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BRIEF REPORT

Does Categorical Perception in the Left Hemisphere Depend on Language?

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Categorical perception (CP) refers to the influence of category knowledge on perception and is revealed by a superior ability to discriminate items across categories relative to items within a category. In recent years, the finding that CP is lateralized to the left hemisphere in adults has been interpreted as evidence for a kind of CP driven by language. The present research challenges this conclusion. In 2 experiments, we found that CP for novel object categories was stronger in the left hemisphere than in the right, consistent with a role for language. However, both labeled and unlabeled categories gave rise to such effects, and to comparable degrees. These results suggest that left-lateralized CP does not depend on language but rather may reflect the left hemisphere's more general propensity for categorical processing. Our findings raise implications for research on linguistic relativity.

Keywords: categorical perception, language and thought, categorization, left hemisphere, object perception

Categorical perception (CP) refers to the influence of category knowledge on perception (Goldstone & Hendrickson, 2010; Harnad, 1987). This influence is revealed when stimuli from different categories are discriminated faster or more accurately than stimuli from the same category. CP has been observed across a wide range of visual categories, including colors (e.g., Winawer et al., 2007), objects (e.g., Gilbert, Regier, Kay, & Ivry, 2008), faces (e.g., Kikutani, Roberson, & Hanley, 2010), and even fur patterns on cattle (Goldstein & Davidoff, 2008). Findings from these and other recent studies have suggested the existence of two kinds of CP: one that is nonlinguistic and one that is driven specifically by language. Evidence for the nonlinguistic variety comes from findings of CP in prelinguistic infants (e.g., Franklin, Drivonikou, Bevis, et al., 2008) and nonhuman animals (e.g., Baugh, Akre, & Ryan, 2008). Evidence for language-driven CP comes from studies in which CP effects are specific to the category boundaries of one's native language (Goldstein & Davidoff, 2008; Roberson, Davies, & Davidoff, 2000; Roberson, Pak, & Hanley, 2008; Thierry, Athanasopoulos, Wiggett, Dering, & Kuipers, 2009; Winawer et al., 2007), selectively disrupted by verbal interference (Gilbert, Regier, Kay, & Ivry, 2006, 2008; Roberson & Davidoff, 2000; Roberson et al., 2008; Winawer et al., 2007), associated with activity in language areas of the brain (Siok et al., 2009), and linked to acquisition of the relevant words (Franklin, Drivonikou, Clifford, et al., 2008). Tying together these various strands of evidence is the finding that CP in adults is stronger in the left hemisphere than in the right (Drivonikou et al., 2007; Gilbert et al., 2006, 2008; Roberson et al., 2008; Zhou et al., 2010; but see Franklin, Catherwood, Alvarez, & Axelsson, 2010). Because the left hemisphere is dominant for language (Kolb & Whishaw, 1985), left-lateralized CP has been regarded as particularly strong evidence that language plays an online role in CP (Regier & Kay, 2009; Roberson & Hanley, 2010). The present research provides a critical test of this conclusion.

While certainly consistent with a role for language, left-lateralized CP might result from causes other than the online influence of language. As originally proposed by Kosslyn et al. (1989), the left hemisphere may be specialized for the processing of categorical distinctions independent of language. Hence, CP may be left-lateralized because the left hemisphere partitions experience into categories, linguistic or otherwise. Research on hemispheric laterality from Kosslyn et al. and others (cf. Jager & Postma, 2003; Marsolek, 1999) has provided considerable support for a left hemisphere advantage in categorical processing, but given that such research has focused exclusively on categories with preexisting labels (e.g., *above/below*), it is unclear whether this advantage is fully language-independent.

In the present research, we provide a stronger test of the hypothesis that left-lateralized CP is driven by language. Specifically, we investigated whether categories without labels would, like labeled categories, give rise to left-lateralized CP. If both types of categories are shown to produce left-lateralized CP, the phenomenon could no longer be regarded as diagnostic of the online role of language in CP. Further, if the two types of categories produce comparable left-lateralized CP effects, it would suggest that nonlinguistic category representations in the left hemisphere, not language, are the source of CP, even for labeled

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categories. To address these questions, we selected categories composed of novel objects with no preexisting labels, varying whether the categories were learned with labels and examining whether they subsequently gave rise to left-lateralized CP.

