2011

Understanding the Nature of Online Linguistic Influence in Lateralized Categorical Perception

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Understanding the Nature of Online Linguistic Influence in Lateralized Categorical Perception

by

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A Thesis

Presented to the Graduate and Research Committee

of Lehigh University

in Candidacy for the Degree of

Master of Science

In

Psychology

Lehigh University

August 12, 2011

Thesis is accepted and approved in partial fulfillment of the requirements for the Master of Science in Psychology.

Understanding the Nature of Online Linguistic Influence in Lateralized Categorical Perception
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Abstract

Categorical perception – perceiving stimuli as more discriminable if they belong to different categories than to the same category – has previously been found to be lateralized to the left hemisphere for colors (Gilbert et al. 2006). We tested the hypothesis that the lateralized categorical perception effect for color depends on active labeling of the relevant categories prior to the main task. In two studies, we manipulated explicit label activation and the category level (basic or subordinate) of the labels in a lateralized visual search paradigm. We predicted a stronger lateralized categorical perception effect when explicit labeling occurred before the task. We found categorical perception in all conditions, but the strength of the effect was not affected by the labeling manipulation or hemisphere. The results, particularly the lack of lateralization of the categorical perception effect, suggest that active language access alone may not be driving the effect.

Understanding the Nature of Online Linguistic Influence in Lateralized Categorical Perception

Do linguistic categories affect perception? This question has been asked many times since Whorf suggested that habitual ways of speaking lead to habitual ways of thinking (Whorf, 1956). The Sapir-Whorf hypothesis that language influences thought was investigated through color research in the late 1960's and beyond (Berlin & Kay, 1969; Regier, Kay, Gilbert, & Ivry, 2010). The main argument was between the idea that there are universal, innate color categories, categories that exist in human beings regardless of language, and the idea that color categories are language relative, that they are different depending on the language the individual speaks. In this debate, some researchers took a 'strong Whorfian' view, often stronger than Whorf himself did, that language determines thought, while others took the 'anti-Whorfian' position that language has no effect on thought at all. Neither extreme was found to be fully correct (Regier et al., 2010). Language has been found to have influences on thought that are complex and subtle: The metaphors used for time in a language affect temporal reasoning, the class of noun used in a language to refer to an entity affects speaker's object vs. substance attributions, and the grammatical gender of a noun is linked with stereotypical gender attribute associations (see Gleitman & Papafragou, 2005, for review). On the other hand, some thoughts seem to be universal regardless of linguistic knowledge such as the division of human locomotion into walking vs. running – many unrelated languages make the same division that reflects the structure of the world rather than a linguistically and socially constructed structure (Malt et al., 2008). This accumulating evidence indicates that neither of the extremes is correct: Language does have effects on thoughts but does not underlie all thought. In the case of color, there appear to be universal tendencies for where labeled color categories are centered and where the boundaries between those categories lie, but languages create variations around the language independent optimal divisions of color space given the number of terms used to divide the space (Regier et al., 2010). The color debate needed to be brought from its original binary opposition to this new level of sophistication and subtlety to be of continued interest.

In recent years, the language relativity question has been re-energized by the finding that colors are subject to lateralized categorical perception (Gilbert, Regier, Kay, & Ivry, 2006). Categorical perception is a phenomenon where items, substances or attributes from different categories are more quickly discriminated and reacted to than the same type of items, substances or attributes that are in the same category when all the items are of equal physical distinctiveness. For instance, for English speakers, a shade of color called *blue* and one called *green* are more quickly discriminated on a millisecond time scale than two equally physically distinct shades of color that are both called *blue* or both called *green*. When this asymmetrically happens for percepts processed in one of the hemispheres, the effect is called lateralized categorical perception (Regier et al., 2010).

The visual search paradigm used in the Gilbert et al. (2006) experiments consisted of displaying an array of color chips in a circle around a central fixation point. Each trial had 11 color chips of one hue and 1 ‘oddball’ stimulus of a different hue. The participants were asked to indicate with a button push which side of the screen the oddball stimulus was on while maintaining central fixation with their eyes. The reaction time from the visual display presentation to the button push was measured. This time period encompassed the processes of perception of the stimuli, deciding on a response, and motor execution of the response. Fixating the eyes on a central point holds the visual fields separate, allowing for independent processing of each visual field. The visual fields are initially processed by the contra-lateral hemisphere of the brain, prior to cross-hemispheric processing. Gilbert et al. (2006) found the reaction times for the between-categories color discriminations in the right visual field/left hemisphere to be significantly faster than the within category discriminations. No significant difference between the discrimination types was found for the left visual field/right hemisphere. This is the lateralized categorical perception effect referred to above.

Since aspects of language are lateralized to the left hemisphere, Gilbert et al. hypothesized that linguistic category activation is the source of the lateralized categorical perception effect. Gilbert et al. (2006) provided further support that language is the source of the greater discrimination time difference in the right visual field/left hemisphere trials by using interference testing, a technique of adding a second task known to use a particular cognitive ability to the original task to see if it disrupts processing. They tested whether a spatial interference task, remembering a grid of black and white squares, or a verbal interference task, remembering a color word such as ‘red,’ would disrupt the categorical perception effect using a one-back match technique. In a one-back match design, the participant is given a new interference stimulus, the grid or color word in this case, at the beginning of each trial. The participant indicates whether the new stimulus matches the previous interference stimulus. Gilbert et al. found a disruptive effect of only the verbal task, indicating that the categorical perception effect depends specifically on access to linguistic capacities in the left hemisphere, allowing them to conclude that online activation of linguistic processes was responsible for the observed lateralized categorical perception effect.

The color lateralized categorical perception finding has been replicated (Drivonikou, Kay, Regier, Ivry, Gilbert, Franklin, & Davies, 2007). In the original experiment (Gilbert et al., 2006), there was no significant categorical perception effect in the left visual field/right hemisphere. In subsequent experiments (Drivonikou et al., 2007; Roberson, Pak, & Hanley, 2008), a statistically significant categorical perception effect has been found in the left visual field/right hemisphere though it is significantly smaller than the effect in the right visual field/left hemisphere. While not as neat as the Gilbert et al. (2006) findings, the replications continue to indicate that online language activation in the left hemisphere strengthens the categorical perception effect.

Furthermore, developmental research has show that categorical color perception is actually lateralized to the right hemisphere in pre-linguistic toddlers (Franklin et al., 2008). Using an eye-tracking version of the visual search task with more dispersed color stimuli, pre-linguistic toddlers had a stronger categorical perception effect in the left visual field/right hemisphere while toddlers who had acquired color labels had a stronger categorical perception effect in the right visual field/left hemisphere as was found in adults. The Franklin et al. experiments show that the lateralized categorical perception effect in adults cannot be due to a lateralized visual color focality sensitivity or some other non-linguistic visual property of the stimuli that preferentially affects the left hemisphere. Learning the labeled color categories of a language appears to equal and overcome a natural sensitivity to certain color discriminations in the left visual field/right hemisphere.

Habitual Thought vs. Thinking-for-Speaking

In each of the experiments in the Gilbert et al. (2006) and Drivonikou et al. (2007) papers, the colors were labeled by the participants prior to completing the main visual search task. This was done in order to ensure that the participant's idiosyncratic color boundary was the same as the pre-tested average color boundary for English speakers. In Gilbert et al.'s (2006) before-task labeling procedure, the participants were shown the four color hues multiple times each and asked to categorize them into *blue,* using a 'b' button push, or *green,* using a 'g' button push. In the Drivonikou et al. (2007) procedure, the participants were asked to categorize the colors into *blue* and *green*, or into *blue* and *purple*, with the colors of the before-task labeling being the colors of the condition to which they were assigned. Although these experimenters' intentions in including the pre-test were only to establish the participants' color boundaries, it may have inadvertently had an additional effect. The before-task labeling process would have activated the color names in the participant's mind and caused them to explicitly categorize the specific color hues by the basic color labels. Gilbert et al. (2006) argued that the lateralized categorical perception effect is a broadly defined influence of language on perception, whether it is directly on perceptual processing or on decision processes that follow the initial perceptual processing. They consider the finding to support the Whorfian hypothesis that thought is shaped by language into habitual patterns, with the qualification that their results support it only for the left hemisphere, the language dominant hemisphere of the brain. However, by using the before-task labeling procedure, the researchers unintentionally ensured that the linguistic categories were active and engaged in the subsequent visual search task. Lupyan, Thompson-Schill, & Swingley (2010) showed that overtly labeling letters before a categorical perception task shifted the timing of the categorical perception effect forward, indicating that even for a domain very closely tied to language, overt labeling changes processing. Although the researchers were not particularly interested in the effect of pre-activating labels, the procedures used in the lateralized color categorical perception experiments have looked for categorical perception through a task in which linguistic categories are overtly invoked, rather than in tasks that may or may not engage linguistic categorization naturally. The conclusion that there is a habitual online influence of linguistic categories on visual processing in the left hemisphere is premature given the empirical evidence thus far collected.

The idea that engaging language in a task might affect task performance is not new. Slobin (1996) put forth the idea that 'thinking-for-speaking' is different from other modes of thinking. While Whorf originally argued that the language an individual speaks causes habitual changes in the way he or she thinks regardless of whether language is being utilized in the moment, Slobin argued that it is when an individual is thinking for the purpose of speaking that linguistic influences would be present, based on the need to encode certain aspects of the world in order to produce grammatically correct speech. For example, if a language requires manner of motion to be described, the individual could either always be thinking of how motion is being accomplished as a matter of habit in Whorf's account, or could engage in thinking about manner of motion only when it is needed to form speech in Slobin's account. Slobin's theory suggests that thought (linguistically influenced or not) is context- and purpose-dependent while Whorf's theory portrays thought as having an ingrained default mode that is determined by the language one speaks. In the Gilbert et al. studies, the participants were engaging their linguistic processing mode by labeling the colors before the main task. Even if participants were capable of processing that is not influenced by language, priming the color language and forcing linguistic categorization may have caused the participants to use a language-based processing mode for the task. Naming the colors could create a color naming context in which the color names would be accessed during the visual search task. If Slobin is correct that context drives linguistic influence on thought, had the participants not labeled the color stimuli before the task, they may not have been prepared to use language related thought processes and would have had the possibility of using other valid non-linguistic thought processes.

