Lateralized Whorf: Language influences perceptual decision in the right visual field

Paul Kay, Terry Regier, Aubrey L. Gilbert, and Richard B. Ivry

1. Introduction

Since the middle of the last century, studies of color naming and color perception have furnished the major empirical locus for the question of linguistic and cultural "relativity" versus "universalism" (see, for example, Kay & McDaniel 1978, Lucy 1997, Roberson, Davies & Davidoff 2000, Kay & Regier 2003, among many other others). The empirical focus on color has spawned two mostly separate research traditions. The first is that of comparative color naming, with universalists touting the similarities among the color naming systems of the world and relativists pointing with equal energy to the differences. It has now been established that there are statistical universal tendencies in the color naming systems of the world but also that they are not exceptionless, even for languages with the same number of basic color terms (Regier, Kay & Cook 2005, Roberson, Davidoff, Davies & Shapiro 2005, Kay & Regier 2007). The moral of that story is that neither a strict universalism nor a strict relativism is adequate to the more nuanced facts of similarity and difference in color naming among the languages of the world (Kay & Regier 2006). Regier, Kay and Khetarpal (2007) propose a simple model, based on the presumed shape of the psychological color solid (Jameson & D'Andrade 1997) and the standard notion of maximizing similarity within, and difference across, categories (Garner 1974) to account for both the similarities and (some of) the differences to be found among the world's color naming systems.

The present chapter is concerned with the second of the two research traditions: investigation of the degree to which the differences in color naming across languages that do exist induce differences in cognition or perception of color among their speakers. And in particular, that these "Whorfian" effects are largely if not exclusively restricted to the right visual field (RVF), which is known to project to the left cerebral hemisphere (LH) (Corbalis 1991, Hellige 1993). It has previously been established that presence of a major color term boundary in a language induces categorical perception (Harnad 1987) at that boundary in the speakers of the language and fails to do so in speakers of languages that lack the boundary (Kay & Kempton 1984, Özgen & Davies 1998, Roberson, Davies & Davidoff 2000, Roberson, Davidoff, Davies & Shapiro 2005, Winawer et al. 2007). Moreover, several of these studies have shown that the categorical perception effect that is presumably induced by the color term boundary can be suppressed by a concurrent task or instruction that places strong demands on specifically verbal resources, reinforcing the inference that the correlation between the color term boundary and categorical perception at that boundary reflects causality of the latter by the former. Taking this basic finding as background, the present chapter reviews recent research showing that the categorical perception effect arising from a color term boundary is, due to projection to the left hemisphere, much stronger in the right visual field (RVF) than the left (LVF) and is in fact possibly unique to the RVF when confounding factors (principally, trans-callosal transfer) are controlled.

2. Initial experiments

Gilbert, Regier, Kay and Ivry (2006) first determined that the lexical boundary for their English speaking participants between green and blue fell between stimuli roughly represented as B and C in Figure 1a.

They then administered a visual search task, following central fixation, using a display in which one of 12 colored patches (the

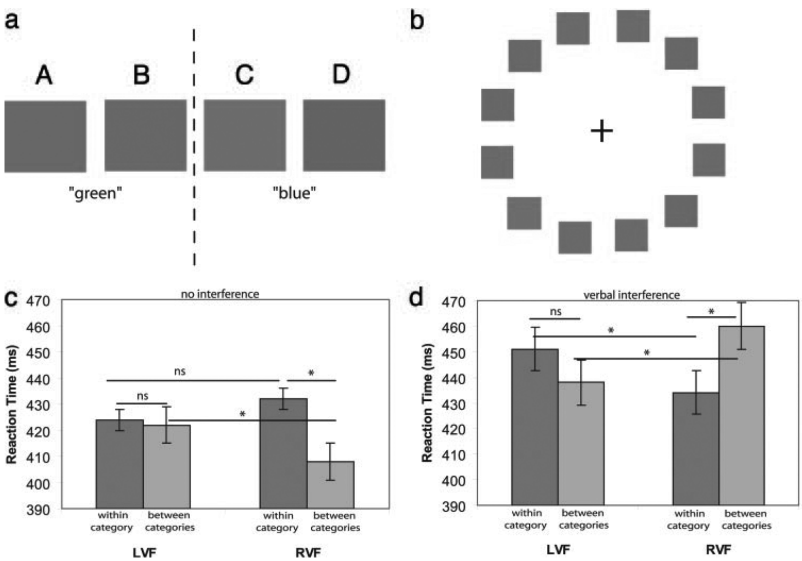

Figure 1. Lexical categories influence perception in the RVF. (a) Print-rendered versions of the four colors used. (b) Sample display for the visual search task. Participants were required to press one of two response keys, indicating the side containing the target color. (c) In the no-interference condition, RTs were faster for the between-category pair and slower for the within-category pairs when targets appeared in the RVF compared with when they appeared in the LVF. (d) Effects were reversed with verbal interference. *, P ≤ 0.05, two-tailed t test, df 10; ns, non-significant. Values are mean ± SEM. Source: (Gilbert, Regier, Kay & Ivry 2006).

target) failed to match eleven identical distractors (Figure1b). The task was to indicate as quickly as possible with a finger press of the left or right index which side of the display the target appeared on. Of interest were (1) whether the target was of the same or different lexical category as the distractors—specifically, pairs (A, B) or (C, D) versus the pair (B, C)—and (2) the visual hemifield in which the target appeared. The Whorfian prediction is that cross-category pairs will be discriminated faster than within category pairs preferentially in the RVF. As shown in Fig 1c, in the RVF cross-category targets were in fact identified much faster than within-category targets, and there was no comparable effect in the LVF. Gilbert et al. christened this finding the lateralized Whorf effect. The visual field difference is plausibly due to the fact that the RVF projects to the LH and the LH is usually the dominant hemisphere for language. To check this inference they performed the same visual search task while the participants had to verbally rehearse a randomly generated eight-digit number. As shown in Figure 1d, the LVF was again not affected but the lateralized Whorf effect in the RVF disappeared; in fact it was reversed, within-category pairs being discriminated more rapidly than cross-category pairs in the RVF.