Experiment 1

Adapting a paradigm used by Gilbert et al. (2008), we gave participants a discrimination task consisting of displays in which a target object was presented within a ring of identical distractors. Participants were asked to indicate whether the target was on the left or right side of the display. In a learning phase that preceded the discrimination task, participants in the label condition (+categories, +labels) learned categories and novel labels for them. Participants in the no-label condition (+categories, −labels) learned the same categories but without labels, and those in the baseline condition (−categories, −labels) received no exposure to the categories or labels. In the discrimination task, left-lateralized CP is indicated by faster responses when the target and distractors are from different categories than when they are from the same category, with a larger difference for right visual field (RVF) targets than for left visual field (LVF) targets.

If left-lateralized CP depends on language, it should be observed only in the label condition. However, if left-lateralized CP is driven by nonlinguistic category representations, it should also be observed in the no-label condition. No CP should be observed in the baseline condition, in which the category distinction is not meaningful.

Method

Participants. One hundred eleven right-handed adults participated for course credit or payment. Fifteen participants were excluded because they failed to learn the categories (<85% accuracy at the end of the learning phase; $N = 2$) or performed at chance on the discrimination task ($N = 13$).

Materials. Stimuli were four silhouettes of novel objects (courtesy of M. J. Tarr; www.tarrlab.org). We used the results from a speeded same/different judgment task ($N = 15$) to group the objects into two categories (see Figure 1A) such that similarity was comparable within and across categories. In the discrimination

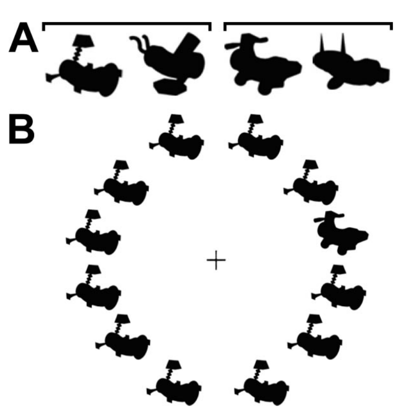

Figure 1. Novel object stimuli, with brackets indicating the categories learned in the initial learning phase of each experiment (A), and one of the displays used in the discrimination task (B).

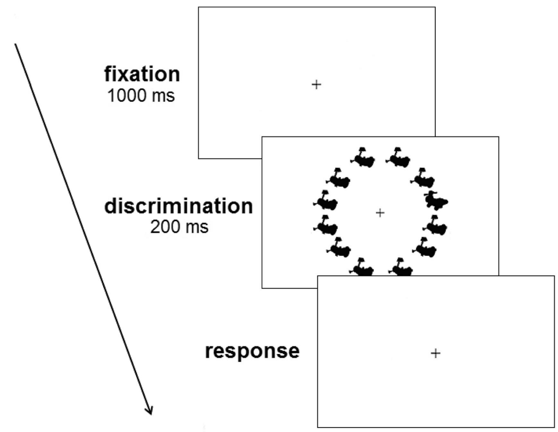

Figure 2. Trial structure in the discrimination task.

task, each display consisted of a fixation marker surrounded by a ring (15° in diameter) of 12 objects: one target and 11 identical distractors (see Figure 1B).

Design and procedure. In the learning phase of the label condition, participants were presented with a sheet of paper displaying the objects and their category assignments. Participants were told that the two objects in the top half of the paper went together and were called *daxes*, and that the two objects in the bottom half went together and were called *zifs*. After studying the sheet for 2 min, participants completed a categorization task. On each of 96 trials, participants judged whether an object was a *dax* or a *zif* by pressing one of two computer keys. Feedback was provided after each trial. The learning phase in the no-label condition was the same, except that no labels were given for the categories, and in the categorization task, participants judged whether a second object belonged to the same category as the preceding object. Participants in the baseline condition received no exposure to the objects, categories, or labels.