There is one experiment using color stimuli in a visual search paradigm that did not have a before-task labeling procedure (Roberson et al., 2008). Roberson et al. conducted a cross-linguistic experiment comparing Korean and English native speakers using a linguistic color boundary that exists in Korean but not English. This distinction is between *yeondu* (yellow-green) and *chorok* (green). Korean speakers showed the categorical perception effect for both visual fields with a stronger effect in the right visual field/left hemisphere, consistent with Drivonikou et al. (2007). English speakers did not show a categorical perception effect in either visual field, as would be predicted by the literature on lateralized categorical perception since all of the stimuli belonged to one linguistic category for these participants. This finding argues against a universal, innate set of color categories that persist after language is acquired and for a language relativity account. This experiment tested a boundary that does not exist linguistically for the English speakers – there isn't linguistic category information available to influence perception for half the participants, the half that spoke English and had no Korean language abilities. Since the participants were tested on a non-English boundary, the experiment does not allow for comparison with previous English language experiments in this paradigm, and there has been no experiment with Korean speakers in which the subjects label the colors before the visual search task that would allow for a direct comparison.

The results of the Roberson et al. (2008) experiment also were not as clear as previous experiments. The full dataset showed the categorical perception effect in both visual fields for the Korean speakers with no significant difference in strength. The authors divided the participants in half by overall reaction time, and found the predicted results of the stronger categorical perception effect in the right visual field/left hemisphere only for the faster participants. The authors justified splitting the participants into slower and faster groups based on the idea that the data for the faster participants reflected earlier, more lateralized processing while the slower participants could have had cross-hemispheric transfer. The splitting of the groups into faster and slower participants could be reflecting processing differences other than the amount of cross-hemispheric transfer; the faster participants could be spontaneously labeling the colors and activating their color categories while the slower participants were not. Without further evidence, the Roberson et al. results are not very convincing. If we find less categorical perception for unnamed categories when directly comparing them to overtly named categories using more controlled materials, the Roberson et al. results could be interpreted as a result of language activation levels rather than cross-hemispheric transfer.

In short, linguistically based lateralized categorical perception is a newly discovered phenomenon that has not been fully investigated. Thus far, most experiments (Drivonikou et al., 2007; Gilbert et al., 2006; Gilbert, Regier, Kay & Ivry, 2008) have primed language prior to conducting the main task, then attributed the effect to habitual language. These researchers have shown that language can produce this effect when explicitly activated, but the pervasive habitualness of the phenomenon has not been tested. When language was not primed (Roberson et al., 2008) the results were less strong and clear. In the present experiments, we will investigate the role of explicit language activation in the lateralized categorical perception phenomenon.

Perceptual Processing vs. Decision Processes in Categorical Perception Effects

Beyond the main argument of the current work described above, there is another current debate surrounding the categorical perception effect, lateralized and non-lateralized. In the original article, Gilbert et al. (2006) raise two possibilities for the source of the phenomenon in regards to color. The lateralized categorical perception effect could be due to a change in basic perceptual processing or could be a result of altered post-perceptual decision-making processes. In the direct perceptual account, by calling a particular color *blue*, the lexical-conceptual idea of *blue* interacts with the perceptual experience of the actual color hue in the perceptual system, creating a pattern of activation that is more typically blue than would be the case without a categorization. Participants 'see' the colors as more different than they physically are in terms of the raw perceptual system input, and as a result, distinguish the colors as different faster than when the colors are not influenced by a conceptual difference. In the post-perceptual, decision-making account, the influence of color labels on response times is based on linguistic information added independently from the perceptual information at the decision-making stage of processing that allows for reaching a decision threshold faster.

Roberson et al. (2008) champion a version of the decision-making account with basic level perception and label activation co-occurring independently (see Pylyshyn, 1999, for a comprehensive review of the theoretical position). According to Roberson et al. (2008), a certain amount of time is needed to accumulate enough perceptual evidence that the color chips are different shades of color and make the different/same decision. When the labels are different, the perception of the color chips activates the different labels, which allows the comparative perceptual process to be augmented with the added evidence of the linguistic processing. If the color chips have the same label, the perceiver would have to rely on the perceptual comparison to overcome the linguistic processing, which is providing evidence that the colors are the same linguistically. By this reasoning, the decision that the chips are different colors can therefore be made faster with the different labels than if they had the same label. Rather than the perceptual processing of the color being changed by the knowledge of color labels, the color processing itself is the same with an additional, separate linguistic process occurring to help reach the ‘different color’ decision.

Lupyan and colleagues (Lupyan et al., 2010) champion a version of the direct perceptual account of the categorical perception effect. Rather than two separate channels of processing, perceptual and conceptual (with linguistic information being a subset of the conceptual), working independently and being compared at a decision-making level of processing, Lupyan et al. suggest that early in perceptual processing there is interaction between the top-down conceptual processing and the bottom-up perceptual processing. This could be realized as a cognitive structure involving cross-talk between the two systems or could be a feed-forward structure that has a perceptual/conceptual combination level prior to a decision-making level of processing. They do not believe a final decision-making level integration of the perceptual and conceptual information would be sufficient to explain the categorical perception effect in their tasks.

The thinking-for-speaking view of lateralized categorical perception could potentially work in either model. In the decision-making level model, either the linguistic-conceptual channel of processing is strongly influencing the decision process or it is not. When language and the conceptual knowledge attached to language are not being accessed, very little output from the conceptual channel will reach the decision-making level. Similarly, in the conceptual penetration of perceptual processing account, the conceptual system is not strongly accessed if labels are not activated. In a feedback version of the model, there is little activation in the conceptual areas allowing the visual processing to proceed uninfluenced. In a feed-forward version of the model, the conceptual path in early visual processing would not be utilized, allowing the visual output to pass through a pre-decision-making visual/conceptual combination level unaltered. While the thinking-for-speaking model of lateralized categorical perception would most easily work within the decision-making model where conceptual information is easily separable from visual processing, it could be that the conceptual penetration model better fits what may be complex data, with relative intensity of conceptual influence being seen rather than an all-on or all-off scenario. Similarly, evidence of the habitual influence of language and categories on color perception would be more readily modeled by the interacting direct perceptual account, but could also work in a decision-level account with the conceptual channel always 'on.'

The data collected in the present experiments presumably reflects the interaction of perceptual and linguistic-conceptual processing. We will discuss how the current data address the debate about the nature of the interaction, though we did not expect the data to conclusively differentiate between the two theoretical stances.

Typicality Influence on Within-Category Trials

Typicality is a conceptually based phenomenon. Typicality is a product of the graded structure of categories (Barsalou, 1987) where some members of a category are considered to be better exemplars of the category than other members. Recently, Hanley and Roberson (2011) reanalyzed a number of past categorical perception experiments with color and face stimuli to examine the influence of typicality on within-category trials. The paradigm they looked at was two-alternative forced choice. One stimulus, the target, is shown to the participant followed by two stimuli side-by-side, the target and a distracter. The participant is asked to indicate which of the two stimuli on the second screen was a match to the original stimulus. The categorical perception effect is demonstrated in this memory task by a higher accuracy on between-category trials than on within-category trials. In this experiment, some of the original stimuli were more typical of a labeled color category than others. Breaking up the data by which stimulus was the target vs. distracter for the within-category discrimination pairs, a systematic typicality influence was found to be present. If the stimulus more typical of the category was the target, the participants performed only slightly less accurately than in the between-categories trials. If the less typical stimulus was the target, it was significantly less accurately identified than in between-categories trials. They found that this pattern did not hold if verbal interference was added to the task.

Hanley and Roberson (2011) put forth an explanation for these effects that depends on linguistic categorization. The target as originally presented must be stored in working memory in order to compare it to the subsequent stimuli. If part of this storage process involves categorizing the item, the initial categorization could help or hinder the accuracy of the forced choice. For example on its own, a peripheral green may be labeled *green*. When presented again in the context of a more typical green, the peripheral green may be labeled *blue* rather than *green*. There would then be a mismatch between the categorizations for the peripheral color that would lend itself to more inaccuracy during the forced choice. This would be less likely to occur with a good example of a category because typical category members are more consistently named and less affected by context.

The present research did not use the two-alternative forced choice task. However, in within-category trials, more and less typical members of color categories served in each of the stimulus roles, context and target. The within-category trials of the present experiments can be analyzed for typicality effects in a separate secondary analysis from the main analysis examining the categorical perception effect.

Overview of Studies

In two studies, we examined the effect of labeling on lateralized categorical perception. As mentioned, the Gilbert et al. (2006) researchers made strong claims of Whorfian linguistic influences on perception in the left hemisphere, stronger claims than their data warrant. They did not test the effect when language was not explicitly activated, which is a crucial circumstance under which lateralized categorical perception should be found for the Whorfian habitual thought hypothesis. In each of the studies, we manipulated the labeling of the color stimuli to occur before or after the task evoking the categorical perception effect. If the lateralized categorical perception effect for color is independent of a linguistic categorization context, i.e. habitual, the same pattern of reaction times should be seen regardless of whether the participants label the color stimuli prior to the task. In that case, the colors would be processed the same way, their perception activating the label of the color instantly, since Gilbert et al. (2006) showed that the effect depends on the availability of language. If instead the lateralized categorical perception effect for color is dependent on the linguistic categorization context, the effect should be more strongly seen when there is a before-task labeling procedure in contrast with an after-task labeling procedure. The linguistic distinction would only have an effect when linguistic processing was purposefully engaged in the task. The comparison of these conditions allows us to make inferences that speak to the habitualness of the lateralized effect of language on perception.