Both as a replication and to make sure the interference effect was strictly verbal, a second experiment was run with a different verbal interference task, as well as an equally difficult spatial interference task.[1] The results are shown in Figure 2.

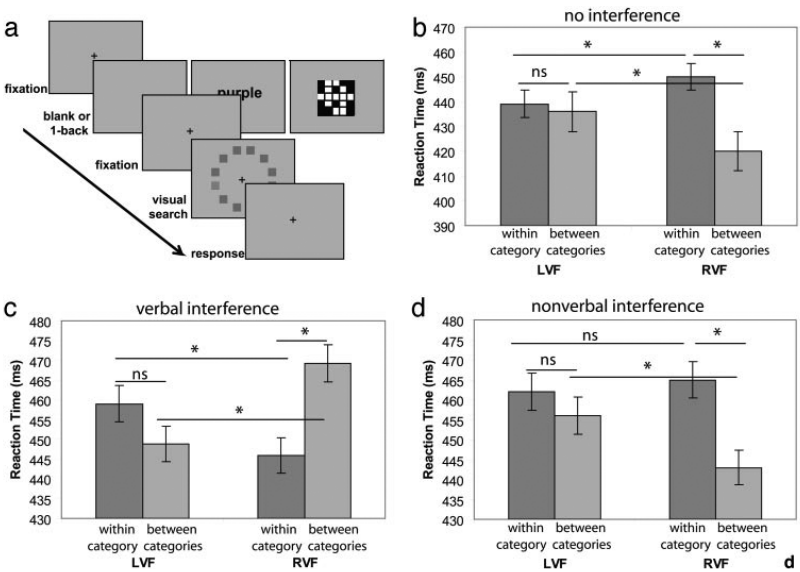

Figure 2. Modulation of color-category effects in the RVF is specific to linguistic demands of the interference task. (a) Trial events. Within a block of trials, the visual search task was interleaved with blank displays, displays containing a color word, or displays containing a spatial grid. (b and c) No-interference and verbal-interference results replicate those obtained in the first experiment. (d) For the nonverbal-interference condition, performance followed a pattern similar to that observed in the no-interference condition. *, P ≤ 0.05, two-tailed t test, df 10; ns, non-significant. Values are mean ± SEM. Source: (Gilbert, Regier, Kay & Ivry 2006).

The no-interference and verbal interference results exactly paralleled those of the initial experiment: compare panels b and c of Figure 2 with panels c and d of Figure 1. The interference task was interleaved with the visual search task. For the verbal interference task, an irrelevant color term (e.g., the word "violet") was presented between search trials and the subjects indicated when the same term was presented on successive trials. For the non-verbal interference task, the stimuli were grids of white and black squares and subjects again performed a 1-back task, indicating when the same pattern was presented on successive trials (Figure 2a). Unlike the verbal interference task, the non-verbal interference task (Figure 2d) produced the same pattern as produced with no interference (Figure 2b). This pattern of results suggests strongly that on-line use of verbal labels, in either the process of perception itself or rapidly thereafter, promotes discrimination of cross category judgments relative to within category judgments in the RVF-LH pathway and less or not at all in the LVF-RH pathway.

In summary, these results demonstrate an apparently Whorfian effect, but one limited to stimuli presented to one half of our perceptual space. To the extent that one can generalize from these experiments, it seems that at each moment half of our visual input comes to us filtered through linguistic categories and half comes not so filtered. We might say that all times "human beings are at the mercy of the particular language which has become the medium of expression for their society" (Sapir 1949: 69) as regards half of their visual experience.

3. Further Replication

The experiments described above were performed at the University of California, Berkeley. Further replication has come from experiments carried out at the University of Surrey. The first experiment in this study (Drivonikou, Kay, Regier, Ivry, Gilbert, Franklin & Davies 2007) was in fact a reanalysis of an earlier study (Daoutis, Pilling & Davies 2006), which employed a fortuitously lateralized paradigm assessing within- versus cross-category perceptual discrimination of colors to assess a hypothesis unrelated to lateralization. That hypothesis was that the linear separation effect—according to which the middle color of three on a straight line in CIE u'v' space is harder to find in visual search among distractors of the other two kinds than either of the end colors (Bauer, Jolicoeur & Cowan 1996a, b, 1998, D'Zmura 1991)—will be eliminated if the three colors belong to distinct named categories (Figure 3a, b). In these experiments, the participant was shown a color and then had to locate it as quickly as possible in a field of distractors consisting to the other two colors in the set (all of same category or all of different categories; see Fig 3a, b). In the Daoutis et al. study the RT data were averaged across visual fields.[2] Drivonikou et al. reanalyzed the data by visual field, with the results shown in Figure 3c, d. Considering both the linearly separable colors alone and both linearly separable and non-separable colors, Whorfian effects were found in both visual fields with the stronger effect in the RVF. The fact that the stronger Whorfian effect was found in the RVF replicates the earlier (Gilbert et al.) findings. It will be argued below that the weaker, although significant, effect found in the LVF in this experiment was due in large measure, if not exclusively, to trans-callosal transfer.

