Right Away: A late, right-lateralized category effect complements an early, left-lateralized category effect in visual search.

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Abstract

According to the Sapir-Whorf hypothesis, learned semantic categories can influence early perceptual processes. A central finding in support of this view is the *lateralized category effect*—namely, the finding that categorically different colors (e.g., blue and green hues) can be discriminated faster than colors within the same color category (e.g., different hues of green), especially when they are presented in the right visual field. Because the right visual field projects to the left hemisphere, this finding has been popularly couched in terms of the left-lateralization of language. However, other studies reported bilateral category effects, which has led some researchers to question the linguistic origins of the effect. Here we examined the time-course of lateralized and bilateral category effects in the classical visual search paradigm by means of eye tracking and RT distribution analyses. Our results show a bilateral category effect in the manual responses, which is combined of an early, left-lateralized category effect and a later, right-lateralized category effect. The newly discovered, late, right-lateralized category effect occurred only when observers had difficulty locating the target, indicating a specialization of the right hemisphere to find categorically different targets after an initial error. The finding that early and late stages of visual search show different lateralized category effects can explain a wide range of previously discrepant findings.

Keywords: Sapir-Whorf hypothesis, Whorfian effect, Visual search, Category effect, Categorical perception, Eye movement.

Introduction

Categorically distinct colors are easier to find than categorically identical colors (e.g., Bornstein & Korda, 1984; Harnad, 1987, 2003). That is, an odd-man out color target in visual search will be found faster when it is categorically different from the distractors (e.g., blue amongst green) than when the target and distractor share a color category (e.g., different hues of green; Daoutis, Pilling & Davies, 2006). This occurs even when distance in colour space is controlled, which should theoretically render targets and distractors equally discriminable on a perceptual level (e.g., Gilbert, Regier, Kay & Ivry, 2006; Wolfe, 1998). Several studies have reported that such color category effects are lateralized, in that they are only present (Gilbert et al., 2006), or more pronounced (Drivonikou et al., 2007), when the target is presented in the right visual field (RVF) rather than the left visual field (LVF). Since the RVF projects predominantly to the left hemisphere (due to contralateral visual pathways), the finding of (hemispherically) left-lateralized color category effects has been linked to the lateralization of language, which is also left-lateralized in the majority of the population (Kay & Kempton, 1984; Frost, et al., 1999). For this reason, the left-lateralized color category effect has often been interpreted in support of the *Sapir-Whorf hypothesis*, that categories prescribed by language, can influence perceptual processes (e.g. Drivonikou et al., 2007; Gilbert, Reiger, Kay & Ivry 2006, 2008).

Still, a number of recent studies have questioned the linguistic origins of this effect. First, similar left-lateralized category effects have been obtained using unlabeled categories (Holmes & Wolff, 2012, see also Holmes & Regier, 2017). Second, several studies failed to find left-lateralized category effects, but found only bilateral effects (e.g. Witzel & Gegenfurtner, 2013; see also Brown, Lindsey & Guckes, 2011; Fonteneau & Davidoff, 2007; Holmes, Franklin, Clifford & Davies, 2009), giving rise to non-linguistic theories of these effects.

The aim of the present paper is to obtain fine-grained measurements about the time-course of lateralized and bilateral category effects in visual search, in order to assess whether the discrepant results can potentially be explained with reference to differences in the time courses of these effects (regardless of the possible linguistic or non-linguistic origins of the category effect).

What factors could explain the discrepant findings of bilateral versus lateralized category effects?

At a very basic level, a bilateral category effect could be due to a perceptual confound—for example, when the across-category targets[1] are perceptually more dissimilar, and therefore pop out more strongly than the within-category targets (e.g., green targets of different hues; Duncan & Humphreys, 1989; Witzel & Gegenfurtner, 2013). Such a perceptual confound would produce an "artificial" bilateral category advantage (but not a lateralized category effect). Alternatively, the presence of bilateral category effect (and/or the absence of lateralized category effects) could be due to eye movements: When observers are allowed to freely move their eyes, objects presented on the right side of the display will not necessarily project to the left hemisphere and vice versa, which could produce bilateral category effects (even if the category effect is left-lateralized). These explanations, however, are decidedly unsatisfying, given that bilateral category effects have been reported even in studies that carefully controlled for perceptual confounds and/or eye movement artifacts (see, e.g., Witzel & Gegenfurtner, 2013).