In Experiment 1 presented below, the visual search paradigm of Gilbert et al. (2006) was repeated, but with an added manipulation of the labeling procedure. Half the participants did the before-task labeling procedure as was done in the Gilbert et al. experiments while the other half did an after-task labeling procedure. This design allowed the idiosyncratic *blue*/*green* boundary of each participant to be verified in both labeling conditions while only priming color language and categorization in the before-task labeling condition. We expected to find the categorical perception effect to be stronger in the right visual field/left hemisphere than in the left visual field/right hemisphere and, importantly, for this difference to be larger and more reliable when labels were explicitly evoked before the task.

Experiment 2 further tested the dependence of the lateralized categorical perception effect on context-driven language activation. The Gilbert et al. (2006) research group used color stimuli from two basic color categories in English. The colors *green* and *blue* have been ubiquitous in American college students' lives from learning the colors of the rainbow in kindergarten, to being able to know what train to get on in a color coded subway system as an adult. The distinguishing of these color categories is required regularly in American society and the color labels are likely to be readily accessible with low activation thresholds creating a situation where activating the labels may be automatic for the average American college student, even without explicit priming. If instead the color boundary being tested was not automatic, it would provide a better test of whether language is only optionally recruited into processing when the task context indicates that linguistic processing will be helpful. To avoid the basic level of labeling, the color stimuli were chosen from within the basic category *green*. The before-task labeling condition for this experiment distinguished two common sub-categories of *green*: *sea green* and *grass green*. Preliminary testing on a separate group of participants established the familiarity of the two categories used. These sub-categories are much less likely to automatically engage a language mode of thought in the visual search task when there is no explicit priming. In line with the hypothesis that linguistic processing is contextually cued rather than habitually utilized, we expected a categorical perception effect in the right visual field/left hemisphere only when labels were explicitly evoked. Additionally, in this second experiment, a sex variable was introduced to examine whether reaction times were influenced by the different average color naming competence of the sexes, as reaction times have been in other color stimuli experiments (Stroop, 1935).

Experiment 1: Effect of Labeling on Discrimination of Basic-Level Colors

In Experiment 1, we manipulated the labeling conditions to test whether explicitly categorizing the stimuli before the visual search task had an effect on the reaction time measure of categorical perception. We predicted that there would be a stronger categorical perception effect in the right visual field/left hemisphere than in the left visual field/right hemisphere and that the difference will be greater in the before-task labeling condition.

Method

Participants.

Thirty-three Lehigh University undergraduates participated for course credit. The participants were native English speakers and right handed. The participants were screened for color blindness using the CITY test (City University, 2002).

Design.

The experiment had a 2 x 2 x 2 Mixed Design. Visual field (left vs. right) and discrimination type (between- vs. within-category) were within-subject independent variables. The labeling procedure (before- vs. after-task) was a between-subjects independent variable. The dependent variable was reaction time measured from display onset to the button push indicating a color discrimination had been made.

Additionally, just for the within-category trials, we conducted a test of the influence of typicality on reaction times. The color hues farther from the color boundary are more typical than the color hues that are closer to the color boundary. The typicality variable is part of a separate 2 x 2 x 2 Mixed Design. The typicality variable has the context color being either more or less typical than the target color, and the pair variable represents either *blue* or *green*. Typicality and pair are within-subjects variables. Labeling condition, before-task or after-task labeling, is a between-subjects variable.

Materials.

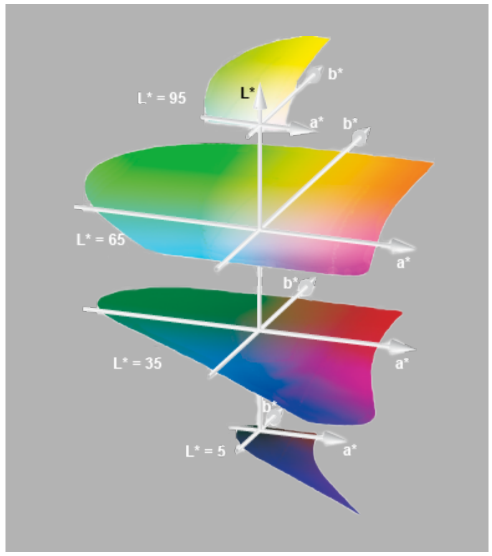

Figure 1. A 3-dimensional illustration of CIE L*a*b* color space. (Binder, 2010)

We chose four colors, two that English speakers generally call *green* and two that are generally called *blue*. The colors were created in Adobe Photoshop using CIE L*a*b* color space (see Fig. 1), with the intention of creating four color stimuli each with equal physical distance from its neighbors (see Fig. 2, the 2 *green*s, the 2 *blue*s and the *green* and *blue* on either side of the color boundary all have the same physical distance within the pairs). The CIE L*a*b* represents a standardization of physical color space, encompassing the visual spectrum. The L* coordinate stands for brightness (the vertical dimension in Fig. 1) while a* and b* represent the 2 dimensions at each brightness plane. Saturation changes with distance from the center, creating rings of equal saturation, and hue is constant along a line radiating from the center point, changing as the angle of that line changes.

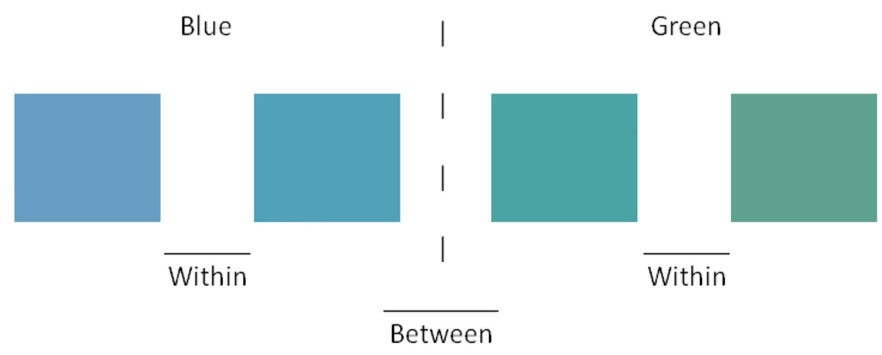

*Figure 2.*The four color stimuli of Experiment 1. The two colors on the left are generally called *blue* by native English speakers and were a within-category discrimination pair, the two colors on the right are generally called *green* by native English speakers and were the second within-category discrimination pair, and the two central stimuli were the between-categories discrimination pair.

The brightness (L*) and saturation (square root of ($a^{*2}+b^{*2}$)) of the colors were held constant[1] while the hue was varied by 13.5 +/- .5 units. The coordinates were calculated using trigonometric functions in Excel. The colors were then created in Adobe Photoshop by inputting the coordinates. Adobe Photoshop only recognizes L*, a*, and b* coordinates in integers limiting the level of precision of calculating equal hue variation between the colors, forcing rounding of the values to the nearest whole number. The two *blue*s and the two *green*s (the within-category discriminations) were each approximately 13.5 units apart from one another in hue, and the adjacent *blue* and *green* colors to the boundary were also approximately 13.5 units different in hue. Essentially, each discrimination pair consisted of two colors that are physically different from the other by the same amount as in the other pairs. The device-independent CIE L*a*b* colors were

[1] Brightness was held exactly constant by inserting the same number into Photoshop for the L* coordinate for each stimulus. Saturation and hue co-depend on the a* and b* coordinates. Therefore saturation was not held completely constant but had a margin of difference +/- 1 unit.

then converted in Adobe Photoshop using its standard conversion tools to sRGB, the standard monitor color space, which is used by the computer to display the colors.

Labels	L*	a*	b*
A — *Blue*	56	-9	-28
B — *Blue*	56	-20	-20
C — *Green*	56	-27	-8
D — *Green*	56	-28	5

Table 1. The CIE L*a*b* coordinates of the color stimuli in Experiment 1.

Procedure.

In both labeling conditions, the main task was the visual search task developed by Gilbert et al. (2006). The key visual search display consisted of twelve color squares arrayed in a circle around a central fixation cross. One of the squares was a different color from the others. The participant was given the task of identifying which side of the display the different square was located on by pressing ‘a’ for the left side of the screen and ‘l’ for the right side of the screen. During the task, the participant had his or her head stabilized by a chin rest and was instructed to keep his or her eyes fixated on the cross in the center of the screen. By fixating in the center of the screen and responding to one side of the screen or the other, the participant was holding his or her visual fields constant and would initially process each side of the screen in different hemispheres. Through anatomical connections in the brain, the left visual field is initially processed in the right hemisphere and the right visual field is initially processed in the left hemisphere. Also with the aim to keep separate the initial processing of the two visual fields, a 200 ms exposure to the visual display was used to limit the ability of participants to move their focus from the fixation cross. In this time frame, it is possible that the first saccade would be made, and without access to eye-tracking equipment we could not verify that the participants were staying fixated, but this time scale was used in previous research that showed visual field differences.

As with contra-lateral visual processing, the right arm is controlled by the left hemisphere and the left arm is controlled by the right hemisphere. The buttons were assigned so that no extra cross-hemisphere processing would be required. If the different stimulus were in the left visual field, the correct button would be ‘a’ which is located on the left side of the keyboard and pressed by the left hand. In the example display below, all external perception and action occurs on the left, and therefore would be processed and controlled using the right hemisphere.