Drivonikou et al. then performed an experiment similar in design to the Gilbert et al. paradigm, although instead of presenting target and distractor colors against a neutral background a setup was employed in which the background itself served as the non-target color. In Figure 4, panel a shows the stimuli used in Munsell coordinates and panel b shows an example of the display configuration for the color detection task (in gray scale), with the target color indicated by the arrow.

The relevant results are displayed in Figure 4, panel c and e.[3] In both the blue vs. green (panel c) and blue vs. purple (panel e) tests a significant Whorfian effect is found: The RVF favors cross-over within-category discrimination relative to the LVF.. The blue-purple set showed no CP in the LVF. The blue-green set (panel c) showed LVF CP on a t-test, although less strongly than the RVF, despite the overlap of the 95% confidence limits error bars.

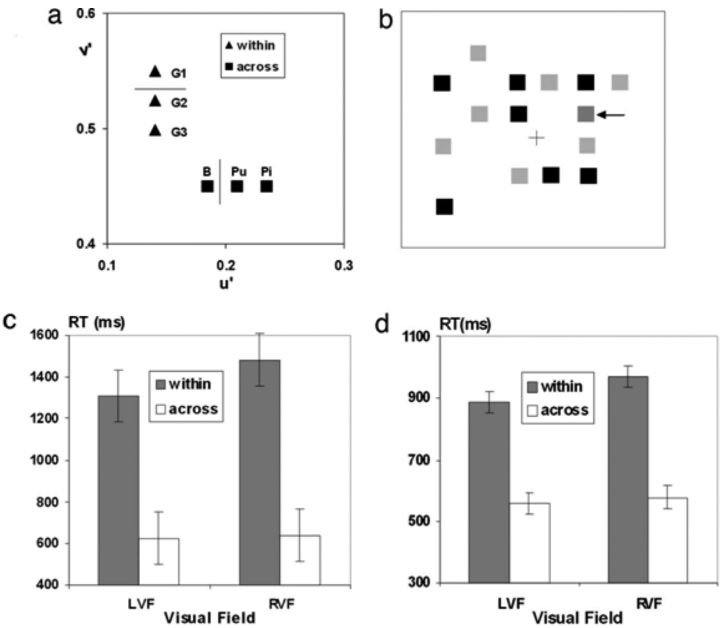

Figure 3. The category effect is larger in the RVF than in the LVF in a reanalysis of the data from a color identification task used by Daoutis et al. (16). (a) Stimuli in CIE coordinates. The within-category set contains three hues of green: G1, G2, G3; the across-category set contains a blue (B), a purple (Pu), and a pink (Pi). Perceptual distance is the same for all adjacent pairs across both sets (G1-G2, G2-G3, B-Pu, and Pu-Pi). When a peripheral stimulus (e.g., G1) is the target, it is linearly separable from the distractors (G2 G3). (b) Illustration of a target-present trial with 15 distractors. The target is indicated here by the arrow, which, however, was not present in the display itself. (c and d) Target detection times for within- and across-category targets by LVF and RVF: collapsed across linear separability (c) and linearly separable targets alone (d). Error bars show 95% confidence limits. Source: (Drivonikou, Kay, Regier, Ivry, Gilbert, Franklin & Davies 2007).

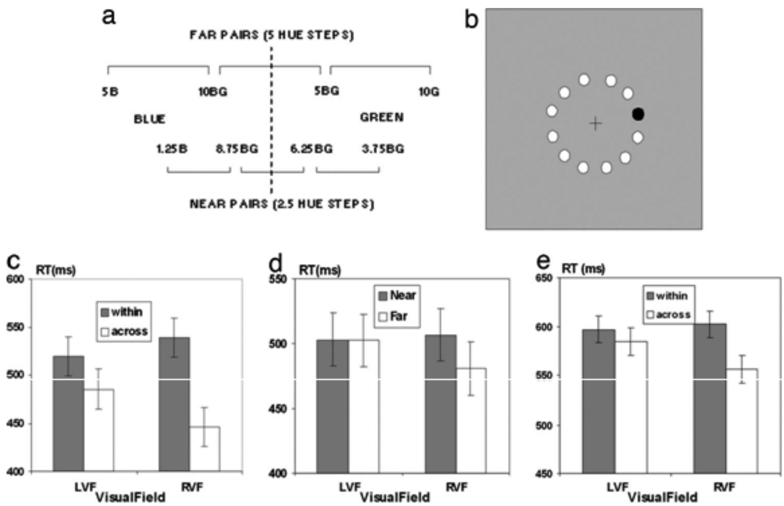

Figure 4. A larger category effect is observed in the RVF on a color detection task. (a) Munsell codes of the stimuli; stimuli varied in hue at constant value and chroma. Hue separations were either five steps (far set) or 2.5 steps (near set). The target was either in the same color category as the background (e.g., 10BG on 5B, both blue) or in the adjacent category (e.g., 10BG on 5BG, blue on green). (b) Illustration of a test frame: white circles show possible target locations around the fixation cross, and the black circle representing the target. (c and d) Blue-green set: The difference in RT between within- and across-category is larger in the RVF (c). Target-background perceptual separation only affects the RVF (d). (e) Blue-purple set: Again, the difference in RT between within- and across-category is larger in the RVF. Error bars are 95% confidence limits. Source: (Drivonikou, Kay, Regier, Ivry, Gilbert, Franklin & Davies 2007).

4. Generalizing beyond color

Is the lateralized Whorf effect restricted to the color domain? Initial results indicate that it is not. An experiment was performed using the same visual search paradigm—with no interference, verbal interference and non-verbal-interference conditions as in the experiments described in section 2, but using silhouettes of cats and dogs as within—and cross-category stimuli rather than colors, as shown in Figure 5.

