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Brief article

The conceptual grouping effect: Categories matter (and named categories matter more)

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Abstract

Do conceptual categories affect basic visual processing? A conceptual grouping effect for familiar stimuli is reported using a visual search paradigm. Search through conceptually-homogeneous non-targets was faster and more efficient than search through conceptually-heterogeneous non-targets. This effect cannot be attributed to perceptual factors and is not explained by a long-term representational reorganization due to perceptual-learning. Rather, conceptual categories seem to modulate visual representations dynamically, and are sensitive to task-demands. Verbally labeling a visual target further exaggerates the degree to which conceptual categories penetrate visual processing.
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1. Introduction

People interpret what they see – quickly and automatically recognizing familiar objects as members of categories (Grill-Spector & Kanwisher, 2005). To what degree is visual processing itself shaped by conceptual knowledge? The classic separation

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between perceptual and conceptual systems has been challenged by mounting evidence for a much more interactive view (for review see Goldstone & Barsalou, 1998). Evidence from single-cell recordings has further blurred the line between the bottom-up processes of ''pure'' perception and top-down feedback that is potentially open to conceptual influences (Hupe et al., 2001; Lamme, Super, & Spekreijse, 1998; Lee & Nguyen, 2001). The remarkable speed at which object categorization occurs (Fabre-Thorpe, Delorme, Marlot, & Thorpe, 2001) further suggests that basic perceptual processes such as attentional selection and grouping may be penetrable by conceptual knowledge. While much is known about the effects of category-learning on perceptual organization, for example, the improved ability to discriminate stimuli following category training (e.g., Goldstone, 1994), considerably less is known about how object categories influence perceptual processes on-line. The present experiments use the paradigm of visual search to study how what we know affects what we see.

Theories of visual processing have often overlooked the possible contributions of conceptual categories (Wolfe & Horowitz, 2004 for discussion). In particular, the idea that conceptual categories affect performance in the domain of visual search has fallen into disfavor following failures to replicate Jonides and Gleitman's (1972) oh-zero effect (e.g., Duncan, 1983) and findings arguing that category effects hinge on perceptual rather than conceptual factors (Krueger, 1984; Levin, Takarae, Miner, & Keil, 2001). At the same time, it is clear that visual search performance cannot always be reduced to low-level visual factors. It is strongly affected by familiarity (Frith, 1974; Malinowski & Hubner, 2001; Wang, Cavanagh, & Green, 1994) and controlling for physical differences, is sensitive to the categorical relationship between targets (T's) and non-targets (N-T's) such as ''blue vs. green'' (Daoutis, Pilling, & Davies, 2006) and ''steep vs. non-steep'' (Wolfe, Stewart, Friedman-hill, & O'Connell, 1992). The origin, mechanisms, and specificity of these effects remain largely unknown. For instance, it is unclear to what degree representational differences between color categories and tilt categories are the product of experience and learning versus physiological constraints, and to what degree they are due to long-term representational change versus online representational reorganization.

The first aim of this work was to test for the presence of category effects in visual search while (1) controlling for all physical factors and (2) using familiar yet clearly learned stimuli. This was achieved by varying the *conceptual heterogeneity* of letter non-targets. It is known that physical N-T heterogeneity correlates positively with search times – searching for a T among L's is harder if L's are presented in varying orientations due to grouping of perceptually similar N-T's (Duncan & Humphreys, 1989). Experiment 1 tests for the presence of *conceptual grouping* by investigating whether N-T heterogeneity similarly slows search.

An effect of conceptual categories on visual processing can be attributed to two sources. First, items within a conceptual category may have become represented as more similar due to extensive practice with categorizing together these stimuli (e.g., Goldstone, 1994; Harnad, 1987). In this way, conceptual homogeneity may have turned into perceptual homogeneity. Alternatively, con-

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ceptual grouping may arise dynamically, through top-down modulation of visual representations by category-level representations. Experiments 2 and 3 examined these possibilities.

2. Experiment 1

The main goal of this experiment was to test for the existence of *conceptual grouping* effects by varying conceptual non-target heterogeneity (between-category versus within-category) among perceptually equidistant non-targets. A secondary goal was to examine the specificity of this effect by manipulating the distinctiveness of the target and the familiarity of the non-targets.