A potentially more compelling explanation of the frequent failure to obtain lateralized category effects is that left-lateralized category effects emerge only transiently, at an early stage

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[1] The green–blue boundary has been a popular boundary to investigate, and it has been argued that this boundary is most likely to result in perceptual confounds (see Witzel & Gegenfurtner, 2015, 2016 for details on the mechanisms specific to this boundary thought to result in spurious results).

of visual search (Roberson et al., 2008, see also Regier & Kay, 2009). According to this explanation, the commonly used measurements of manual response times (RT) may fail to show the lateralized category effect because mean RTs probe visual search at a very late stage (i.e., after visual selection, target identification, response selection and execution) and are therefore not very sensitive to effects occurring only at an early stage of visual search (Becker, 2010a, 2010b).

In line with this explanation, several studies have shown that the lateralized category effect indeed emerges at an early stage of visual search. For instance, when observers are asked to make a fast eye movement to a color target, a left-lateralized category effect is found in the saccadic latencies of the first eye movements (i.e., the time needed to visually select the target), indicating that early processes in visual search can already produce lateralized category effects (Al-Rasheed, Franklin, Drivonikou & Davies, 2014, but see Brown et al., 2011). Similarly, in an electroencephalographic (EEG) study, Liu et al. (2009) found a left-lateralized category effect in the N2pc (Liu et al., 2009), an event-related potential that indexes the time required to covertly attend to the target (Luck & Hillyard, 1994). Interestingly, in the study of Liu et al. (2009), the mean response times (RTs) simultaneously failed to show a lateralized category effect and instead revealed a bilateral category effect. This is a particularly intriguing result, as it suggests that an early, lateralized category advantage can transform into a bilateral category effect at later stages of visual search. Yet, the factors mediating the occurrence of bilateral effects versus lateralized effects remain unclear.

Here we examine how lateralized and bilateral category effects develop over time by monitoring participants' eye movements. In the experiment, participants were asked to search for an odd-one-out color target among 11 same-colored distractor stimuli and to indicate the location

of the target (right/left side) with a button press (see Figure 1). Four equiluminant colors that varied along the blue-green continuum were chosen as target and distractor colors (green, green–blue, blue–green, blue), and only the most similar color pairs were chosen as target and distractor colors; that is, green/green-blue and blue/blue-green constituted the within-category pairs, and blue-green/green-blue constituted the across-category pair. To ensure that the colors were categorised as blue versus green, participants were asked to label the four colors as either blue or green prior to the experiment.

Category effects were examined in two blocked conditions: In the *Saccade Task*, observers were instructed to make a fast and precise eye movement to the target, and time-course information was obtained by analyzing eye movement parameters at different stages of visual search. Following standard procedures, we tapped into early processes of visual search by analyzing the accuracy and latency of the first eye movements, and examined later processes (e.g., including distractor rejection) by probing the time required to select the target (for similar approachs, see Becker, 2010a, 2010b; Becker, Harris, Venini & Retell, 2014; Zhao et al., 2012). To examine whether the results would generalize to conditions in which eye movements were not allowed, observers also completed a *Fixation Task*, in which they had to remain fixated on the central fixation cross during the entire trial. In the Fixation Task, coarse-grained time-course information was obtained by analysing category effects separately for different portions of the RT distribution (fast vs. slow RTs).

Method

Participants. Sixteen right handed volunteers (nine female, seven male; *M*=24.31 years, *SD*=2.85 years) from the University of Queensland, Australia, participated for AUD10. All

participants gave informed consent, had normal or corrected-to-normal vision, and were

reimbursed with $10 (AUD) for participating in the experiment.
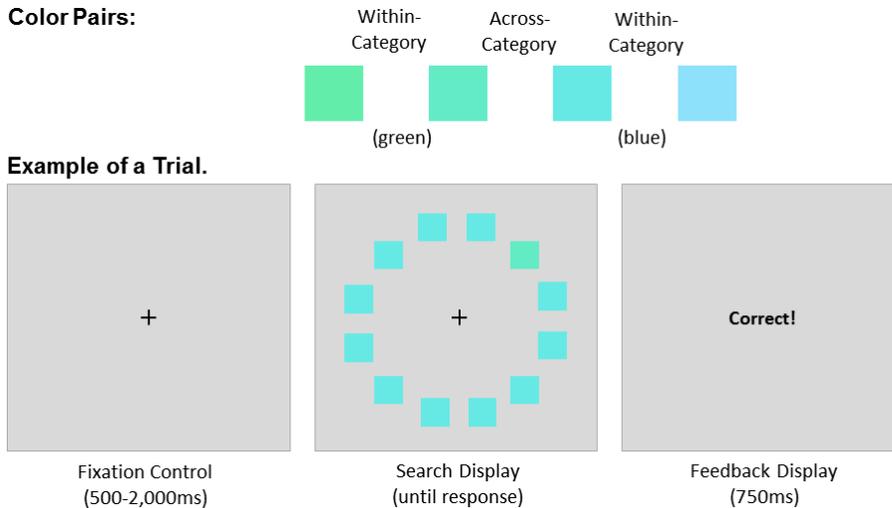
Color Pairs:

Within-Category / Across-Category / Within-Category

(green) (blue)

Example of a Trial.

| Fixation Control (500-2,000ms) | Search Display (until response) | Feedback Display (750ms) |

Figure 1. Example of a trial. Observers had to fixate on the central cross and report the location of the target by pressing the corresponding (left or right) button. Stimuli are not drawn to scale, and the colors may be different from the colors used in the experiment.

Apparatus. The apparatus consisted of a PC with a 2.4 GHz Intel Core 2 Duo CPU running

Presentation (Neurobehavioral Systems), a 21 inch color LCD monitor (BenQ FP92V;

resolution: 1,280 × 1,024; refresh rate: 75 Hz), a video-based infra-red eye tracker (EyeLink

1000, SR Research Ltd., Ontario, Canada), and a standard USB optical mouse.

Stimuli. The search display consisted of 12 colored squares (1.8° x 1.8°) that were presented

equidistantly (5.5°) away from a central black fixation cross (0.3° x 0.3°) against a light grey

background (see Fig 1). The colors of the search stimuli were blue (CIE x,y =.265, .273), blue-

green (CIE x,y =.243, .312), green-blue (CIE x,y =.252, .338) and green (CIE x,y =.266, .372)

and were matched for luminance with a CRS ColorCal colorimeter (63.9–64.6 cd/m^2; mean:

64.2cd/m^2).

Design. The visual search task consisted of two blocked conditions (Saccade Task, Fixation Task), presented in random order. Within each block, the target position (left/right hemifield) was chosen randomly. Target category was controlled: the colors for the target and distractor were always chosen in pairs of the most similar colors, resulting in three possible color pairs, of which blue/blue-green and green/green-blue were the within-category color pairs, and green-blue/blue-green was the across-category color pair. The target-distractor pairs were presented equally often for a total number of 300 trials per block.

Procedure. Prior to the experiment, observers were asked to label the colors as green or blue presented individually on the screen. Responses were recorded manually by the experimenter. To ensure stable and accurate eye tracking, observers were calibrated (9-point calibration), and a fixation control was implemented before each trial**.** This control was particularly important to ensure participants did not shift their head or eyes prior to the trial in such a way that would result in stimuli being projected to incorrect visual fields. A fixation cross was presented, and after participants continuously fixated within 1.3° on the central cross (for at least 500ms, within a time-window of 2,000ms) the search display was presented. If appropriate fixation was not registered by the eye tracker the participant was calibrated anew. The search display was presented until the participant made a manual response to indicate if the target was on the left or the right and the search display was followed immediately by a feedback display consisting of the words "Correct" or "Wrong" (in 12-pt Arial font presented for 750ms, followed by an intertrial interval [ITI] of 250ms), plus the words "No Fixation" when the participant had moved their eyes during the fixation task, or "No Eye Movement" when the participant had failed to make an eye movement in the saccade task (in which case the entire feedback display was presented for 1,250ms, followed by an ITI of 750ms).

In the saccade task, eye movements were attributed to a stimulus (target or non-target) when the saccade (eye movements with a velocity >30°/s or acceleration >8,000°/s²) ended within 1.5° of the center of the stimulus.

Results

Data. Prior to data analysis, outlier responses (RTs of <200 ms or >2000 ms), and trials where participants broke fixation (fixation task) or failed to saccade to a stimulus (saccade task) were excluded. This led to a loss of 7.68% of data in the fixation task (failure to fixate: 6.96%) and 17.81% of data in the saccade task (failure to saccade to a stimulus: 16.86%).

The results from the naming task showed that 100% of participants (n=16) correctly categorized the blue colors and 81% (n=13) correctly categorized the green colors. The visual search results did not differ when participants with an incorrect categorization judgement were excluded (probably because this applied only to very few participants); hence, in the following report all participants were included.