Figure 5. Cat and dog stimuli used in experimentation. Source: (Gilbert, Regier, Kay, & Ivry 2007).

Stimuli were presented, after central fixation, in the same configuration as in Gilbert et al. (2006) (see, e.g., Figure 1), and again reaction time to press a key with the corresponding index to indicate the side on which the target (odd ball) silhouette appeared was recorded, as shown in Figure 6.

The results, as shown in Figure 7, again replicated the original findings of a lateralized Whorf effect,[4] in the no-interference and non-verbal interference conditions and no such effect in the verbal interference condition. In this case, unlike the previous experiments, no reversal of effect in RVF (within faster than between) was observed.

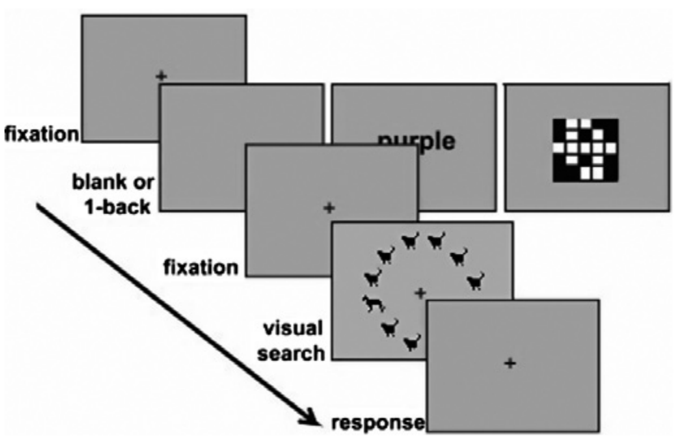

Figure 6. Trial events. Within a block of trials, the visual search task was interleaved with blank displays, displays containing a color word, or displays containing a spatial grid. Source: (Gilbert, Regier, Kay & Ivry 2007).

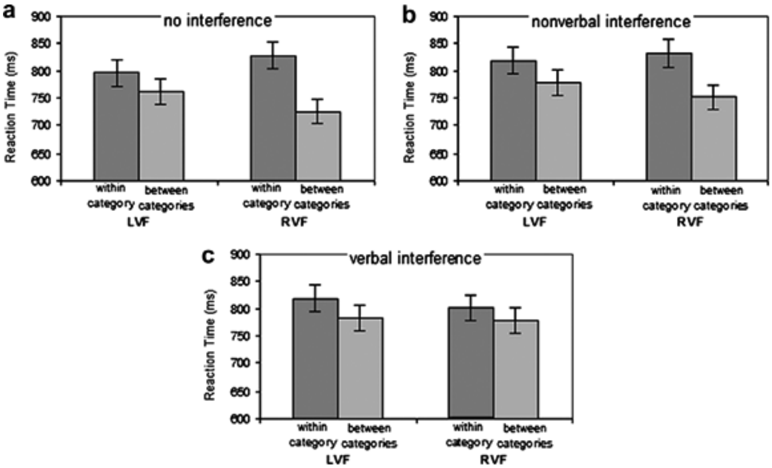

Figure 7. Data for conditions without interference and with verbal and nonverbal tasks (n = 11). Error bars show 95% confidence limits. Source: (Gilbert, Regier, Kay, & Ivry 2007.

5. Experiments with patients whose corpus callosum has been surgically severed

The corpus callosum consists of axonal tracts that allow the two hemispheres to directly communicate with each other. In certain cases of severe epilepsy, relief has been obtained by severing this structure. While this procedure keeps seizure activity from spreading, it also eliminates direct communication between the two hemispheres. Callosotomy patients have thus presented unique opportunities to study the operation of each hemisphere in isolation, and have provided some of the most compelling evidence of the dominant role of the LH in language (reviewed in Gazzaniga, 2000). In fact, the experiments reported in section 1 were originally conceived as experiments on callosotomy patients.[5] Comparable experiments can now be reported on two such patients.

"One such individual, JW, was tested on a version of the visual search task [of section 1]. JW underwent a two-stage callosotomy operation in 1979–1980 for intractable epilepsy (Sidtis et.al. 1981). The linguistic competence of each hemisphere in this individual has been extensively documented, and, despite slight improvement in right hemisphere linguistic competence when tested 15 years after surgery, JW has remained consistently left hemisphere language dominant (Baynes et. al. 1995). JW has suffered two strokes over the past two years, resulting in LH lesions primarily in the parietal lobe. Chronic deficits related to the stroke include a right-sided somatosensory deficit and reduced dexterity of the right hand. There is no clinically observable neglect or aphasia, and JW had little difficulty understanding and performing the tasks" (Gilbert 2007). Doubtless because of extensive LH lesions, JW was slower for both within and between pairs in the RVF. Nonetheless he was faster for between- than within-category discriminations in the RVF, with no difference in the LVF, confirming the lateralized Whorf prediction again (Figure 8).