2.1. Methods

2.1.1. Participants

Twenty-one Carnegie Mellon University undergraduates (aged 18–22) volunteered for the experiment in exchange for course credit or $7. Two participants were eliminated for having accuracy below 80%.

2.1.2. Stimuli and procedure

Participants completed four blocks in counterbalanced order, searching for a non-letter target among conceptually heterogeneous non-targets (B and p) or conceptually homogeneous non-targets (B and b). The full assignment of targets and non-targets to blocks is shown in Fig. 1. Each character subtended $.7° \times .8°$ of visual angle,

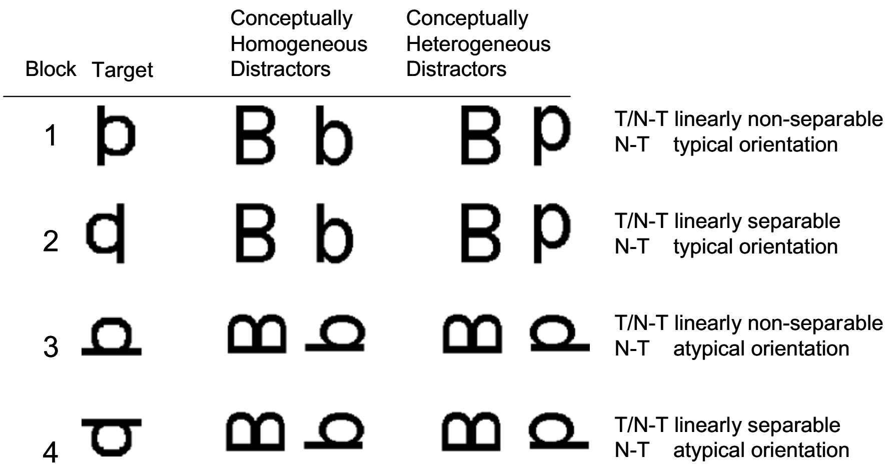

Fig. 1. The assignment of targets (T) and non-targets (N-T) to blocks in Experiment 1. Linear separability refers to a difference in gross orientation between T and N-T's. All conditions are within-subject with participants completing the blocks in counterbalanced order. Within each block, the two trial-types (homogeneous and heterogeneous) were intermixed.

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displayed on a 17″ CRT monitor. The characters were white, displayed on a black background and arranged along the circumference of an imaginary circle (7° diameter) around a fixation cross (.5° diameter). The placement of the target and non-targets was random with the stipulation that the same number of items were present on the left and right sides of the display.

Each block consisted of 12 practice trials followed by 9 repetitions of 12 trials (target-present versus target-absent × 3 display sizes – 4, 6, 10× within-category versus between-category N-T's). Trial order was random with the target present on exactly half the trials. Participants gave two-alternative target *present*/*absent* responses using a Gravis Gamepad Pro® controller. Response mapping of right/left hands to present/absent responses was counterbalanced between participants. Participants were instructed to respond as quickly as possible without compromising accuracy. If accuracy dipped below 92% for 24 trials, participants were prompted to try to be more accurate. The inter-trial interval was 750 ms. Feedback in the form of a buzzing sound was provided for incorrect responses. Stimuli delivery was controlled by Presentation® v9.70. (http://www.neurobs.com).

2.2. Results and discussion

Incorrect responses and responses shorter than 150 ms or longer than 3500 ms were excluded from analyses. Search in blocks in which the T and N-T faced in different directions (were linearly separable) was much faster, $F(1,18) = 114.51$, $p < .0005$ and produced shallower search slopes (was more efficient), $F(2,36) = 37.85$, $p < .0005$ than when T and N-T faced in the same direction (linearly nonseparable). Search through upright letters was faster, $F(1,18) = 19.18$, $p < .0005$ and more efficient, $F(2,36) = 3.82$, $p = .03$, than search through rotated letters (Fig. 2). Analyses of target-absent trials paralleled these results: $M_{\text{linearly-separable}} = 971$ ms, $SD = 216$; $M_{\text{linearly-nonseparable}} = 1332$ ms, $SD = 251$ ms, $F(1,18) = 177.80$. Search through upright letters was likewise faster ($M = 1067$ ms, $SD = 41$ ms) than search through rotated letters ($M = 1236$ ms, $SD = 51$ ms), $F(1,18) = 35.84$.