The sequence of screens consisted of the fixation cross for 1000 ms followed by the visual display for 200 ms followed by the fixation cross until a response was made, after which there was an inter-trial interval of 250 ms (see Fig. 4). There were 3 blocks consisting of 120 trials each for a total of 360 trials. Each block contained all three critical color contrasts, the within-category *green* discrimination, the within-category *blue* discrimination and the one-step difference between-categories discrimination, along with two non-critical discrimination pairs consisting of the two-step difference between-categories discriminations (referring to Fig. 2, the left most *blue* was paired with the left *green* and the right *blue* was paired with the right *green*). The three-step discrimination was not included. Each stimulus of each discrimination pair served as both the context

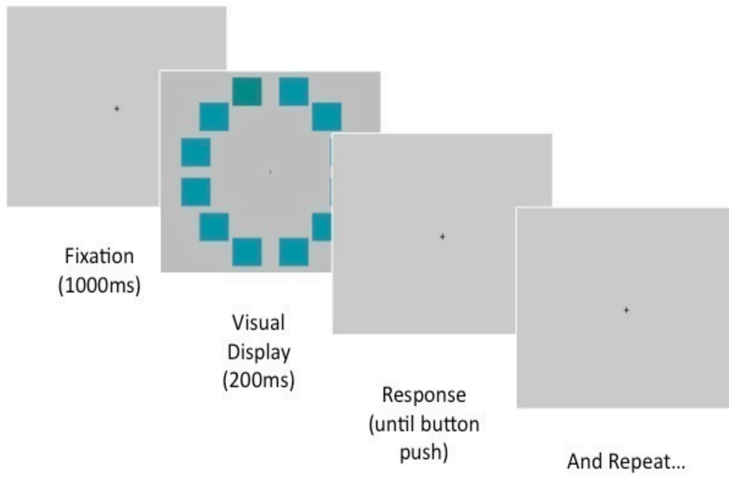

Figure 3. The sequence of screens during the visual search task.

color (the 11 chips) and as the different color (the 1 chip), and appeared in all 12 locations as the different color. The 5 (pairs) X 2 (each color of a discrimination pair serving as the context color) X 12 (locations) produces 120 unique visual search screens, each being presented once during each block. The one critical between-categories discrimination was displayed for 24 relevant trials per block, half in the left visual field and half in the right visual field. The two critical within-category discrimination pairs were the stimuli for 48 relevant trials per block, split between the visual fields. The 3 blocks resulted in a total of 72 between-category trials and 144 within-category trials per participant.

Half of the participants had the visual search task as their first task followed by the labeling task, while for the other half of the participants the visual search task was preceded by the labeling task. The labeling task consisted of the four colors being presented as single squares in the center of the screen for 200 ms followed by a textbox in which the participants typed ‘green’ or ‘blue’. In the Gilbert et al. (2006) procedure, the participants only responded by pressing ‘g’ or ‘b’. We wanted to make the labeling more explicit, therefore requiring the full label to be typed out. Each stimulus was presented 8 times for a total of 32 labeling trials. The labeling task preceded the visual search task in the before-task labeling procedure. It occurred after the visual search task in the after-task labeling procedure.

Additionally in the before-task labeling procedure, color differences were explicitly referenced in the visual search task instructions. In the after-task labeling procedure, there was no explicit mention of color in the instructions. The key instructions in the before-task labeling condition read:

> “Twelve *colored* squares will flash briefly on the screen. One of the squares will be *a* different *color* from the others. Your task is to determine which side of the screen contains this different*ly colored* square while keeping your eyes fixated on a “+” in the center of the screen. *The squares will be shades of green and blue.*
>
> You will be making your responses with the keyboard. If the different*ly colored* square is on the LEFT side of the screen, press A. If the different*ly colored* square is on the RIGHT side of the screen, press L. The display will appear very briefly. Please respond as quickly and accurately as possible. If you are unsure which side contained the

different*ly colored* square, just make your best guess and move on to the next trial."

The participants in the after-task labeling condition were given the instructions without the italicized and underlined portions. While this is a minor difference, the use of color language in the before-task labeling procedure reinforces the use of color language while the non-use of color language in the after-task labeling procedure serves to *not* indicate that there is a linguistically defined difference among the stimuli.

At the end of the session, the participants were asked to verify their right-handedness, and shown the CITY colorblindness test (City University, 2002) to verify self-reported normal color vision. They were debriefed and thanked.

Results

Eight participants were excluded from analysis: 3 for having correct response rates below 85%, 4 for having less than 3 of the last 4 labeling trials[2] for each individual color stimulus correct relative to the experimenter-determined names, and 1 for no data being collected due to a program error. Twenty-five participants remained, 12 in the before-task labeling condition and 13 in the after-task labeling condition.

A 2 x 2 x 2 Mixed Design ANOVA was run on the reaction time data from the one-step difference discriminations with discrimination type (between- vs. within-categories) and visual field (left vs. right) as within subject factors and labeling condition (before- vs. after-task) as the between subjects factor. Assumptions of the mixed design ANOVA were met.

[2] There were 8 trials per color overall. Only the last 4 were considered, giving the participant time to practice and decide where the color boundary was within the four stimuli.

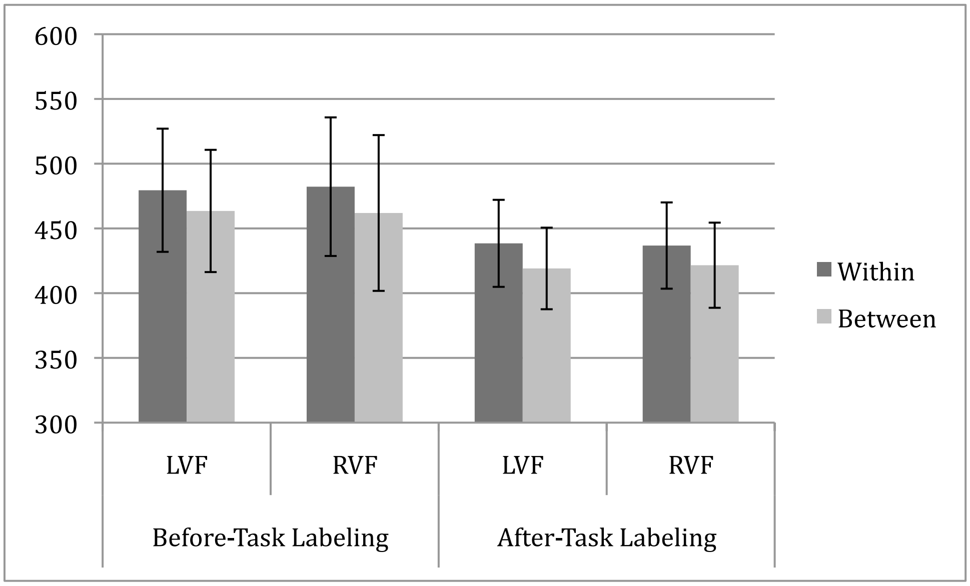

Figure 4. Reaction times as a function of discrimination type, visual field, and labeling task for Experiment 1. The error bars represent +/- 1 standard deviation.

First we assessed whether the basic categorical perception effect was present in each condition. The categorical perception effect presents as faster reaction times between than within categories. From the means displayed in Figure 5, it can be determined that the between-categories discrimination was more quickly made and acted upon than the within-category discriminations for both the before- and after-task groups. There was a significant main effect of discrimination type, $F(1,23)=96.309$, $p<.001$. This indicates that collapsing across labeling (before-task vs. after-task) and visual field (right vs. left), the between-category discrimination was reacted to significantly faster than the within-category discriminations. This categorical perception effect was displayed in all conditions (all two-tailed paired sample t-tests had p-values of $<.01$). There was also a main effect of labeling condition, $F(1,23)=6.621$, $p<.05$. Collapsing across visual fields and discrimination type, the after-task labeling group had faster reaction times than the before-task labeling group.

We had predicted that the categorical perception effect would be stronger for before-task labeling than for after-task labeling, and that the labeling effect would be stronger in the right visual field/left hemisphere than in the left visual field/right hemisphere, a three-way interaction. There was not a significant three-way interaction of visual field by discrimination type by labeling condition (F(1,23)=.692, p>.05). No other interactions were significant.

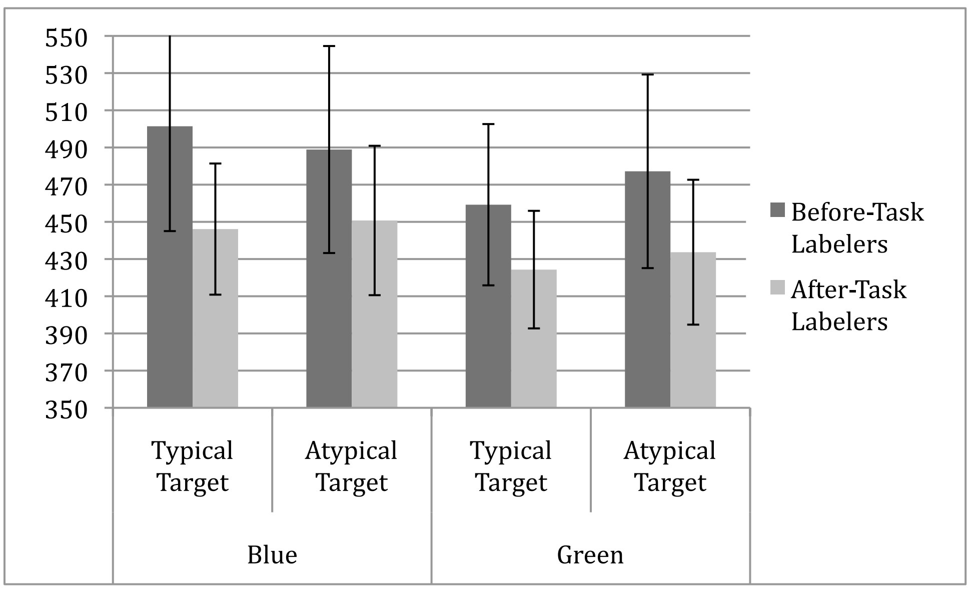

Figure 5. Within-category trial reaction times as a function of pair and typicality for the Experiment 1. The error bars represent +/- 1 standard deviation.

An asymmetry of reaction times based on context color typicality was found. Using a 2 (pair) x 2 (typicality of target) x 2 (labeling condition) Mixed Design ANOVA, there was a main effect of pair, F(1,23)=24.269, p<.001, with green hues being reacted to faster than blue hues on average. There was also a main effect of typicality, F(1,23)=9.300, p<.01, with the more typical color hue of a color pair serving as the target leading to a faster average reaction time than when the atypical member of the same pair was the target. There was an interaction of typicality and labeling condition,

$F(1,23)=4.973$, $p<.05$, represented by a typicality effect in the before-task labeling condition while there was not a clear influence of typicality in the after task labeling condition. There was a main effect of labeling condition, $F(1,23)=6.674$, $p<.05$, with the after-task labeling group's reaction times being faster than the before-task labeling group's reaction times.