Mean RT. We analyzed the mean manual RT for both tasks with a 3-way repeated-measures ANOVA comprising the variables of task (fixation, saccade), visual field (target in LVF, RVF) and category (across- / within-category target). Manual RTs were significantly faster in the fixation task (*M*=556ms) than in the saccade task (*M*=656ms), $F(1,15)=16.72$, $p=.001$, $\eta_p^2=.53$, and faster for across-category targets than within-category targets, $F(1,15)=49.45$, $p<.001$, $\eta_p^2=.77$. Category effects (across-category RT minus within-category RT) were significantly larger in the saccade task than in the fixation task, $F(1,15)=5.3$, $p=.037$, $\eta_p^2=.26$ (see Fig. 2). Critically, however, the category effect did not interact with the target's visual field, $F(1,15)=2.4$, $p=.15$ (all other Fs<2.9, ps>.11). Thus, the RT results showed a clear bilateral category effect in the manual RTs, both in the saccade task and the fixation task (see Figure 2).

Mean Errors. The manual error scores are listed in Table 1. The same ANOVA computed over the mean errors showed that more errors were committed in the fixation task (M=4.11%) than in the Saccade Task (M=1.7%), $F(1,15)$=17.16, p=.001, η_p^2=.54 (all other Fs<4.3, ps>.05).

Table 1. Mean Errors for Across- and Within-Category Targets in the right and left hemifields (RVF, LVF).

	LVF		RVF	
	Across Cat	**Within Cat**	**Across Cat**	**Within Cat**
Fixation Task	3.08 [1.11]	6.18 [1.11]	2.31 [2.15]	4.88 [2.15]
Saccade Task	1.31 [0.36]	1.62 [0.36]	1.84 [0.74]	2.07 [0.74]

Numbers in brackets denote the standard error of the mean for within-subjects effects.

First Eye Movements to Target. To assess whether the results of the saccade task comprised an early, left-lateralized category effect, we next analyzed the accuracy of first eye movements to the target. A two-way repeated-measures ANOVA comprising the variables visual field (target in LVF, RVF) and target category (across-/ within-category target) revealed a significant main effect of target category, $F(1,15)$=11.79, p=.004, η_p^2=.44, and a significant Category × Visual field interaction, $F(1,15)$=6.84, p=.019, η_p^2=.31. As shown in Figure 3, participants selected the across-category target more accurately than the within-category target, and this category effect was significant only for RVF targets, $t(15)$=4.76, p < .001, not for LVF targets, t < 1. Comparing target selection for across-category targets between the visual fields revealed that across-category targets were selected more accurately when they were in the RVF than when they were in the LVF, $t(15)$=3.1, p=.008, whereas selection of within-category targets did not differ between RVF and LVF, $t(15)$=1.1, p=.26, thus reflecting a left-lateralized category effect.

Analyzing the latencies of first eye movements to the target in the same manner revealed only a significant main effect of color category, $F(1,15)$=8.0, p=.013 (all other Fs < 3.4, ps > .08). To

test whether the category effect was present both in the RVF and LVF, we computed two pair-wise t-tests. The results showed a left-lateralized category effect (similar to the proportion of first eye movements): Although, numerically, the category advantage was similarly large for RVF targets (10ms) and LVF targets (9ms), the category effect was only significant for RVF targets, $t(15)=3.0$, $p=.008$, not for LVF targets, $t(15)=1.5$, $p=.17$. Thus, in line with earlier findings, early processes in visual search (as indexed by the accuracy and speed of the first eye movement in a trial), show a clear left-lateralized category effect.

Target Fixation Latencies. To probe category effects at a later stage of visual search, we next analyzed the time from the onset of the search display to the point in time in which the eyes first fixated on the target. To ensure that the hemispheric mapping of the target was retained, only trials in which eye movements did not alter the hemispheric mapping of the target were included (i.e., target consistently in LVF or RVF, despite eye movements; 73.2% of trials). The results showed only a significant main effect of target category, $F(1,15)=27.88$, $p<.001$, $\eta_p^2=.65$, with across-category targets being selected 25ms earlier than within-category targets, but no significant effect of visual field or an interaction, all $Fs < 1.9$, $ps > .19$. The category effects were significant for both RVF and LVF targets separately, $t(15)=3.41$, $p=.004$, and $t(15)=3.59$, $p=.003$, and there were no differences in search times for across-category targets in the LVF versus the RVF, $t(15)=1.14$, $p=.27$. Thus, this later measure (of the time needed to visually select the target) showed a bilateral category effect.