The finding of faster search through familiar than unfamiliar non-targets is hardly new, but what is significant is that the present finding cannot be attributed to a difference in novelty between target and non-targets (Malinowski & Hubner, 2001; Treisman & Gelade, 1980; Wang et al., 1994) – since the target was always novel – supporting the interpretation that such effects have more to do with greater processing efficiency of familiar stimuli than differences in familiarity between Ts and N-T's (Rauschenberger & Yantis, 2006; Richards & Reicher, 1978). Interestingly, the effect of linear-separability was itself mediated by familiarity: linearly nonseparable search was particularly difficult when the N-T's were in a less-familiar orientation; linear nonseparability was less detrimental for letters in their canonical orientation, $F(1,18) = 9.98$, $p = .005$ (for target-absent trials: $F(1,18) = 18.29$, $p < .0005$). The differences in RTs were paralleled by error data which showed no evidence of a speed-accuracy tradeoff in any of the blocks (Fig. 2 right).

The subsequent analyses focus on the conceptual relationship between non-targets. A comparison of search through within- and between-category non-targets

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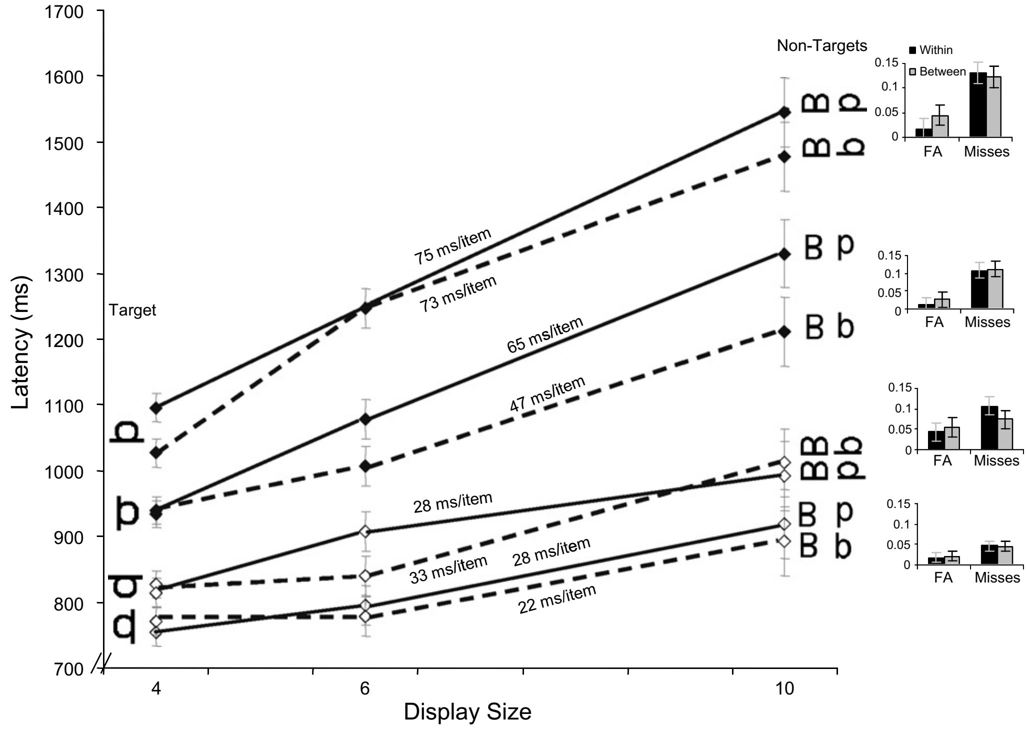

Fig. 2. Search times by block and trial-type, as a function of display size in Experiment 1. Only target-present trials are shown. Solid symbols indicate linearly non-separable blocks. Error data is shown on the right, separate by error type (false alarms versus misses) and trial type (within-category non-targets versus between-category non-targets). Bars show within-subject 95% confidence intervals based on condition interactions (Loftus & Masson, 1994).

revealed significantly faster RTs for same-category non-targets. For target-present, trials: $F(1,18) = 6.27$, $p = .02$; for target-absent trials: $F(1,18) = 12.70$, $p = .002$. There were no overall difference in error rates for target-present trials (misses), $F < 1$, but false-alarms were significantly higher on between-category ($M = .037$) compared to within-category trials ($M = .022$), $F(1,18) = 16.20$, $p = .001$, showing that the RT difference was not due to a speed-accuracy tradeoff.