A second callosotomy patient, VP, "underwent a two-stage callosotomy for the control of intractable epilepsy at the age of 27 years. Her post-surgery intelligence fell within a normal range (Gazzaniga et. al. 1984). Sidtis et. al. (1981) and Gazzaniga et. al. (1984) provide extensive background on VP's medical history and cognitive abilities" (Gilbert 2007). This patient was tested with a

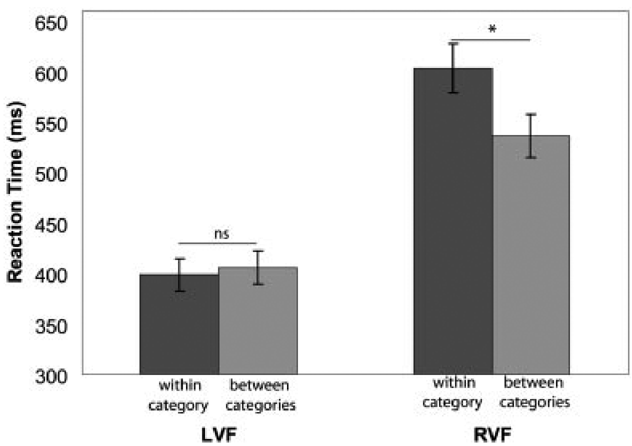

Figure 8. Lexical categories influence perception in the RVF of a callosotomy patient (JW). *, P ≤ 0.05, two-tailed t test, df 1; ns, non-significant. Source: (Gilbert, Regier, Kay & Ivry 2006)

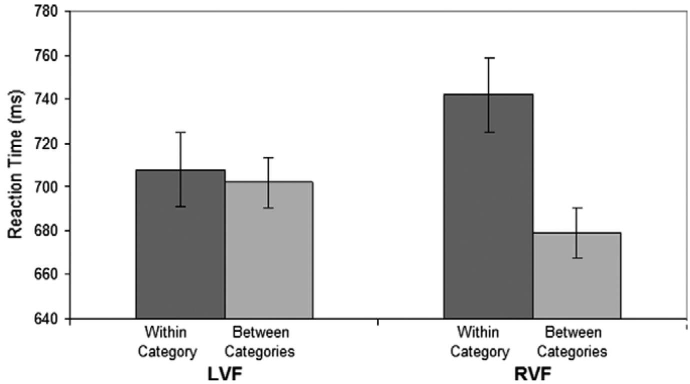

Figure 9. Visual search task results from callosotomy patient testing. Error bars show 95% confidence limits. Source: (Gilbert, Regier, Kay & Ivry 2007).

version of the cat-dog stimuli of the previous section and showed the results depicted in Figure 9, again confirming the lateralized Whorf prediction.

Investigations on callosotomy patients thus reinforce the lateralized Whorf effect found in normal adults. Moreover, the complete absence of LVF CP in these patients suggests that the weak LVF CP found in normals, especially apparent when reaction times are relatively long (Gilbert et al. 2007), may be attributable to transcallosal transfer.

6. Languages other than English

As noted above, non-lateralized studies have found color CP effects for lexical category boundaries that do not occur in English for speakers of the corresponding languages and vice versa (Kay and Kempton 1984, Özgen and Davies 1998, Roberson, Davies & Davidoff 2000, Roberson, Davidoff, Davies & Shapiro 2005, Winawer et al. 2007). Investigations of lateralized Whorfian effects have just begun, but the results of one in-press study are now available (Roberson, Pak & Hanley 2007). Roberson et al. "compare[d] discriminations around the boundary between the

Korean categories yeondu (yellow–green) and chorok (green). This boundary is obligatory for Korean speakers, who have no single term that covers both yeondu and chorok, but falls within the green category for English speakers." Perceptual discrimination was tested in a paradigm similar to that of Gilbert et al. (2006). The results were a function both of language and of whether subjects responded slowly or quickly. A Whorfian effect was found for slow Korean-speaking responders in both visual fields, but only in the RVF for fast responders. In contrast, no English speakers showed a CP effect at the Korean lexical boundary not shared by English.

The data indicate a lateralized Whorfian effect in the RVF for those Korean speakers who responded quickly, reflecting perception sensu stricto or immediate post-perceptual processing, with the similar effect in the LVF among slower responders apparently reflecting, on the other hand, trans-callosal transfer. At the time of writing, this is the single study so far published of a lateralized Whorf effect at a lexical boundary that does not occur in English.

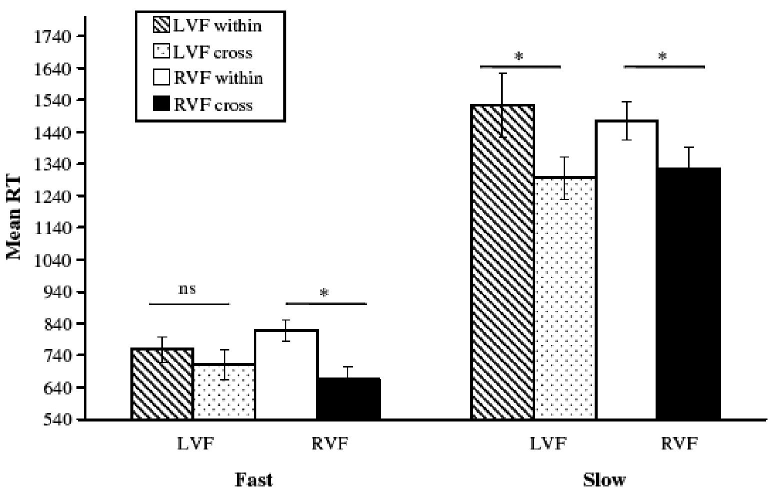

Figure 10. Mean RTs (with standard error bars) for English and Korean speakers to identify targets from either cross- or within-category distractors at the boundary between the Korean colour categories yeondu and chorok. Source: (Roberson, Pak & Hanley 2007).

Drivonikou, Davies, Franklin & Taylor compared lateralized color CP in Greek, which makes a light blue versus dark blue lexical distinction, English, and several African languages that do not make any lexical distinction in the green-to-blue area. "CP was shown by faster detection of targets on different- than same-category backgrounds. However, lateralisation of CP was only found when category boundaries were marked by the language" (Drivonikou, Davies, Franklin & Taylor 2007). Further work is needed to assess lateralized Whorf effects in additional languages. These two initial studies support the correlation of lateralized color CP effects with cross-linguistically varying lexical boundaries.