The results of the first analyses show an early left-hemispheric category effect in the accuracy of first saccades, which transforms into a bilateral category effect in later measures. It is interesting to note that observers were more accurate with the first eye movement to RVF across-category targets than LVF across-category targets and yet showed the same target fixation

latencies for LVF and RVF across-category targets. This indicates that, after an initial disadvantage of localizing LVF across-category targets, these targets produce a stronger category effect that neutralizes the initial advantage for RVF across-category targets.
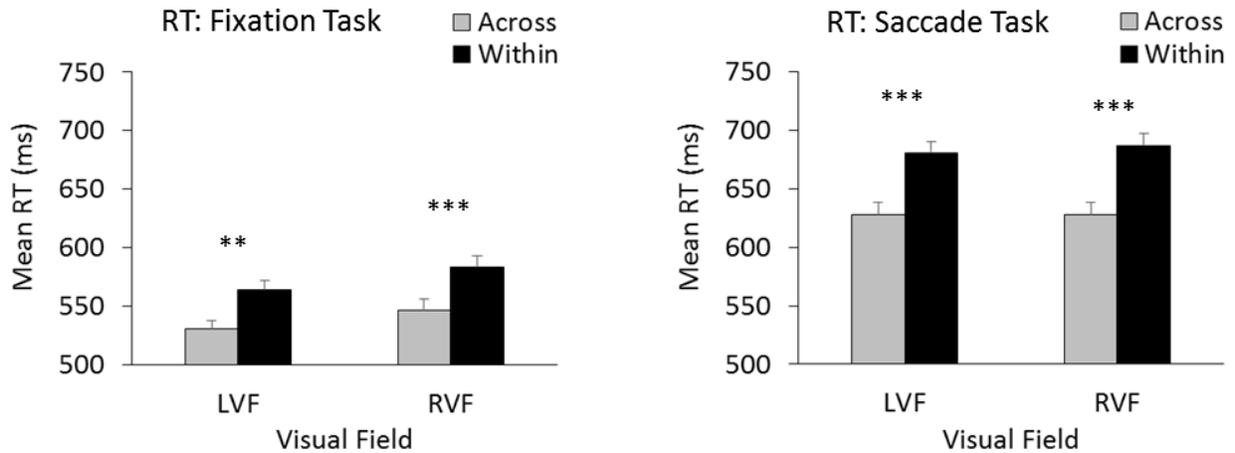

Figure 2. Mean response times (RTs) in the fixation (left panel) and saccade task (right panel) tasks. Both tasks showed significant category effects (i.e., advantage for across-category targets compared with within-category targets). The category effects were bilateral, without any differences between left and right visual field (LVF, RVF). Error bars denote the standard error of the mean for within-subjects effects (Loftus & Masson, 1994). ** *p*<.01. ***p*<.001.
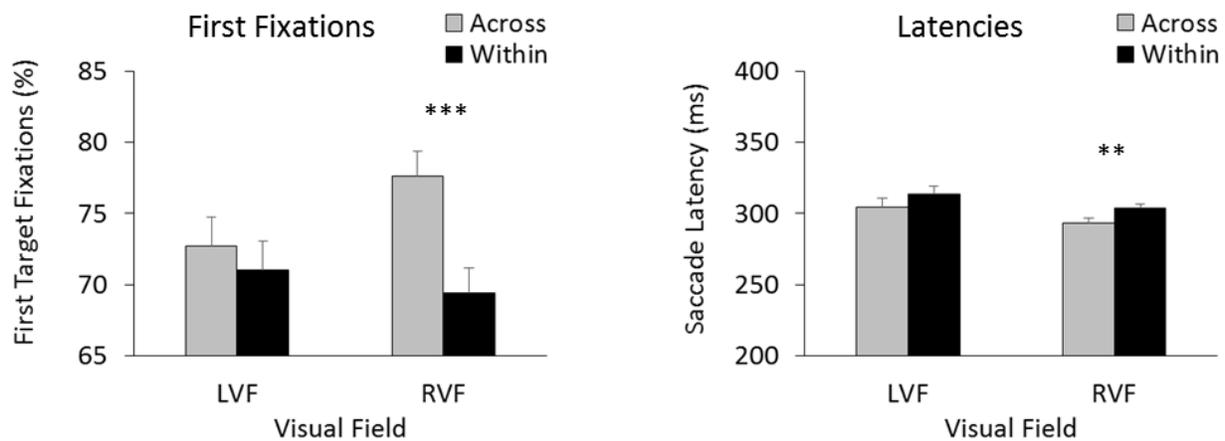

Figure 3. The proportions of first eye movements to the target (left panel), and the time needed to select the target (right panel) show a left-lateralized category effect, with a higher proportion of first eye movements (with shorter latencies) to across-category than within-category targets only in the RVF, not

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in the LVF. Error bars in both panels denote standard error of the mean for within-subjects effects (Loftus & Masson, 1994). * $p<.05$. ** $p<.01$. ***$p<.001$.