Planned comparisons revealed that the conceptual relationship between the N-T affected performance most while searching for Þ among upright letters. In this block, search through within-category non-targets was both faster, $F(1,18) = 6.22$, $p = .02$, and more efficient, $F(2,36) = 5.21$, $p = .01$, reducing search slopes from 65 ms/item to 47 ms/item (Fig. 2). Analysis of responses on target-absent trials, revealed marginally faster search on within-category trials, $F(1,18) = 3.20$, $p = .09$, suggesting that the advantage when searching through within-category non-targets did not arise from a response bias. Analysis of error rates revealed no overall differences, $F < 1$, though, accuracy was significantly higher for the smallest display size of the within-category (B–b) condition, $F(1,18) = 4.18$, $p < .05$. Together, these results pro-

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vide evidence for a conceptual grouping effect for familiar stimuli, particularly when discriminating between T and N-T's is difficult.[1]

3. Experiment 2

There are several possible explanations for the conceptual grouping effect observed in Experiment 1. Given years of experience categorizing B's and b's as members of the same category, the two letters may have come to look increasingly similar to each other – a type of categorical perception (or perceptual warping) effect (Goldstone, 1994; Kuhl, 1994). Alternatively, the conceptual grouping effect may emerge on-line during the search task possibly due to top-down effects of category-level information. The purpose of Experiment 2 was to evaluate the first alternative by using a speeded same–different judgment task. If B is more similar to b than p, then one should observe slower RTs in judging of physical difference of B–b pairs compared to B–p pairs. A second goal of Experiment 2 was to ensure that the difference between within- and between-category non-targets in Experiment 1 was not due to unforeseen perceptual confounds, such as the target Þ being represented as more similar to a b than a p (in which case the observed effect could be attributed directly to differences in T/N-T similarity).

3.1. Methods

3.1.1. Participants

Fourteen Carnegie Mellon undergraduates participated for course credit.

3.1.2. Stimuli and procedure

The stimuli were identical to Experiment 1. A speeded same/different judgment task was used. Participants were presented with T/N-T combinations used in Experiment 1. The pairs were randomly placed to the left or right of fixation and participants were instructed to respond "same" only if the stimuli were physically identical. Participants completed 8 practice trials followed by 120 same–different judgments containing 15 repetitions of the comparisons shown in Fig. 3. Trial-types were intermixed. Feedback in the form of a buzzing sound was provided for incorrect responses.

3.2. Results and discussion

Mean RTs and statistical comparisons are shown in Fig. 3. There were no differences in RTs for responses to B–b and B–p pairs, arguing against the idea that perceptual-warping is the source of the conceptual grouping effect. There were also no

[1] When analyzed separately, the effect of conceptual homogeneity reached significance only for Block 1 of Fig. 1. However, as might be expected, search on target-absent trials of Block 3 showed significantly faster search through conceptually homogeneous N-T's, $F(1,18) = 8.49$, $p = .01$

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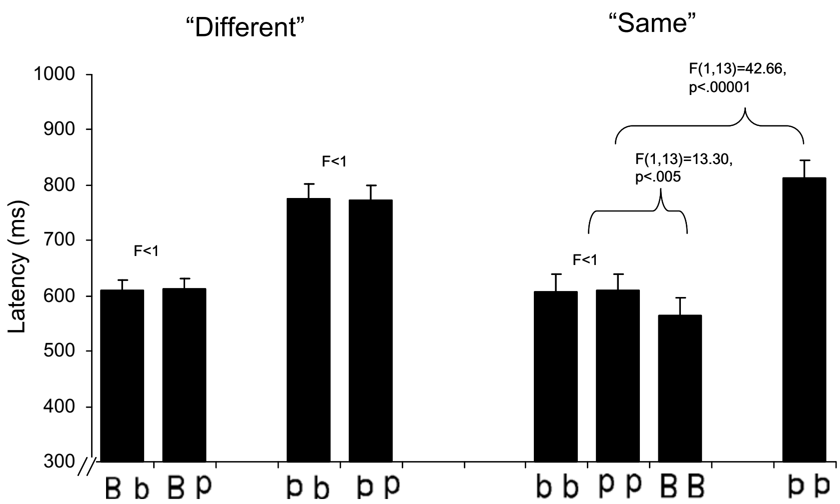