7. EEG evidence for lateralized Whorf

Gilbert, Oliveira & Ivry (in preparation) report an EEG study that supports lateralized Whorf. Stimuli for an event-related potential study were constructed using three of the four colors (B, C and D) used in the experiments reported in section 1 (cf. Gilbert et al. 2006). Each stimulus consisted of a central fixation cross or circle flanked by two color patches. Color C, the blue color near the blue/green boundary, occurred in each visual field 80% of the time. Subjects were presented with a sequence of familiar stimuli (color C on both sides of the central fixation symbol), interrupted occasionally with a "deviant" stimulus, where C was replaced with either D (same category: blue) or B (different category: green) in either RVF or LVF. These color changes were not mentioned in the instructions. Instead, subjects were instructed to focus their attention on the center of the display and indicate when the central fixation symbol changed from a cross to a circle. At issue was whether any of the four kinds of deviant stimulus, (same versus different category) × (RVF versus LVF), might elicit the visual mismatched-negativity (V-MMN) response, which occurs when repeated presentations of a familiar stimulus are interrupted by presentation of a deviant stimulus. This experimental paradigm is pictured in Figure 11.

To analyze the MMN response, the EEG signal time-locked to the presentation of the standard display is subtracted from the EEG

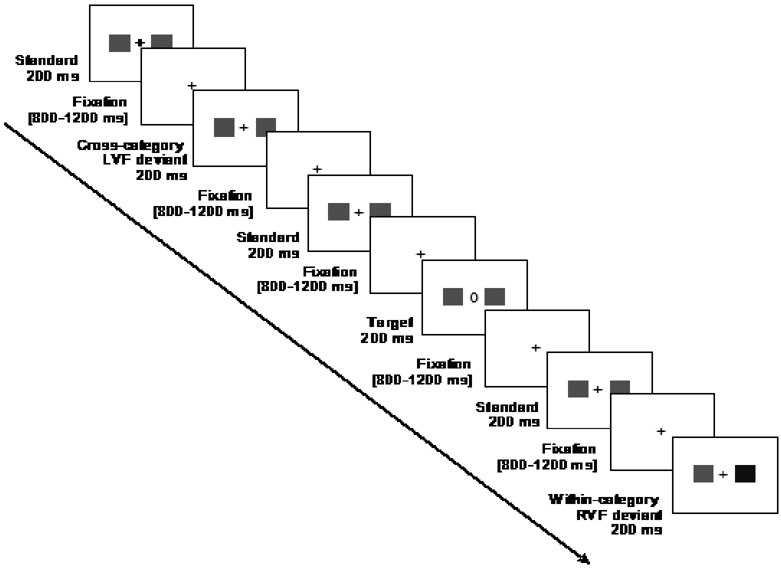

Figure 11. Experimental paradigm for EEG lateralized Whorf study. Source: Gilbert, A.L., Oliveira, F., & Ivry, R.B. EEG findings associated with the lateralized Whorf effect. In preparation. Data and figures are also available in Gilbert (2007).

signal time-locked to the presentation of the display containing the deviant colors. Two mismatch effects were observed in this difference wave, one at 150-300 ms in the occipital and extrastriate areas and a second at 400-700, prominent over more frontal sites. The occipital and extra-striate MMNs were left hemisphere localized and the later MMNs were bilateral with a larger component in the left hemisphere. Interestingly, all deviant-related MMNs were to cross-category deviants presented to the RVF, consistent with a lateralized Whorf prediction. The results are shown in Figure 12. Gilbert et al. interpret their results as favoring online lexical access over the possible alternative of permanent warping of color space by language acquisition. They do not consider the question whether lexical categories are accessed in the course of perception or post-perceptually.

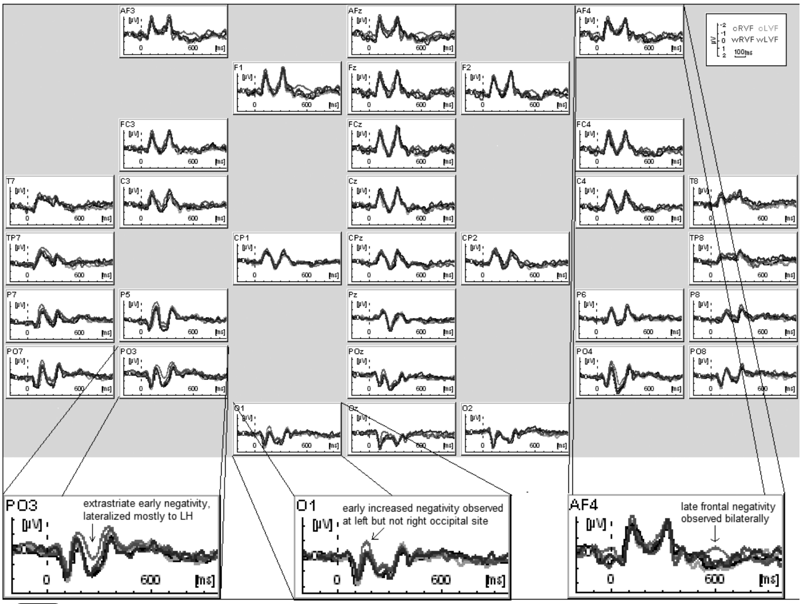

Figure 12. "Grand-averaged ERPs to standard (in black) and each of the deviant stimuli. The only deviant to evoke ERPs with significant differences from those evoked by standard stimuli was the cross-category deviant (in red) and these differences only occurred when this deviant was presented in the RVF. The significant differences of note are an earlier (~150-300 ms) increased negativity at occipital and extrastriate sites that is lateralized mostly to the LH, and a later (~400-700 ms) increased negativity at frontal sites that is observed bilaterally" (Gilbert 2007). Source: (Gilbert 2007).