Discussion

The main effects of discrimination type and labeling condition, with an absence of interactions between the discrimination type, visual field and labeling condition variables, constitute a different pattern than the results of the Gilbert et al. (2006) experiments. The categorical perception effect was present as expected, with the between-categories discrimination being reacted to faster than the within-category discriminations. The before-task labeling condition of this experiment followed the same procedure as the Gilbert et al. experiments, yet there was no lateralized categorical perception effect in the present results, only a categorical perception effect that was equally strong for stimuli presented in either visual field.

This pattern of results suggests that there is no hemisphere-specific influence of processing occurring during this experiment. Despite the previous research on lateralized categorical perception, portions of language being lateralized to the left hemisphere did not facilitate faster reaction times as a consequence of verbal and perceptual processing coinciding during the visual search task. The active recruitment of linguistic processing did not selectively facilitate processing in the left hemisphere. The lack of an interaction of discrimination type, the indicator of the categorical perception effect, with visual field and/or labeling condition suggests that the strength of the categorical perception effect is independent of these variables. This finding was unpredicted based on the previous research and surprising.

Interestingly, the before-task labeling procedure actually slowed down participants' reaction times independent of the visual field and discrimination type variations in the task. This result was also unpredicted and, in fact, counter-intuitive. If activating labels gives participants more information with which to distinguish the color hues, particularly on the between-categories trials, the straight forward prediction would be for the before-task labeling participants to be faster than their after-task labeling counterparts. Instead, the act of labeling the color hues prior to the visual search task slows down reaction times by about 40 milliseconds.

Due to the lack of a labeling condition by discrimination type interaction, this is an effect independent of categorical perception. By labeling the colors prior to the task, the participants appear to be engaging a different mode of processing than if they had not. There is additional cognitive processing that is taking about 40 milliseconds to accomplish, but as to what exactly that processing encompasses, it is hard to say. From the present experimental manipulations, we can suggest that it does not have to do with the processes underlying categorical perception as the strength of the effect holds across the labeling conditions, and that it does not have to do with lateralized processing since the visual fields were equally affected by the labeling manipulation.

The typicality results interestingly were affected by the labeling manipulation where the categorical perception effects were not. The typicality effect was in the predicted direction for the before-task labeling condition but was less strong in the after-task labeling condition. The labeling manipulation interacted with the typicality variable, suggesting that active labeling of the colors strengthened the influence of typicality on the visual search response time. This was an exploratory analysis based on findings from a task that requires memory and incorporates more processing time into the task. If this pattern holds, it could reflect the influence of typicality, which is a property of concept membership, on processing occurring within 500 milliseconds. Only when labels were activated did category typicality have an effect, showing that there is an online, interactive component to visual processing on a short timescale.

The color stimuli in this experiment were insufficiently controlled. The color hues were calculated precisely but the equipment used to produce the final colors displayed had a large amount of uncontrolled approximation and variation. For this reason, the suggestions just discussed from the data patterns must be considered tentative.

Additionally, the use of the *blue*/*green* boundary may not be the best test boundary for creating a non-linguistic condition out of the after-task labeling procedure. The participants could be spontaneously activating their color names due to their strong association with the colors, resulting in the equally strong categorical perception effect in the after-task labeling condition and before-task labeling condition. This would be consistent with the Stroop effect (Stroop, 1935) in which participants have trouble suppressing the color name for the color of the ink when reading an incongruous color word; the activation of the visual color name is stronger than the activation of the written color name. Experiment 2 was designed to address this point.

Experiment 2: Effect of Labeling on Discrimination of Non-Basic-Level Colors

Experiment 1 was designed to use the same *blue*/*green* boundary that previous research (Gilbert et al., 2006; Drivonikou et al., 2007) has tested. However, the boundary does not provide a full separation of linguistic vs. non-linguistic processes on categorical perception. There was activation of the labels for the color stimuli in the before-task labeling conditions by design, but additionally, with a basic boundary for English speakers such as *blue*/*green* there was a spontaneous labeling process that did not depend on a language context, as shown by the pervasive and consistent categorical perception effect in the Experiment 1 after-task labeling condition. This spontaneous process potentially engaged the linguistic processing of the stimuli. Therefore, Experiment 2 is designed to use a non-basic color boundary as the test boundary in the same task as Experiment 1. Since there is less of a chance of spontaneous linguistic category activation, Experiment 2 has a greater possibility of reflecting perception independent from linguistic influence in the after-task labeling group – while still leaving room for a lexical influence on perception to come into play when names are explicitly activated by a before-task naming procedure. We predicted that there would be a stronger categorical perception effect in the before-task labeling group. Due to not getting a lateralized categorical perception effect in Experiment 1, we did not have a prediction of finding the lateralized effect but will test for it. Finally, we predicted a replication of the before-task labeling group having overall slower reaction times than the after-task labeling group.

We added a sex variable to Experiment 2. This was to look at whether the average color naming competence of the sexes, particularly on sub-category boundaries, would effect the reaction times, as it has in other experiments using color stimuli (Stroop, 1935). If sex were to interact with the other variables, it would be expected that women would have more of an effect of naming, with the naming tapping into more conceptual knowledge, than men. This would present as a three-way interaction of sex by pair type by labeling condition. If the lateralized effect to present in this experiment, a four-way interaction of sex by visual field by pair type by labeling condition would represent a difference in the strength of the lateralized categorical perception due to both labeling and sex.

Pretest

While the colors for Experiment 1 were calculated to be centered on the pre-established blue/green boundary for English speakers, there was no pre-determined line within the category of green for the hues to be based around in Experiment 2. We wanted to use stimuli that could be divided by two labels reliably by a majority of English speaking students. Four hues were created with a constant brightness and saturation. Hue was varied evenly and the colors were all on the green side of the blue/green border. The initial hues were judged to be dividable into two groups by the experimenter and were then tested.

Procedure.

The pretest was run on a separate group of participants.

The first pretest procedure began by displaying the four hues and required the participant to choose two color labels of their own by which to divide the hues. They then did the same naming task as in Experiment 1 using the *green* hues and their own labels. The labels produced by the participants who were able to consistently label the color chips in such a way that they separated them along the central color boundary were analyzed for highest frequency. The first set of color hues tested on seven participants was not divided two hues to each label. A second set of color hues was created adjusting to the boundary that participants were using to divide the hues. Thirty-two participants were tested in this set. Approximately half of the participants used some form of *sea* (sea, seafoam, ocean, etc.) for the bluish green pair and about half used some form of *grass* (grass, forest, moss, etc.) for the yellowish green pair.

Labels	L*	a*	b*
A - *Sea*	63	-55	7
B - *Sea*	63	-53	17
C - *Grass*	63	-49	26
D - *Grass*	63	-44	34

Table 2. The CIE L*a*b* coordinates of the color stimuli in Experiment 2.

The next group of 20 participants was asked to do the same labeling task used in Experiment 1 and the first iteration of the pretest, but this time the participants were supplied with the *sea* and *grass* labels. The majority of participants (60%) met the naming criteria of less than 3 ‘incorrectly’ named.

Method

Participants.

Sixty-eight undergraduate and graduate students at Lehigh University (32 female) participated in the main experiment for course credit or as volunteers. As in Experiment 1, participants were pre-screened to be right-handed, have normal or corrected-to-normal vision, normal color vision, and consider English to be their primary language. None of the participants participated in Experiment 1.

Design.

The experiment had a 2 x 2 x 2 x 2 Mixed Design. Visual field (left vs. right) and discrimination type (between- vs. within-category) were within-subject independent variables. The labeling procedure (before- vs. after-task), and sex (male vs. female) were between-subjects independent variables. The dependent variable was reaction time measured from display onset to the button push indicating a color discrimination had been made.

As in Experiment 1, just for the within-category trials there is a test of the influence of typicality on reaction times using a 2 x 2 x 2 Mixed Design. The typicality variable has the context color being either more or less typical than the target color, and the pair variable represents either *sea green* or *grass green*. Typicality and pair are within-subjects variables. Labeling condition, before-task or after-task labeling, is a between-subjects variable.

Materials.

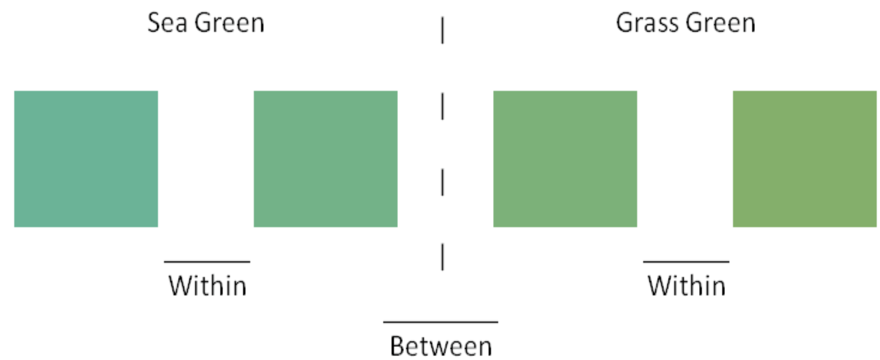

Figure 6. The four color stimuli of Experiment 2. The two colors on the left were pretested to be called *sea green* by native English speakers and were a within-category discrimination pair, the two colors on the right were pretested to be called *grass green* by native English speakers and were the second within-category discrimination pair, and the two central stimuli were the between-categories discrimination pair.

The color stimuli were calculated in standardized color space as in Experiment 1. The colors were created using more advanced equipment. Without a colorimeter, the colors displayed in Experiment 1 may not have been precisely the colors that were calculated when determining the CIE coordinates. Also, the computer monitor used in Experiment 1 was a basic low-end monitor that distorted the color stimuli on the screen by viewing angle. The use of a Spyder3 colorimeter and a Dell UltraSharp U4210 monitor was implemented when creating the new stimuli. The CRT monitor used in Experiment 1 was replaced by a monitor which has in-plane switching technology that allows for a 180° viewing angle, allowing the color stimuli presented at different points on the screen to look like the same hue from the stationary perspective of the participant.