Fig. 3. Reaction-times for same/different judgments in Experiment 2. Participants judged the pairs for physical identity. Each bar shows the mean RT for the pair indicated. Bars show within-subject 95% confidence intervals.

differences in RTs between Þ–p and Þ–b responses, confirming that the non-letter target Þ was perceptually equidistant from both ‘‘b" and ‘‘p" non-targets, thus ruling out any spurious perceptual confounds in Experiment 1. There was a very substantial effect of familiarity. The RTs for responding ‘‘same" to Þ–Þ were more than 200 ms longer than for making ‘‘same" responses to familiar letters. Of interest also is that B–B comparison was faster than b–b/p–p comparison, further adding to the literature on effects of symmetry in visual perception (Richards, 1978).

The failure to find significant differences between B–p and B–b judgments does not support a perceptual-learning account in which the conceptual-grouping effect can be explained through long-term changes to representations of stimuli in the same conceptual category. The possibility that conceptual effects in visual search arise on-line through top-down modulation of visual representations with conceptual knowledge was tested in Experiment 3.

4. Experiment 3

Experiment 3 examined the impact of verbal category labels on visual search. Consider that the visual stimulus ‘‘B" is not just a member of a familiar category (one that can be instantiated using a variety of perceptual forms: b, *b*, B), it is a member of a named category. Over time, category labels (i.e., ‘‘bee") become strongly associated with features that are most diagnostic (or typical) of the named category. If conceptual categories affect visual processing on-line, then hearing a category name prior to the appearance of a search display may further modulate the degree to which visual representations are shaped by conceptual categories. The purpose of Experiment 3 was to determine whether cuing a target (B) with a verbal label

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("bee") facilitates search over and above simply knowing what the target is. A facilitation effect would support the hypothesis that conceptual category effects results from on-line top-down modulation. Insofar as verbal labels are associated with category exemplars, hearing a label may allow conceptual categories to further penetrate visual processing. This effect should be sensitive to task requirements. Hearing a label ("find the B") may facilitate search when T and N-T's are in different conceptual categories (B–p), but hinder search when they are in the same category (B–b).

4.1. Methods

4.1.1. Participants

Twenty-eight Carnegie Mellon undergraduates participated for course credit. Data for one participant was missing for Block 2 due to experimenter error.

4.1.2. Stimuli and procedure

Participants completed two blocks in counterbalanced order: In Block 1, they searched for a "B" among "b" N-T's (within-category trials) or "p" N-T's (between-category trials). Prior to each search trial, the target ("B") was either verbally cued (*label* condition) or not. Target identity was always known, so the label