To probe the data for such a late, right-lateralized category effect, we next analyzed the manual RTs separately for instances in which the target was successfully selected with the first eye movement versus when the first eye movement initially went to a distractor (including only trials in which the hemispheric mapping of the target was preserved). A three-way ANOVA comprising the variables of first selected item (target vs. distractor), target hemifield (RVF vs. LVF) and target category (within vs. across color category target) revealed that manual RTs were faster when the target was selected immediately, $F(1,14)=108.44$, $p < .001$, $\eta_p^2=.88$. More importantly, the category effect, $F(1,14)=38.13$, $p < .001$, $\eta_p^2=.73$, was qualified by a significant three-way interaction between the first selected item, target category and visual field, $F(1,14)=6.56$, $p=.032$, $\eta_p^2=.32$. As shown in Figure 4, when the target was selected with the first eye movement, the manual RT showed a left-lateralized category effect, with significant category effects only for RVF targets, $t(14)=3.69$, $p=.002$, not for LVF targets, $t(14)=1.5$, $p=.15$. This reflects that the early, left-lateralized category effect did in fact propagate to later measures (i.e., the manual RT). Importantly, when the first eye movement *missed* the target, the data showed exactly the reverse effect: significant category effect for RVF targets, $t(14)=1.89$, p=.07, but a category effect only for LVF targets, $t(14)=6.56$, $p<.001$ (which was also significantly stronger than the non-significant category effect for RVF targets, $t(14)=2.18$, $p=.047$).

In sum, the data show that the bilateral category effects observed in the manual RT consists of two components—an early, left-lateralized category effect when the target is selected immediately, and a right-lateralized category effect when observers initially miss the target and continue searching.
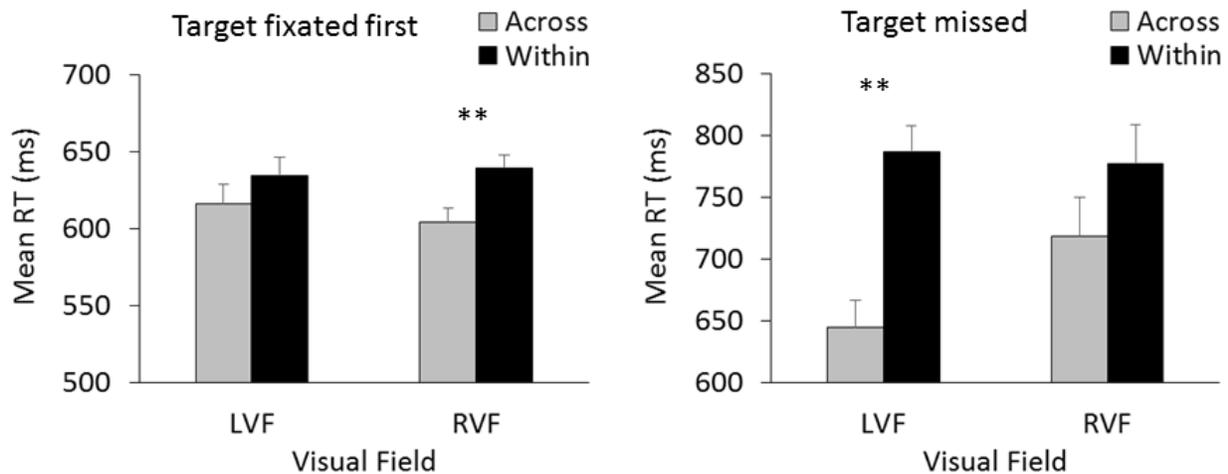
Figure 4. Mean response times (RTs) for a sub-population of trials when the first eye movement was directed to the target (left panel) versus when the first eye movement missed the target and ended on a non-target (right panel). Whereas the RTs for accurate eye movements show a left-lateralized category effect, the RTs for erroneous eye movements show a large right-lateralized category effect, with faster RTs for across- than within-category targets only in the LVF. Error bars depict the standard error of the mean within-subjects differences (Loftus & Masson, 1994). **$p<.01$; ***$p<.001$.