The stimuli were calculated in CIE L*a*b* color space. Rather than initially using L*a*b, the colors were first calculated in CIE L*C*H° which is another standardized color space that has coordinates for brightness (L), saturation, a.k.a. chroma, (C), and hue

(H). In this color space, brightness and saturation can be held constant by maintaining the same values in the L and C coordinates. Hue could be varied equally by adding or subtracting the same unit differences to a starting value. Thus, the CIE L*C*H° color space was easiest to work with while determining the colors used in the pretest. The final coordinates were then converted to CIE L*a*b* color space (see Fig. 13 above).

The color chips were created in Adobe Photoshop. Colors can be input into the program using CIE L*a*b* coordinates in a device-independent file. The file was then converted to be device-dependent. In Experiment 1, this was done using a generic color profile that was not specific to our monitor. Here a colorimeter was used to create a color profile uniquely calibrated to the monitor used in the experiment. The colors were converted using the monitor-specific color profile creating a JPEG image file. This process ensured that the colors were shown on the specific monitor as they were intended to be shown by the calculations. Finally, the files were converted to bitmap format, which is the picture file type most easily handled by E-Prime 2, the experiment design software.

Procedure.

The procedure was the same as the procedure in Experiment 1 with one small exception: in order to strengthen the labeling manipulation, there was an additional shortened labeling task between the blocks of the visual search task, with each color hue being presented and named twice, in order to keep the labels activated during the visual search task. The participants were simply told that they would repeat a shorter version of the original naming task between blocks with not further explanation for why they were doing the task.

Results

Two participants reported not being able to see the difference between the colors in the after-task naming condition and did not complete the task. One participant did not follow the experiment instructions. Another fourteen participants did not meet the accuracy threshold, which was lowered to 80% from the 85% threshold in Experiment 1 to reflect the greater task difficulty during the visual search task with all *green* color hues. An additional eleven participants did not meet the naming criterion that 3 of the last 4 naming trials of the main labeling task be correctly labeled according to the experiment-determined labels. Six participants from the before-task labeling group were excluded because they had two or more inter-block labeling trials incorrect, indicating that they were not maintaining a steady boundary placement throughout the experiment. One final participant had reaction times more than 2 SD from the grand mean. After removing the data from these participants, the data of 33 participants were analyzed below, 18 (7 women) in the before-task naming condition and 15 (7 women) in the after-task naming condition.

The reaction time data was analyzed using a 2 x 2 x 2 x 2 Mixed Design ANOVA. There was a significant main effect of discrimination type $F(1,29)=22.448$, $p<.001$. This indicates that for the sea/grass distinction, the basic categorical perception effect was present. There was also a marginal main effect of labeling condition, $F(1, 29)=3.868$, $p=.059$, repeating the pattern from Experiment 1 of faster reaction times in the after-task

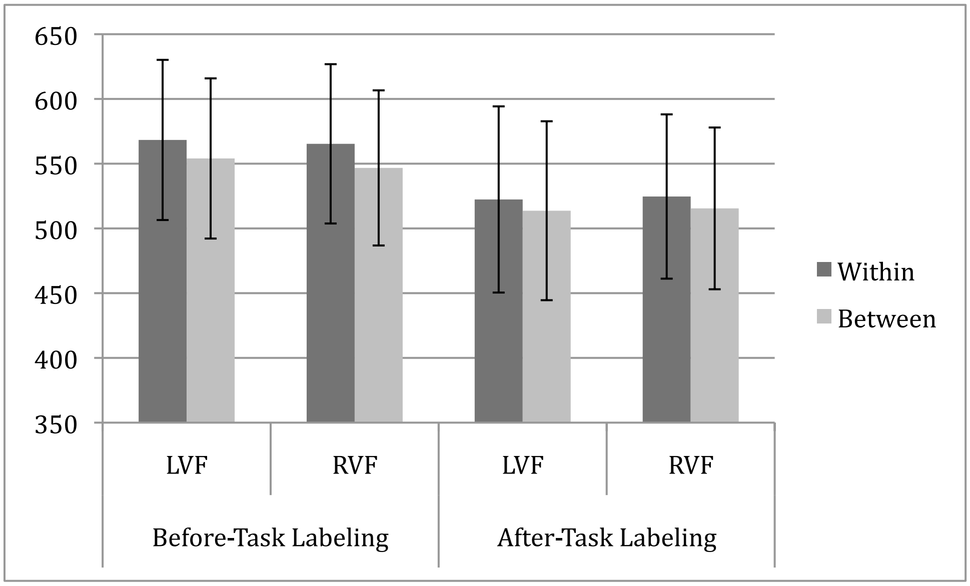

Figure 6. Experiment 2 reaction times as a function of discrimination type, visual field, and labeling task. The error bars represent +/- 1 standard deviation.

labeling condition than in the before-task labeling condition. The three-way interaction of discrimination type, visual field and labeling condition was not significant, $F(1,29)=.058$, $p>.1$. An influence of the visual field of presentation was not found as in Experiment 1. The two-way interaction of discrimination type and labeling condition was not significant, $F(1, 29)=2.084$, $p>.1$.

There was also a significant interaction of labeling condition and sex, $F(1, 29)=8.601$, $p<.01$. Women reacted faster in the after-task naming condition than in the before-task naming condition while men reacted faster in the before-task labeling condition. The number of participants per group is uneven, particularly for the women. There are 11 women in the before-task labeling group and only 6 in the after-task labeling group. With such a small *n* this is not a very reliable test of significance.

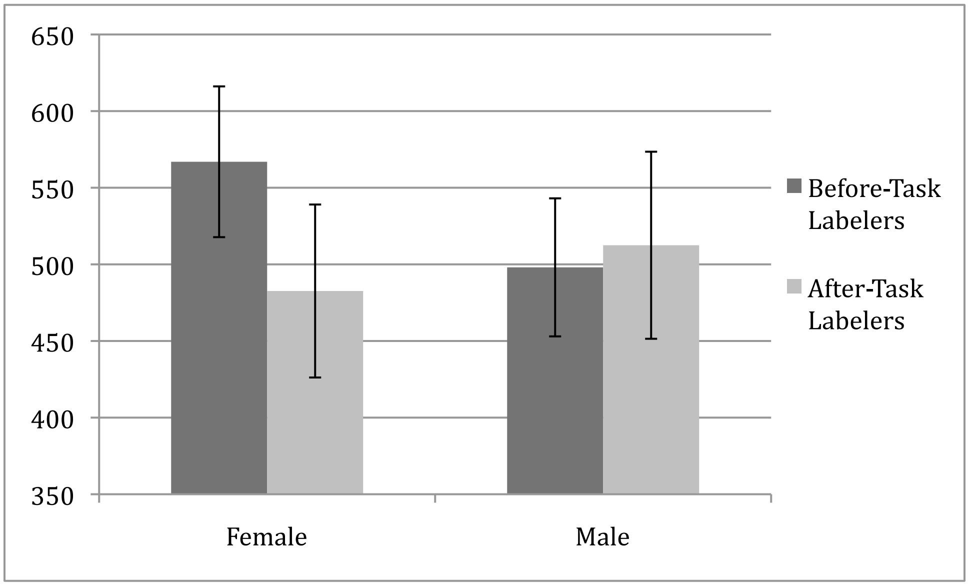

Figure 7. The interaction of labeling condition and sex in Experiment 2. The error bars represent +/- 1 standard deviation.

Using a 2 (pair) x 2 (typicality of target) x 2 (labeling condition) Mixed Design ANOVA, there was a main effect of typicality, $F(1,31)=5.870$, $p<.05$, indicating that regardless of the hue pair or the labeling condition reaction times were faster when the more typical hue was the target color in the visual search task. An interaction of pair and typicality was present, $F(1,31)=10.466$, $p<.01$, due to the greater influence of typicality on the blue pair than on the green pair which showed the opposite pattern. Finally, there was a marginal main effect of labeling condition, $F(1,31)=4.025$, $p=.054$, again showing that the after-task labeling reaction times were faster than the before-task labeling reaction times.

Looking just at the sea green data which follows the pattern of the Experiment 1 results with a 2 (typicality of target) x 2 (labeling condition) Mixed Design ANOVA, there is a main effect of typicality, $F(1,31)=19.873$, $p<.001$, a main effect of labeling condition, $F(1, 31)=4.245$, $p<.05$, and a marginal interaction of typicality and labeling

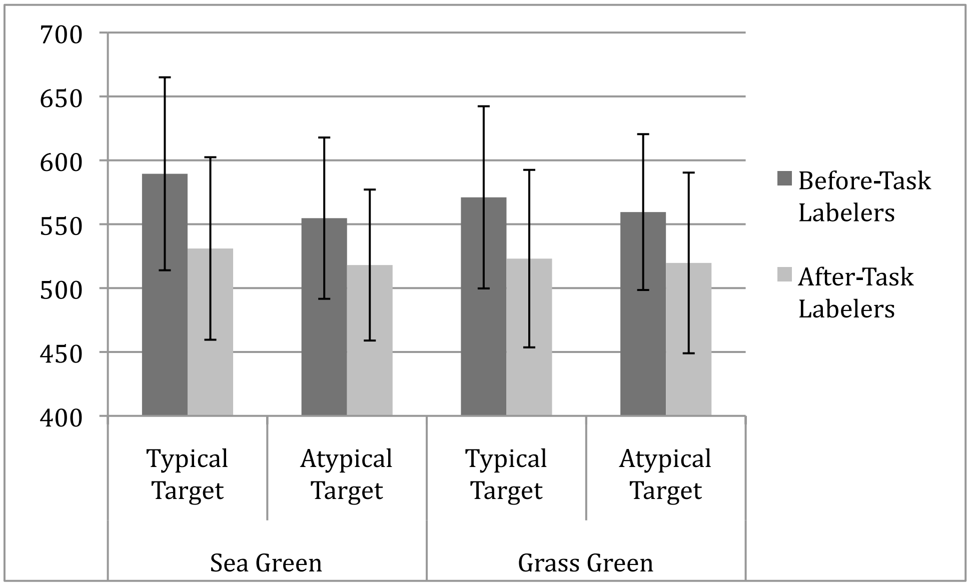

Figure 8. Within-category trial reaction times as a function of pair, typicality, and labeling condition for Experiment 2. The error bars represent +/- 1 standard deviation.

condition, $F(1,31)=4.136$, $p=.051$. These results confirm the pattern seen with the blue and green hues in Experiment 1, that the more typical color hue as the visual search target leads to faster reaction times and that the difference is stronger when there has been before-task labeling prior to the visual search task.