8. Aphasia and lateralized Whorf effects

We have noted that the lateralized Whorf effect is suppressed in normal subjects when a concurrent verbal interference task is imposed. It is plausible that aphasias resulting from lesions affecting the language areas of the brain would have an analogous effect. A recent study administered the speeded visual search task of section 1 (Gilbert et al. 2006) to fifteen aphasia patients who had suffered left hemisphere strokes and to twelve matched controls (Paluy, Gilbert, Baldo & Ivry 2007). The controls produced the expected lateralized Whorf pattern: faster between-category responses in the RVF only. The aphasic patients showed the same reversal as is sometimes seen in normals with verbal interference (e.g., Gilbert et al. 2006): the RT advantage for between-category targets in the RVF disappeared and instead the LVF showed an advantage for between-category discriminations (Figure 12)—in this case suggesting a common reorganization of brain function following trauma, in which the undamaged hemisphere assumes some of the functions of the damaged hemisphere.

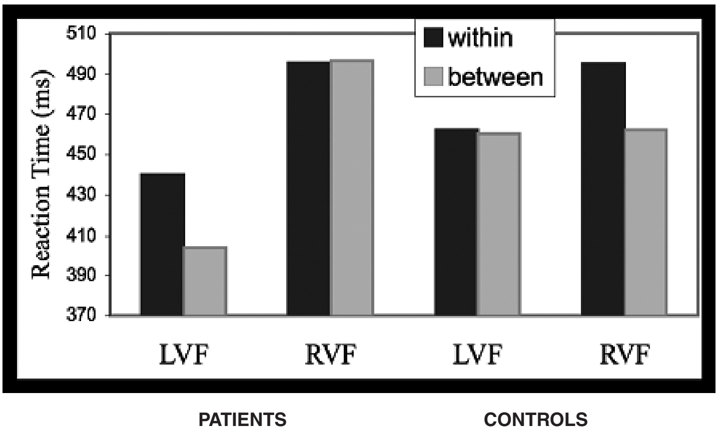

Figure 13. Results of 15 aphasic patients and 12 controls tested on the no-interference visual search task of Gilbert et al. (2006). Source: (Paluy, Gilbert, Baldo & Ivry 2007).

9. Relation of evidence of LVF CP to lateralized Whorf hypothesis

In two of the eight behavioral experiments in which evidence for lateralized Whorf (RVF RT advantage for cross-category discriminations) was sought (and found), a significant, although weaker, LVF advantage for cross-category pairs was also found. The question arises what bearing this finding has on the lateralized Whorf conclusion. Lateralized Whorf means that only the RVF accords relative advantage to between-category discriminations. What is the significance of the LVF advantage for between-category discriminations when that is found? As shown in Table 1, average

EXPERIMENT	RT (mean, approx.)	LVF CP?
Callosotomy 1	(400)	NO (transfer impossible)
Callosotomy 2	(700)	NO (transfer impossible)
BERKELEY 1	425	NO
BERKELEY 2	440	NO
SURREY 2	540	NO/YES*
Roberson (fastest Ss)	740	NO
SURREY 1	1375	YES (transfer probable)
Roberson (slowest Ss)	1420	YES (transfer probable)

Table 1: Approximate mean response times for the eight experiments that show lateralized Whorf effects, with indication of significant LVF CP. Only the two studies with RTs well over 1000 ms show LVF CP, suggesting trans-callosal transfer and scanning as possible causes. * In this experiment one color boundary showed LVF CP and one did not.

response times in the two experiments showing unequivocal LVF CP were two to three times as great as response times in the other six experiments. This suggests that the LVF CP effects may have resulted from transcallosal transfer, consistent with the hypothesis that the asymmetric Whorfian effects are due to the contribution of linguistic processes in the left hemisphere. It is also possible that subjects failed to maintain fixation in conditions with long RTs. If some fraction of the input on "LVF" trials is in fact based on central (or RVF) exposure, CP effects actually arising from the RVF may be incorrectly attributed to the LVF.

10. Summary so far

The results so far considered may be summarized as follows.

1. Lateralized RVF color CP has been found in a variety of tasks on normal adults.
2. Lateralized RVF color CP has been found in callosotomy patients.
3. Lateralized RVF CP has been found outside the color domain (dog and cat silhouettes).

4. Color CP has been found in LVF in some experiments. It is always weaker than RVF CP and the generally longer response times in these experiments suggest trans-callosal transfer and/or scanning. Either or both of the latter factors could render apparent LVF CP in normal adults illusory.

5. ~~The inference from RVF CP to left hemisphere activity has been confirmed in an EEG study.~~

6. A completed study and one study in progress testing for lateralized RVF CP at lexical boundaries not present in English have found RVF CP at those boundaries for speakers of the relevant language, and not for English speakers.

Hence, all the results reviewed so far are consistent with language as the cause of CP.

~~11.~~ Infant color CP

"[Four- to-six month old] infants were faster at fixating [a colored] target [against a different colored background] when the difference was between-category than when it was within-category' (Franklin, Pilling & Davies 2005). In this study four- to six-month old infants' eyes were tracked. (The data from 15 of the original 21 infant participants was useable.) First, the infant's visual attention was drawn to a central fixation point on a colored monitor with a flashing bull's-eye. Then a target color, distinct from the background color and of either the same or a different lexical category, appeared in any of twelve locations forming a circle around the fixation point (See Figure 4b), and the time was recorded for the infant's eyes to locate the target. The infants focused between-category targets significantly faster than within-category targets. The procedure was checked with adult controls, which produced the same CP result. This finding and similar earlier ones (e.g., Bornstein, Kessen & Weiskopf 1976, Franklin & Davies 2004) indicate that not all color CP in all humans can be language caused.