After the learning phase, all participants completed a discrimination task (see Figure 2). On each trial, participants indicated the side (left/right) of the target by pressing one of two computer keys. Each display appeared for only 200 ms, ensuring that the information in each visual field was initially processed by the contralateral hemisphere. Across trials, each object served as target and distractor at all 12 positions in the display, resulting in 144 combinations of objects and positions. Each combination was presented twice.

Results and Discussion

The results provide no evidence that left-lateralized CP depends on language. As shown in Figure 3, left-lateralized CP was observed not only when categories were learned with labels but also when learned without labels, and to comparable degrees.

Accuracy at the end of the first learning phase was high in both the label ($M = 95.2\%$, $SD = 4.1$) and no-label ($M = 93.8\%$, $SD = 3.6$) conditions. In the discrimination task, mean accuracy was 72.8% ($SD = 6.4$). Reaction times (RTs) greater than 2,500 ms (1.4% of correct trials) were excluded from the analyses, with no difference across conditions in the number of trials excluded ($p >$ .4). We conducted a $2 \times 2 \times 3$ analysis of variance (ANOVA) on

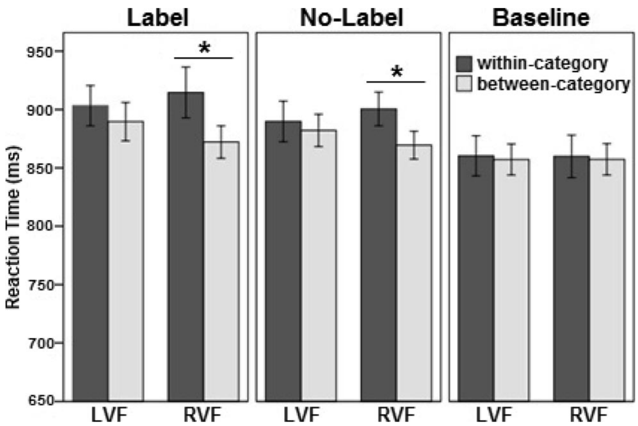

Figure 3. Mean reaction time to discriminate targets across trial types and conditions in Experiment 1. Error bars are 95% within-subjects confidence intervals. LVF = left visual field; RVF = right visual field.

correct RTs, with visual field (left/right) and trial type (within-/between-category) as within-subjects factors and condition as a between-subjects factor. There was a main effect of trial type, $F(1, 93) = 16.74$, $p = .0001$, $\eta^2 = .15$, and an interaction between trial type and condition, $F(2, 93) = 3.28$, $p = .04$, $\eta^2 = .07$. No other main effects or interactions were significant. Because discrimination tended to be faster on between-category than on within-category trials in both visual fields, the lack of a three-way interaction is not surprising. Importantly, the size of the difference was larger in the RVF than LVF for participants who learned the categories, as indicated by an interaction between visual field and trial type in the label and no-label conditions, $F(1, 62) = 4.75$, $p = .03$, $\eta^2 = .07$. Consistent with this interaction, RVF targets were discriminated faster on between-category than on within-category trials in both conditions, label: $t(31) = 3.58$, $p = .001$, $d = 0.26$; no-label: $t(31) = 3.18$, $p = .003$, $d = 0.21$. For LVF targets, these differences did not reach significance (ps > .15). In the baseline condition, no effects were observed (ps > .7).[1]

While the results provide no evidence that left-lateralized CP is driven by language, the possibility remains that participants in the no-label condition spontaneously labeled the categories and that it was these covert labels, not their associated category representations, that gave rise to left-lateralized CP. Given the comparable effect sizes in the two conditions, this possibility seems unlikely, since any labels generated by participants in the no-label condition would have had to be represented as strongly as those learned in the label condition. Moreover, informal polling of participants provided no support for a covert labeling strategy. Nevertheless, to rule out the possibility more definitively, we conducted an additional experiment.

Experiment 2

To investigate the possibility of covert labeling, we employed a relabeling task. The procedure mirrored that of the previous experiment, but after the discrimination task, participants in the label condition learned a new set of labels for the same objects, while participants in the no-label condition learned overt labels for the first time. If covert labels in the no-label condition are represented as strongly as the overt labels learned in the label condition, both sets of prior labels should impede learning of a new set of labels to the same degree. However, if covert labels in the no-label condition are not represented as strongly, possibly because they were not generated at all, prior labels should impede learning of a new set of labels more in the label than no-label condition.