Discussion

The categorical perception effect was present in Experiment 2. The categorical perception effect was not lateralized, was not affected by the labeling manipulation, and was not affected by the sex of the participants. The categorical perception effect was steady and reliable across conditions. There was no hemispherically based facilitation found in the reaction time data. Language lateralization does not appear to have an impact on categorical perception, as in Experiment 1.

The main effect of labeling condition was marginally significant, similar to the significant result in Experiment 1. Again, the before-task labeling condition produced slower average reaction times than the after-task labeling condition, with a difference of about 50 milliseconds. As the labeling condition variable did not interact with the other independent variables, it is again hard to say what this labeling condition based reaction time difference represents in terms of changed processing. Finding the same pattern of the after-task labelers being on average faster than the before task labelers as in Experiment 1 lends itself to the conclusion that there is truly a change in processing based on the labeling manipulation, though we can only speculate as to what that change in processing encompasses.

The sex and labeling condition interaction reflects a greater influence of the labeling procedure on females than males. This result is consistent with the Stroop (1935) finding of female participants having a stronger reaction to color stimuli than male participants. Particularly at the sub-category name level, the color words used in the experiment are likely to have better established concepts in women's minds than in men's minds. The sex-based interaction does not differentiate between a perceptually based attunement to color categories or an online influence of genuinely conceptual processing, however. It is possible that having more developed color knowledge attunes visual processing to perceptual distinctions along color boundaries and/or provides more clearly distinguished categories to call upon. That sex and the labeling condition variables did not jointly interact with the discrimination type variable or the discrimination type and visual field variables indicates that the sex based difference reflected in the two-way interaction does not affect the same underlying processes as categorical perception, lateralized or non-lateralized.

The typicality results showed a more complicated pattern than was revealed in Experiment 1. The typicality effect was in the predicted direction for the before-task labeling condition for the *sea green* hues but was less strong in the after-task labeling condition for the *sea green* hues, as in Experiment 1. The pattern of reaction times split by typicality was less clear in the *grass green* hue data. The pattern reversed, with cases where the color hue farther from the color boundary (which we considered to be the more typical instances) served as the visual search target producing longer reaction times than when the color hue closer to the color boundary (which we considered to be the less typical instances) served as the target. The difference between the typicality levels was larger for the before-task labeling condition than the after-task labeling condition. One possible reason for this could be that the concept of grass green is a less developed and ubiquitous concept than the ones for sea green as well as green and blue. If the participants don't have a representation of a typical grass green color to activate and use to produce typicality effects, no typicality effects should be seen. Since there does seem to be something occurring with the typicality asymmetry in the grass green before-task labeling condition reaction times, it is possible that our expectation for what is higher vs. lower typicality was wrong and participants considered the color hue closer to the color boundary to be more typical than the color hue further from the boundary. A follow-up test norming the color hue typicalities could resolve this issue.

The labeling manipulation interacted with the typicality variable, suggesting that active labeling of the colors strengthened the influence of typicality on the visual search response time. This was an exploratory analysis based on findings from the two-alternative forced choice task that requires the use of non-perceptual memory and incorporates more processing time into the task. If this pattern holds, it could reflect the influence of typicality, which is a property of concept membership, on processing occurring within 500 milliseconds.

General Discussion

We conducted two studies to test the effect of labeling on lateralized categorical perception of color. In Experiment 1, the predicted pattern of results, a stronger categorical perception effect in the right visual field/left hemisphere in participants who explicitly labeled the color stimuli, was not found. An effect of labeling on overall processing time, but not on the strength of the categorical perception effect, was found. The influence of labeling on the categorical perception effect was explored further by changing the color boundary to a sub-category distinction in Experiment 2. It was reasoned that the lack of a labeling influence on categorical perception could be due to the accessibility of the basic-level terms even without before-task labeling. Again, there was no influence of the labeling manipulation or visual field on the strength of the categorical perception effect. The influence of labeling on overall processing was found again in Experiment 2. The influence of sex of participant on reaction time performance during the visual search task was only examined for Experiment 2. There was an interaction such that women who labeled the colors before the task were significantly slower than the women who did not label the colors before the visual search task, while there was only a small reaction time difference for the men in the two labeling conditions in the opposite direction.

Lateralized Categorical Perception?

Labeling the stimuli as *blue* or *green* before making same/different color decisions in the Experiment 1 did not strengthen the lateralized categorical perception effect in Experiment 1 contrary to our predictions. In fact, lateralized categorical perception was not found to be present at all. Lateralized categorical perception was also not present in Experiment 2. Nowhere in the data collected in the present studies was there evidence that visual field had an influence on the reaction times of participants doing the visual search task.

Previous researchers (Drivonikou et al., 2007; Gilbert et al., 2006; Roberson et al. 2008) have shown a lateralized categorical perception effect using very similar visual search paradigms. In the original Gilbert et al. (2006) experiments, there was no categorical perception effect in the left visual field/right hemisphere. In subsequent experiments (Drivonikou et al. 2007), a signature categorical perception effect of faster between-category discriminations than within-category discriminations was found in the left visual field/right hemisphere, though significantly weaker than the effect found in the right visual field/left hemisphere. In the Roberson et al. (2008) experiment, strong categorical perception was present for both visual fields. Only by splitting the data into fast and slow responders did they find the lateralized categorical perception effect. Now in the present data, with a unimodal distribution of participant average reaction times, not even unjustifiably splitting the participants into fast and slow participants can identify a lateralized categorical perception effect in the data. The evidence of lateralized categorical perception has become weaker with each published experiment. Since null results are harder to publish, the experiments like the present ones that set out to investigate the effect but do not find it are unlikely to be in the publication record.

However, the data from the present experiments do not present an exact replication of the Gilbert et al. (2006) results in ways besides the lateralized categorical perception. The average reaction times for the before-task labeling condition of Experiment 1, the condition most similar to the Gilbert et al. procedure, are about 100 ms longer than the Gilbert et al. average reaction times. There were minor differences in the procedures: We had participants type out 'blue' and 'green' rather than press 'b' or 'g' during the labeling task. Additionally, we used slightly different colors to exert better control over the perceptual distance between them, and we used a CRT monitor rather than a flat screen, either of which could have resulted in less discriminable stimuli in our study compared to the Gilbert et al. stimuli. Finally, we didn't monitor eye fixation to ensure that the visual fields remained independent though Gilbert et al. did not do this either, relying on the short exposure time of the visual display. Somewhere in amongst these changes and the presumption of fixation could be experimental differences that account for our different results.

Alternatively, in a more complex interpretation of the data, it could be claimed that a lateralized categorical perception effect due to language activation is present in the data. This argument rests on the developmental results of Franklin et al. (2008) reviewed in the introduction. Franklin et al. found that toddlers who did not know the color categories well had lateralized categorical perception with a stronger categorical perception effect in the right hemisphere. Perhaps this greater sensitivity to focality does not disappear in adults, but in the adult lateralized categorical perception effect with the stronger categorical perception in the left hemisphere, the baseline without language is below the strength of the effect in the right hemisphere, and language not only strengthens the effect but strengthens it up to and past the visual advantage for the right hemisphere. In this case, our null hypothesis of equal categorical perception effects in the two visual fields/hemispheres does not actually correspond to the case of absence of language influencing responses. Perhaps the Franklin et al. results should be taken to mean that we should adjust the interpretation so that a lateralized categorical perception effect with a stronger categorical perception effect in the right hemisphere means absence of a language influence while equal or stronger categorical perception in the left hemisphere indicates the effect of language.

It is unclear whether the present results reflect lateralized categorical perception not being as robust a phenomenon as originally claimed, a problem with implementing the key components of the Gilbert et al. procedure, or if the assumption of equal perceptual sensitivity of the hemispheres is a bad assumption. Further experiments that experimentally disambiguate these possibilities are needed,.

The Effect of Labeling on Categorical Perception

Categorical perception (non-lateralized) was found to be present in both labeling conditions of Experiment 1 and Experiment 2. In Experiment 1, the participants were being tested on a familiar and ubiquitous basic color boundary. Many of the participants in the after-task labeling condition, the non-linguistic context condition, reported explicitly thinking about the color labels, therefore being in a linguistic context in spite of the experimental manipulation. The manipulation may not have created a non-linguistic task for the after-task labeling condition as was intended. Therefore in Experiment 2, the participants were tested on a sub-category boundary. The sub-category boundary was familiar to the participants but not ubiquitously relevant in the participants' daily lives. Fewer participants reported explicitly thinking of color names in Experiment 2, yet the labeling manipulation again did not produce a statistically significant change in the strength of the categorical perception effect. These patterns of results appear to indicate that there is not an influence of explicit labeling on the strength of the categorical perception effect.

Between the lack of a lateralization of categorical perception in these experiments and a lack of influence of the labeling manipulation on the strength of the categorical perception effect, the categorical perception effect itself was robust and of a reliable strength. If the first interpretation of the lack of lateralized categorical perception were correct, categorical perception appears to be a result of cognitive processes occurring early in processing in both hemispheres and it appears that recent explicit language activation does not have an influence on those cognitive processes. These results counter the results and conclusions of the original lateralized categorical perception research (Gilbert et al., 2006) that categorical perception for color depends on online activation and access to linguistic information stored in the left hemisphere.

Alternatively, if the reason we did not get lateralized categorical perception in the present experiments was due to something about our procedure, getting a strong categorical perception effect in both visual fields, for both labeling conditions, in both experiments without a lateralization effect shows that what can disrupt the lateralization effect and what can disrupt the categorical perception effect are different.

