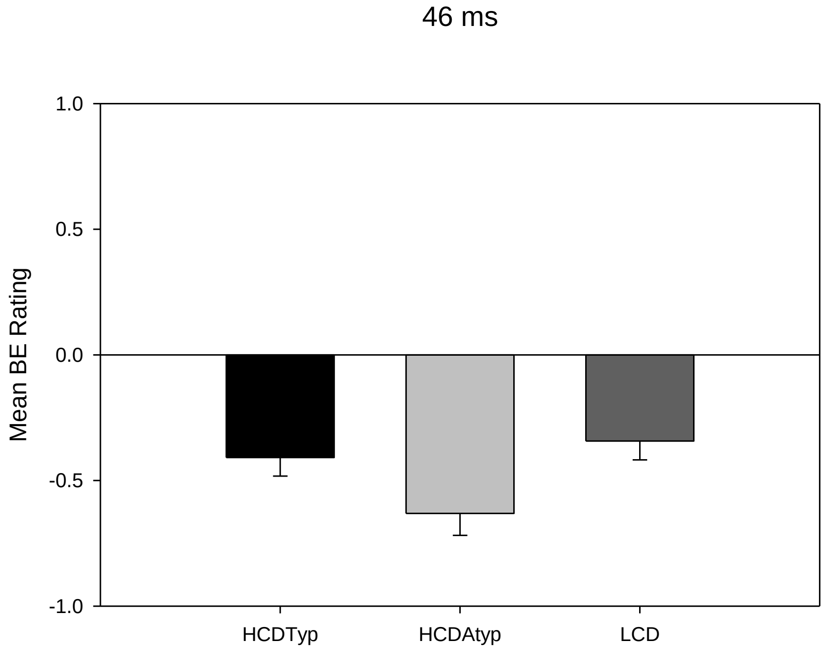

Figure 6. Boundary extension ratings for typically colored HCD, atypically colored HCD, and LCD objects at 46 ms stimulus duration.

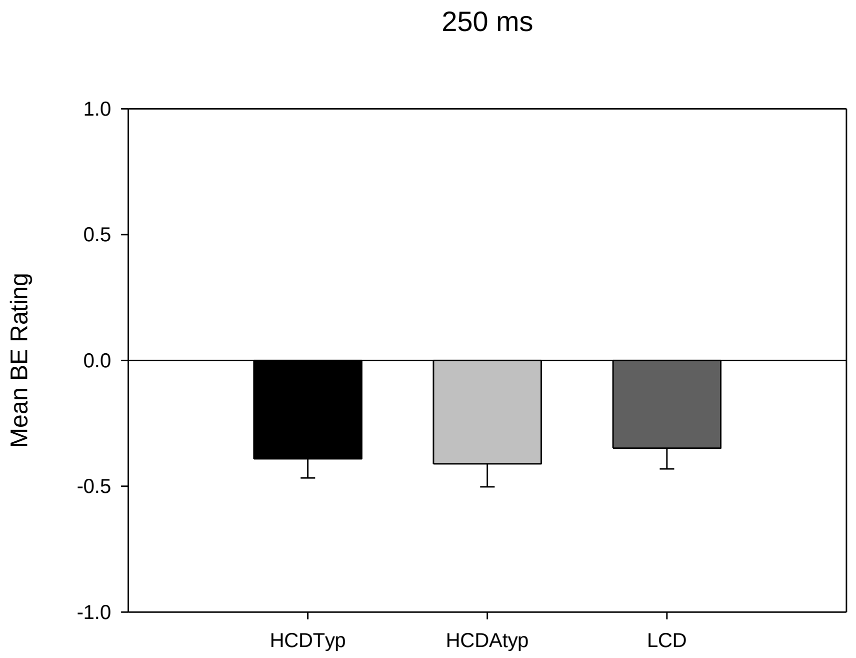

Figure 7. Boundary extension ratings for typically colored HCD, atypically colored HCD, and LCD objects at 250 ms stimulus duration.