Method

Participants. Thirty-eight right-handed adults participated for course credit or payment. Six participants were excluded because they failed to learn the initial categories ($N = 1$) or performed at chance on the discrimination task ($N = 5$).

Materials, design, and procedure. The first learning phase was identical to that of Experiment 1, with the following exceptions: At the beginning of the experiment, participants were told that objects were “in the same category” (vs. “go together” in Experiment 1). The categorization task was also modified to minimize procedural differences across conditions. In the label condition, participants indicated whether two objects had the same or different labels. In the no-label condition, participants indicated whether two objects were in the same or different categories. After the first learning phase, participants completed the discrimination task of Experiment 1.

After this task, participants completed a second learning phase. They were told that they would be learning labels (*new* labels in the label condition), and that their task was to “figure out which objects these [new] labels refer to.” We made the task more challenging by requiring participants to associate the labels (*fep* and *tob*) with pairings of the four objects that differed from the pairings used in the first learning phase. On each of 96 trials, participants indicated whether an object was a *fep* or a *tob* by pressing one of two computer keys, with feedback provided after each trial.

Results and Discussion

The results replicated the previous experiment in showing left-lateralized CP for both labeled and unlabeled categories. Accuracy at the end of the first learning phase was high in both the label ($M = 98.6\%$, $SD = 2.7$) and no-label ($M = 98.4\%$, $SD = 2.5$) conditions. In the discrimination task, mean accuracy was 72.9% ($SD = 5.4$). The RT data were trimmed according to the criteria of Experiment 1, resulting in 1.6% of correct trials excluded, with no difference across conditions ($p > .2$). A 2 (visual field) × 2 (trial type) × 2 (condition) ANOVA on correct RTs yielded a main effect of trial type, $F(1, 30) = 5.34$, $p = .03$, $\eta^2 = .15$, and, critically, an interaction between visual field and trial type, $F(1, 30) = 11.08$, $p = .002$, $\eta^2 = .27$. No other main effects or interactions were significant. As shown in Figure 4, RVF targets were discriminated faster on between-category than on within-category trials in both conditions, label: $t(15) = 2.63$, $p = .02$, $d =$

[1] Analyses of the accuracy data yielded a main effect of trial type, $F(1, 93) = 4.45$, $p = .04$, with accuracy higher on between-category than within-category trials. Trial type did not interact with visual field ($p > .1$), which implies that there was no speed/accuracy tradeoff. No other main effects or interactions were significant (ps > .08).

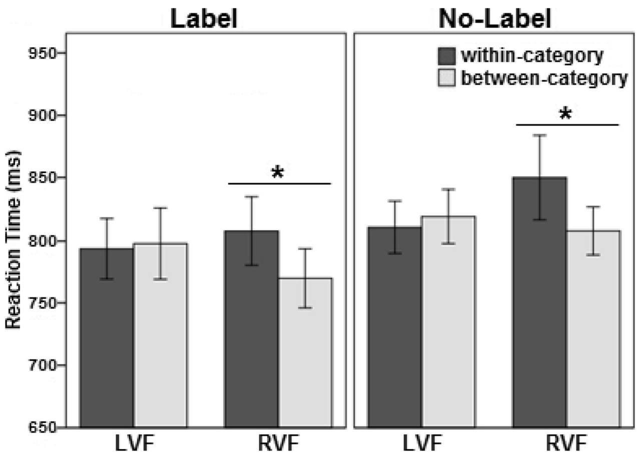

Figure 4. Mean reaction time to discriminate targets across trial types and conditions in Experiment 2. Error bars are 95% within-subjects confidence intervals. LVF = left visual field; RVF = right visual field.