RT Distribution Analysis: Fixation Task. To assess whether the time-course results in the saccade task generalize to the more frequently used fixation task, we used a binned analysis on for the fixation task RTs. We first ordered all correct trials according to their RT (separately for each participant), computed the quartiles of the RT distribution and counted the number of trials with an across-category target versus a within-category target in each bin of the RT distribution (0-25% [fastest RTs], 25%-50%, 50%-75% and 75%-100% [slowest RTs]), separately for targets in the LVF and RVF. We then computed the mean RTs for the subset of trials within each bin (for the advantages of this distribution analysis see Becker, Lewis & Axtens, 2017). As shown in Figure 5, the fastest RTs (0-25%) included a higher proportion of across-category trials than within-category trials in the RVF, $t(15)=2.45$, $p=.027$, but no significant differences in the LVF,

$t(15)=1.6$, $p=.13$. The mean RTs within the fastest bin did not differ between across and within category trials, neither in the RVF nor in the LVF. The second and third bins did not show any differences in the mean RT or proportion of trials, with the only exception that within-category LVF targets had slightly shorter RTs in the second bin, $t(15)=2.2$, $p=.04$. Importantly, the slowest responses (4th bin: 75-100% of distribution) showed a significantly higher proportion of within-category trials than across-category trials in both the RVF, $t(15)=3.29$, $p=.005$, and the LVF, $t(15)=2.59$, $p=.020$ (all other $ts < 2.1$, $ps > .05$; see Fig. 5, black asterisks). In addition, the mean RT were also significantly slower for within-category trials than across-category trials in this bin, both in both the RVF (mean difference: 46ms; $t(15)=2.65$, $p=.018$) and the LVF (mean difference: 67ms; $t(15)=3.82$, $p=.002$).

Taken together, these results reflect an early left-hemispheric category effect in the fastest manual RTs of the fixation task, and a comparatively strong bilateral category effect in the slowest manual RTs. In this, the results mimic the results of the saccade task, which also showed an early, left-lateralized category effect and a bilateral category effect at a later stage of visual search.

General Discussion

The present findings resolve previously discrepant results about color category effects in visual search. The typical dependent variables used to index early processes in visual search (i.e., first eye movement parameters) yielded a clear left-lateralized category effect, whereas the typical dependent variable predominantly used in previous studies (manual RTs) showed a bilateral category effect—both in the fixation and saccade task. Interestingly, our left-lateralized category effect (observed in the proportion of first eye movements to the target in the saccade task and the fastest RTs in the fixation task) translated into a bilateral category effect in later

stages of visual search (i.e., target fixation latencies in the saccade task, slowest RTs in the
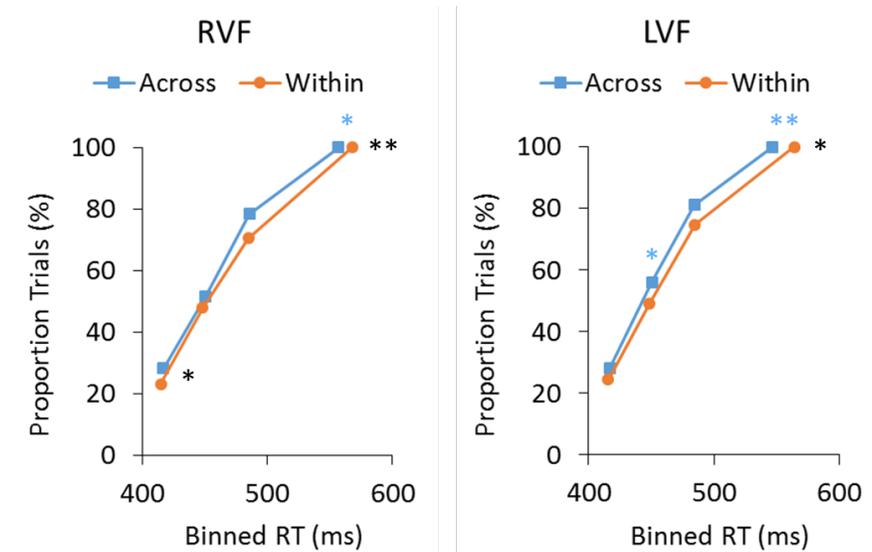
fixation task).

Figure 5. Cumulative distributions in the fixation task, depicted separately for across versus within-category targets in the right and left visual fields (RVF, LVF) across the four bins of the response (RT) distribution. Black asterisks indicate a significant difference in the *proportion* of trials within a bin; blue asterisks indicate a significant difference in the mean RT *latencies* within a bin. * *p*<.05; **p*<.01, as per two-tailed *t*-test.