Moreover, infant color CP is lateralized to the LVF, in contrast to the RVF lateralization of adults. A similar procedure as in the study just described was administered to twenty-six infants, thirteen of whose data were useable, and eighteen adults. The only significant difference in procedure was that the time variable in this study was time to originate a saccade toward target rather than time to fixate the target. Adults again showed RVF CP, as expected. But infant color CP was absent in the RVF and clearly present in the LVF (Franklin, Drivonikou, Bevis, Davies, Kay & Regier. 2008), as shown in Figure 14.

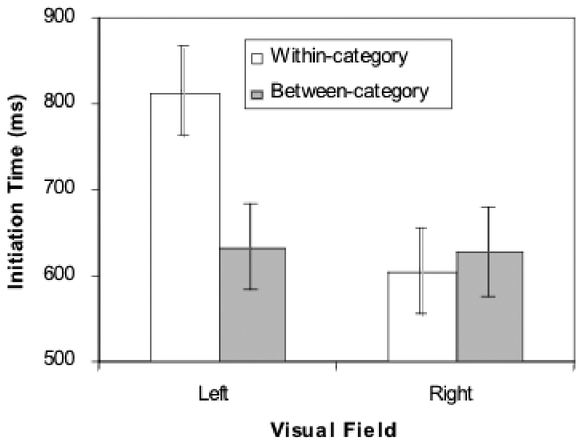

Figure 14. Prelinguistic infants show color CP lateralized to LVF. Source: (Franklin, Drivonikou, Bevis, Davies, Kay &.Regier 2008).

12. Discussion and Conclusions

Investigation of lateralization of Whorfian effects is just beginning and any conclusions drawn here are necessarily speculative. However, in a volume on the evolution of language, a little cautious speculation may not exceed the bounds of propriety. The empirically firmest and most clearly justified conclusion we can draw now is that normal adults under ordinary conditions can make cross-category color discriminations faster than within-category discriminations in the RVF, and less so or not at all in the LVF. Normal adults have language-driven RVF color CP, i.e., lateralized Whorf. That the left cerebral hemisphere is involved and that it is specifically the language function of that hemisphere that is in play are evidenced~~, respectively,~~ by ~~(1) the EEG study reported above and (2)~~ that in every case in which it has been administered, verbal interference eliminates RVF CP while non-verbal interference does not. The observation regarding verbal interference indicates further that lexical categories are accessed online during these tasks, rather than the internal representation of color itself having been warped by the learning of a particular language, as has sometimes been suggested. The fact that in two initial studies LVF color CP coincides with the varying lexical boundaries recognized in different languages reinforces the conclusion that LVF lateralized color CP is properly considered a "Whorfian" effect. Normal adults also appear to have CP for cat and dog silhouette stimuli, as does the one callostomy patient so far tested on non-color stimuli, suggesting that lateralized Whorf is not restricted to color.

LVF color CP also shows up in two normal adult experiments, but (1) it is weaker than RVF CP in these experiments and (2) the experiments showing unequivocal presence of LVF CP have response times two to three times greater than those showing unequivocal absence of LVF CP. Since transcallosal transfer, visual scanning, or both may have taken place in the experiments showing LVF CP, it is not unreasonable to speculate that in ordinary life adult humans have little or no LVF CP. It thus appears that, under normal conditions, the two hemispheres provide somewhat different pictures of the world, one of which is filtered through linguistic categories.

Assuming current results hold up, infants have LVF color CP and no RVF CP. (There exists prior evidence of infant color CP simpliciter.) How do we reconcile infant LVF color CP (without RVF CP) with the existence of RVF CP in normal adults and callosotomy patients, as well as the apparent absence of right hemisphere CP? If acquisition of a language sufficiently restructures the brain so that an inborn color categorization is lost or supplanted by linguistic mechanisms, we can straightforwardly account for all cases of

LVF CP absence. Aside from infants, LVF CP is present, according to these preliminary data, only in aphasics with LH lesions. If we can attribute the LVF (inferentially RH) color CP in aphasics to some degree of post-stroke reorganization in which RH linguistic capabilities are strengthened (e.g., Thompson 2000), then all these data are accounted for by the use-it-or-lose-it hypothesis.

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End Notes

1. Roberson and Davidoff (2000), Witthoft et al. (2003) (See also Winawer et. al. (2007)) had previously used both verbal and non-verbal interference tasks in assessing color CP effects in non-lateralized designs, finding that only the former suppresses lexically induced color CP. Kay and Kempton (1984) had earlier shown that a verbal instruction designed to inhibit categorization by color name suppressed CP in a similarity judgment task with colors spanning the blue/green boundary.
2. In point of fact, Daoutis et al. found that color G2 was harder to find than G1 or G3, while color Pu was not harder to find than Bu or Pi, confirming their hypothesis that lexical category difference can overcome the linear separation effect.
3. Panel d of Figure 4 is not relevant to current concerns.
4. An initial experiment of this study, employing only the no-interference condition, also showed a significant lateralized Whorf effect.
5. Ivry had access to a callosotomy patient and Regier suggested adapting the old Kay and Kempton (1984) study, which compared languages for lexically induced CP effects, to comparing brain hemispheres for these effects.