Finally, however, if the third explanation for the lack of a lateralized categorical perception effect, that the effect is there and currently undetectable, were true, the categorical perception results of each hemisphere would be reflecting different processing, with the processing of the left hemisphere being affected by language.

Unfortunately, without distinguishing between the possible explanations for the lack of a lateralized categorical perception effect, the explanation for what cognitive processes are underlying categorical perception remains unclear.

Labeling Effects on Overall Processing Speed

While labeling the colors before the task did not change the strength of the categorical perception effect, it did have an effect on overall processing. In both Experiment 1 and Experiment 2, the participants who labeled the colors prior to doing the visual search task were significantly slower on average than the participants who did not label the colors prior to the task. This was an unexpected and counter-intuitive finding. According to Gilbert et al. (2006), the facilitation of the response seen in the right visual field/left hemisphere for the between category discriminations is due to online linguistic activation. That facilitation is a reduction in reaction time for those trials, the opposite of the increase in reaction time found (regardless of discrimination type or visual field) in the present experiments. Rather than facilitate processing and responding to the visual search discriminations, explicit labeling inhibited or added to processing resulting in a slower response time. Even though this finding was unexpected and therefore statistically less certain than a predicted result, it was replicated from Experiment 1 to Experiment 2.

What exactly the slow down in reaction time due to labeling for the visual search task reflects in terms of processing is unclear that this point. It appears to be unrelated to the categorical perception effect. Preliminarily, the effect does seem to be influence by the sex of the participant, at least in Experiment 2 where sex was a variable. Women were slowed down on average by labeling before the visual search task with men showing little difference, and what difference there was for men happened in the opposite direction with male participants labeling before the task having a slightly faster reaction time on average. One speculative cause of this difference could be the gender specific role of subcategory color labels. Women are more likely to recognize and use finer color distinctions than men and therefore are more likely to have label-based knowledge to bring to bear on the task after labeling the colors. This would indicate that the cause of the inhibitory labeling effect could have to do with stored conceptual knowledge, though not necessarily linguistic conceptual knowledge since there was no visual field interaction. But again, this is speculative and more research is needed to locate the cause of the effect.

Habitual Thought vs. Thinking-for-Speaking

The effect of linguistic context on the categorical perception effect was not present. The results from the experiments presented here, according to the logic laid out in the introduction, appear to support the Whorfian (1959) habitual thought hypothesis over the Slobin (1996) thinking-for-speaking hypothesis. However, the logic laid out in the introduction followed from the Gilbert et al. (2006) inferences that lateralized categorical perception is a linguistically based effect. Yet, in the present experiments there was no evidence of lateralized categorical perception. Since there was no lateralized categorical perception, there is no reason to presume that the categorical perception exhibited by the participants in the current experiments relied on access to linguistically based processing, which was inferred by Gilbert et al. based on the lateralization of categorical perception to the left hemisphere which is language dominant. The prediction supporting the Whorfian hypothesis in these experiments was built off an assumption that was not met and therefore the data do not support any version of the Whorfian hypothesis.

The only clear, or at least clearly inferable, effect of language in these experiments is the labeling effect in which before-task labeling slows down response times relative to after-task labeling. Although it is a context based effect, it is unclear given the lack of an interaction with discrimination type, our measure of categorical perception, whether the labeling effect is happening at a linguistically influenced thought level that pertains to the Whorfian hypothesis and the thinking-for-speaking hypothesis. The categorical perception effects found could reflect only non-linguistically based differences in ease of some color discriminations related to non-linguistically determined focal color regions. The increased reaction time in the before-task labeling condition could be something as simple as more active processes occurring without meaningful conceptual interaction—increased cognitive load. Without further investigation, the nature of linguistic influences on thought remains an open question.

Within-Category Typicality Effects and the Conceptual influence on Perception

In a secondary analysis, we looked at whether there was a typicality-based asymmetry in the reaction time data dependent on which of a particular pair of stimuli was the target vs. the context color for within-category discrimination trials. For three of the four color categories, we found an asymmetry in the before-task labeling condition such that if the target color was more typical than the context color, the reaction time was shorter than in the reverse configuration. This aligns with the Hanley and Roberson (2011) results, extending their findings from a memory based accuracy categorical perception task to a more immediately perceptual task in the present visual search task.

This analysis contributes to the perceptual and conceptual processing debate that centers on the categorical perception phenomenon (Lupyan et al. 2010; Roberson et al. 2008). The labeling condition variable interacted with typicality in the present experiments. Only when the linguistic categories were explicitly activated prior to the visual search task did the asymmetry based on typicality appear in the data. Since typicality is a property of category membership, it can be inferred that labeling the colors activated the categories more than perceptually experiencing the colors alone did for the non-labeling participants. Furthermore, since categorical information had an influence on reaction time in the visual search task, clearly some aspects of linguistic/conceptual information was affecting perceptual processing.

To take this point deeper, comparing the two-alternative forced choice task of the Hanley and Roberson (2011) experiments and the visual search task of the present experiments, the two-alternative forced choice task is a memory task while the visual search task is more basically perceptual. In the two-alternative forced choice task, participants are shown a stimulus, in this case a color, and tasked with remembering it over the course of a delay prior to being given two color options and asked which was identical to the original. Here the color must be stored in memory over the course of the delay and there is time for the color to be categorized and fully processed prior to a decision being made 15 or more seconds later. In the visual search task, the task is much more immediately perceptual. Here both of the color stimuli of a given trial are on the display simultaneously. They can be perceptually compared to each other in order for the discrimination between the target color square and the context color squares to be made. Yet, before-task labeling produces an asymmetrical typicality effect. Since typicality is a property of category membership, the implication is that categorical knowledge is influencing processing on a time scale of half a second. Furthermore, since the effect is strengthened by, if not dependent on, before-task labeling, it follows that the linguistic-category-relevant context induces an interaction of the conceptual, categorical knowledge with perceptual processing. This cannot be a purely perceptual effect, one based on proximity to a perceptual focal, or most typical, color since it is not present when labeling has not occurred before the visual search task.

Future Directions

The three explanations for the lack of a visual field and discrimination type interaction, (1) the lateralized categorical perception effect is not robust, (2) the current experimental procedure was flawed, or (3) the current presumed baseline of the same perceptual abilities across hemispheres is a false one, need to be disambiguated to understand the relationship between online language activation and categorical perception of color.

The second explanation, that there was something different about our experimental procedure compared to that of Gilbert et al. (2006) that disrupted the effect, is most straightforwardly tested. The procedures could be directly compared in the same lab, using the same equipment and the same experimenters to see if there is some small difference between the current experiments' procedures and that of Gilbert et al. (2006) that reliably changes the pattern of results. The before-task labeling condition of Experiment 1 was intended as a replication of the Gilbert et al. main finding of lateralized categorical perception, but lateralized categorical perception was absent from the present data. Confirming the presence or absence of a lateralized effect through additional replications of the procedure will guide future research toward or away from the lateralized categorical perception phenomenon. Of particular interest would be testing whether the full word vs. initial letter labeling task disrupted the effect. The full word input was added to strengthen the word category activation but perhaps just acknowledging the categories quickly rather than fully producing the labels provides a stronger categorization context.

The complex theory that the left hemisphere categorical perception advantage of Gilbert et al. (2006) is a result of online language activation while the right hemisphere categorical perception advantage of pre-linguistic toddlers (Franklin et al., 2008) is a result of an uneven focality sensitivity is less clearly testable. One possibility would be to test adult speakers of languages with few color terms on color category boundaries that they are not familiar with, but are found in many languages using the lateralized visual search paradigm. A similar procedure to the adult test used in the present experiments could be used without as much influence of language, since the participants wouldn't have relevant linguistic categories. If a stronger categorical perception effect were found in the right hemisphere, that would indicate a new comparison baseline would be warranted.

Any future research using the lateralized visual search paradigm should use the improvements that were implemented on the materials in Experiment 2, including the use of a monitor that more evenly presented the same color to a viewer from different points on the screen, as well as using a colorimeter to increase the precision of the color stimuli. Without these improvements, the Experiment 1 results must be taken cautiously, though the results being largely confirmed by Experiment 2 allows us to have a bit more confidence than the materials alone warrant. Future experiments should use the improvements to give their results more inherent confidence based on less sources of uncontrolled variance.

The surprising inhibiting effect of before-task labeling should be pursued further. Why would online activation of linguistic categories slow or add to processing? From the present experiments it seems that it is not a lateralized effect and does not strengthen or weaken categorical perception. Is it simply a result of the main task being the second task for before-task labelers? Would labeling colors not used in the main visual search task or naming stimuli from a completely different domain such as animals have the same effect? Since the effect was unexpected and we have little evidence of what the processing difference could be there are many avenues to be pursued in order to understand this effect.

Finally, following up on the typicality asymmetry for a perceptually based task is another important direction. As the typicality analyses were added post-hoc, typicality norms for the stimuli were not developed. The assumption was that the color stimulus further from the color boundary for each label was more typical, but that is a crude measure. As evidenced by the lack of an asymmetry for *grass*, particularly with sub-categories, the location of the prototype within the category is ill defined. By norming color stimuli for typicality, more fine tuned distinctions can be made between very typical, somewhat typical and atypical members of a category, providing a more complex look at the dimensions of the effect.

Conclusions

The lateralized categorical perception effect was absent from the present data. At the very least, this failure to line up with previous research raises a lot of questions. This research points to some possible areas where linguistically mediated categorical perception is not found, which can be as theoretically important as where the effect is found. However, the lack of clarity for what processes the categorical perception effect is reflecting makes drawing hard conclusions premature. Less ambiguously, the labeling manipulation appears to have an early effect on the influence of typicality on visual processing, indicative of a perceptual/conceptual processing interaction. Perhaps investigating the influence of online linguistic activation relative to the influence of typicality would be a more fruitful direction for examining the early interaction of perceptual and conceptual processing, while work on categorical perception tries to understand what cognitive processes are at work in the phenomenon.

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Vita

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