Previous studies have already shown that the left-lateralized category effect occurs at an early

stage of visual search (Al-Rasheed et al., 2014; Franklin et al., 2008a, 2008b; Liu et al., 2009;

Mo, Xu, Kay & Tan, 2011; Thierry et al., 2009), but it was unclear whether this left-lateralized

category effect is *only* present at an early stage of visual search, or whether it has a more

sustained, longer-lasting influence on search performance. Our findings suggest that the left-

lateralized category advantage is only a transient, short-lived effect that is limited to an early

stage of visual search.

Second, previous studies (e.g., Liu et al., 2009) documented that an early, left-lateralized

category effect does not necessarily propagate to later measures such as the mean RT, which can

show equally large category effects in both hemifields. The present study clarifies that (1), the

early, left-lateralized category effect can only be observed when the target is found immediately and with the first glance, in which case (2) the left-lateralized category effect does propagate to later measures (e.g., the mean RT). Critically, a bilateral category effect emerges in later measures (e.g., mean RT) because (1) a late, right-lateralized category effect can emerge on trials in which the target is initially missed and distractor rejection becomes a key component of visual search, and (2) this effect adds together with the early, left-lateralized category effect to produce a bilateral category effect in the mean RT (or other late measures, such as the time to select the target).

The finding that the bilateral category effect consists of an early, left-lateralized component and a later, right-lateralized component has important theoretical implications. First, the present findings allow precise predictions about when the results of a given study will show a left-lateralized versus a bilateral category effect. Because the right-lateralized category effect emerged only when the target was initially missed, it follows that the data should show an early, left-lateralized category effect when search is easy (e.g., when the colour contrast is high, or with highly practiced observers), whereas bilateral category effects should emerge when search is more difficult (e.g. with less practiced observers; e.g., Franklin et al., 2008a,b). In addition, the choice of the dependent variable alone could already tip the results towards left-lateralized vs. bilateral category effects. Early dependent measures (e.g., N2pc or first eye movement parameters) should be more likely to show a left-lateralized category effect, whereas later measures such as the mean RT should be equally likely to show a left-lateralized or bilateral category effect (depending on the ease of the search task; for corresponding results see Al-Rasheed et al., 2014; Franklin et al., 2008a, 2008b; Liu et al., 2009; Mo, Xu, Kay & Tan, 2011;

Thierry et al., 2009). With this, the present account can explain a range of previous and apparently discrepant results.

Another important implication of the present findings is that the finding of a bilateral category effect cannot be taken to refute the Whorfian hypothesis that language can affect early perceptual processes (e.g., Witzel & Gegenfurtner, 2013). As demonstrated here, the bilateral category effect includes the left-lateralized category effect that has often been cited in support of the Sapir-Whorf hypothesis. Naturally, it is also possible to explain the left-lateralized category effect in terms of categorical perception without the need for a linguistic mechanism (e.g., Holmes & Wolff, 2012). Still, according to our findings, the left-lateralized category effect is based on early, attentional or perceptual processes that facilitate selection of across-category targets in the right hemifield—for instance, because the initial attentional bias for across-category targets is stronger, or perceptual sensitivity is initially enhanced for such targets in the right hemifield. With this, the left-lateralized category effect is similar to other short-lived attentional processes that can bias visual selection to particular items. Such attentional biases can also alter our perception of these stimuli, as attention can reliably accelerate the perceived timing of events (Hikosaka, Miyauchi & Shimojo, 1999; Priess et al., 2012), and increase the perceived contrast and resolution of the attended stimulus (Carrasco, Ling, Read, 2004; Yeshurun & Carrasco, 1998). Given these findings, it is plausible that across-category targets are perceived differently in the right versus left hemifield, whereas it still remains to be shown whether facilitated visual selection of across-category target in the RVF is indeed due to the involvement of language (e.g., due to the proximity of corresponding brain areas), or a different, language-independent hemispheric specialization.

The major finding of the present study was that there was also a large, right-lateralized category effect that facilitated detection of across-category targets in the left visual field when the target had been initially missed. Earlier studies reported right-lateralized category effects for fine-grained line discriminations (Franklin et al., 2010), suggesting that the right hemisphere may be specialised for subtle category differences (see also Holmes & Wolff, 2012). Our results support this idea, as erroneous selection of a non-target will neutralise all initial top-down biases and require finding the target in terms of its then reduced categorical difference. Alternatively or additionally, the right hemisphere may be specialised for fast, parallel rejection of distractors (e.g., Polich, 1982). Whereas the exact cause for the right-lateralized category effect still needs to be determined, its discovery resolves the long-standing debate about whether category effects are lateralized or bilateral.

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