0.23; no-label: $t(15) = 2.39$, $p = .03$, $d = 0.31$. No differences were observed for LVF targets in either condition (ps $> .2$).[2]

The results of the second learning phase provided no evidence for covert labeling in the no-label condition. Performance was near ceiling after just 12 trials, so we regressed RT on trial number for these trials. The slope in the label condition ($M = -131$, $SD = 61$) was significantly more negative than in the no-label condition ($M = -49$, $SD = 109$), $t(30) = 2.62$, $p = .01$, suggesting that prior labels impeded learning more in the label than in the no-label condition. While the occurrence of labeling in the two conditions differed, the size of the CP effects did not ($p > .8$), providing no evidence that left-lateralized CP was driven by language in either condition.

General Discussion

Across two experiments, we found that CP for categories composed of novel objects was lateralized to the left hemisphere. Critically, we observed left-lateralized CP for both categories with labels and categories without labels, challenging the widely held view that left-lateralized CP is driven by language. In showing that unlabeled categories can give rise to left-lateralized CP, we provide the first unambiguous demonstration in adults that the left hemisphere is associated with categorical processing independent of language. This idea has, of course, been raised before (e.g., Kosslyn et al., 1989), but firm evidence for the proposal has until now been lacking due to an absence of studies controlling for the potential influence of language. Finally, given that we found comparable left-lateralized CP effects for labeled and unlabeled categories, our results challenge the bifurcation of CP into two types. While it remains possible that CP might sometimes be driven by language, the more parsimonious conclusion is that CP, even for labeled categories, is driven by nonlinguistic factors. Rather than coming to depend on language over development (cf. Franklin, Drivonikou, Clifford, et al., 2008), CP may retain its nonlinguistic roots throughout the lifespan.

The idea that CP need not depend on language is not new. In early work on CP in the visual domain, the representations giving rise to CP were assumed to be nonlinguistic (see Goldstone & Hendrickson, 2010), but the categories under investigation in these studies were often given names or designations that could serve as labels (e.g., Goldstone, 1994). More recently, Franklin et al. (2010) showed that CP in adults for subtle differences in line orientation is right-lateralized, suggesting a kind of nonlinguistic CP in the right hemisphere for fine distinctions. These findings might indicate that left-lateralized CP is limited to coarser distinctions, like those examined in our experiments, but they do not address whether such CP depends on language. Similarly, findings of CP in prelinguistic infants (e.g., Franklin, Drivonikou, Bevis, et al., 2008), including left-lateralized CP (Franklin et al., 2010), do not speak to the nature of CP once language is learned.

Our findings suggest a reinterpretation of several lines of research previously regarded as evidence for the online role of language in CP. For example, CP may be disrupted more by verbal than by spatial interference (e.g., Winawer et al., 2007) because the former disproportionately taxes not only linguistic processing but also left hemisphere processing independent of language. In addition, neuroimaging work showing activity in language areas during CP tasks (Siok et al., 2009) does not establish that language is critical to the occurrence of CP, as such activity may be epiphenomenal.

Nevertheless, in suggesting that the representations driving CP are nonlinguistic, our findings point to a more indirect, and perhaps deeper, influence of language on perception. Consistent with developmental work showing that left-lateralized CP emerges with language acquisition (Franklin, Drivonikou, Clifford, et al., 2008), language may invite the formation of nonlinguistic categories (Gentner & Namy, 1999), which may in turn give rise to CP. According to this proposal, demonstrations that CP can differ across languages (e.g., Roberson et al., 2008) may be regarded as evidence for linguistic relativity (see Wolff & Holmes, 2011), even if language has no online role in CP. Indeed, categories that are the product of language may have a particularly strong influence on perception, given that CP at language-specific category boundaries has been shown to occur at the level of preattentive visual processing, as opposed to post-perceptual decision processes (e.g., Thierry et al., 2009).

Recently, several studies have failed to replicate left-lateralized CP for color (Brown, Lindsey, & Guckes, 2011; Witzel & Gegenfurtner, 2011). Our findings run counter to these studies in providing support for the generality of left-lateralized CP. At the same time, they offer new insight into how language and categorization in the left hemisphere may be causally connected: Rather than being categorical because it is linguistic, the left hemisphere may be linguistic because it is categorical.

[2] Analyses of the accuracy data yielded no main effects or interactions (ps $> .09$), providing no evidence for a speed/accuracy tradeoff.

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