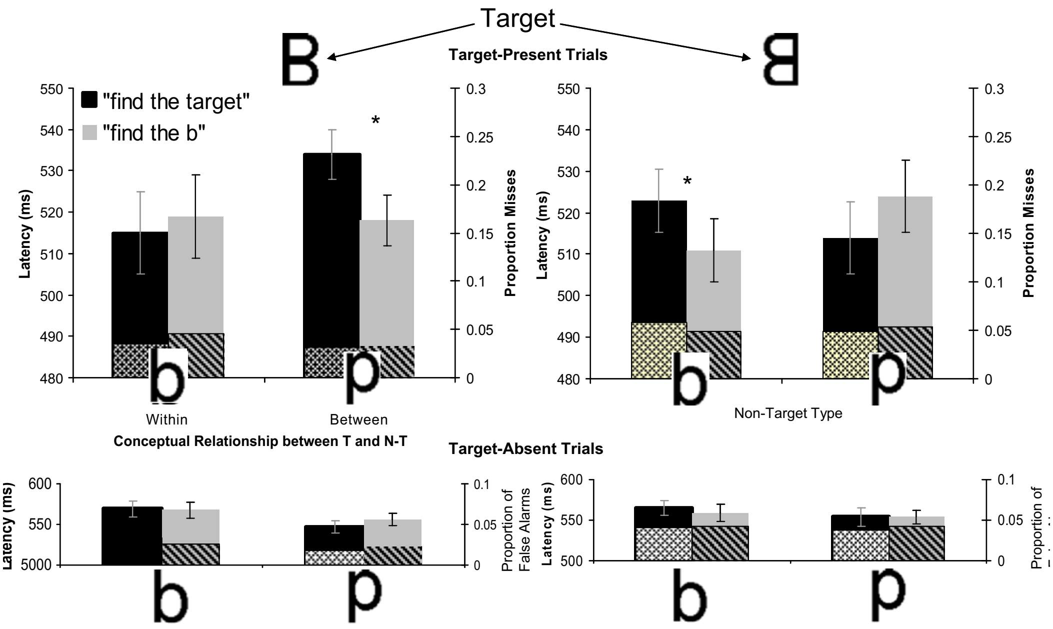

Fig. 4. Target-present RTs (top) and target-absent RTs (bottom) for Experiment 3. Panels show the effect of labels on search times for a familiar target B (left), and for a mirrored B (right). Labels facilitate search when the task requires discriminating a B from a non-B. Bars show within-subject 95% confidence intervals. Asterisks signify significant differences between means at $p < .05$. Proportion of errors are superimposed on the RT bars.

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did not add any additional information. To assess the specificity of any label-effects, an additional block of trials maintained all the low-level properties of the original "B" target, but mirror-reversed it ("ᗺ"), thus arguably disrupting or weakening the association between it and the verbal label. Each trial started with a fixation cross (500 ms) followed by an auditory prompt ("find the B" or "find the target") (1000 ms). The search display appeared 600 ms after the offset of the verbal prompt. For each block, participants completed 12 practice trials followed by 10 repetitions of 24 trials (target present versus target absent $\times$ 3 display sizes $\times$ labeling condition $\times$ trial-type: within-category or between-category). The procedure was otherwise identical to Experiment 1.

4.3. Results and discussion

Search was highly efficient (<5 ms/item) so the analyses collapse across display size. The first analysis includes the block of trials in which the target was the non-reversed letter "B". Hearing "find the B" prior to the appearance of the search display facilitated performance on between-category trials only as revealed by a significant labeling $\times$ trial-type interaction, $F(1,27) = 4.38$, $p = .05$ (target-present trials). When searching for a B among p's, labels significantly reduced search times, $t(27) = 3.44$, $p = .002$ (Fig. 4 left). Analysis of target-absent data revealed no effects of labels, $F < 1$. Analysis of errors revealed a greater accuracy for between-category search, $F(1,27) = 9.37$, $p = .006$, but no effects of labels, F's < 1.10 (Fig. 4). Importantly, there was no indication that the RT advantage on the label trials was due to a speed-accuracy tradeoff or a bias to respond "present" on *label* trials.

This label-facilitation effect was highly specific, showing a very different pattern of results when the target was mirror-reflected (Fig. 4 right). Now, labels facilitated search only when the *non-targets* were lowercase b's, $t(26) = 2.22$, $p = .04$. The labeling $\times$ trial-type interaction was again significant, $F(1,26) = 8.07$, $p = .01$. There were no accuracy labeling $\times$ trial-type interactions in either block, F's < 1. There were no overall differences in RTs or errors between search involving B and ᗺ, $F < 1$.

A parsimonious explanation of this pattern of results is that actually hearing the category label facilitates performance whenever the task requires discriminating a B (lowercase or uppercase) from a non-B. In contrast, no facilitation due to the label is observed in trials requiring discrimination within a conceptual category – B's and b's (indeed, there is a slight though not significant cost in both RTs and accuracy), or when no b's are present in the display (searching for a ᗺ among p's) – Fig. 4 right. This last result highlights the importance of a pre-existing association between the label and the visual stimulus for obtaining the label-facilitation effect. Unlike Experiment 1, in which conceptual effects were most clearly observed only in a difficult search (>40 ms/item), here, labels penetrated visual processing of a highly efficient search.

A curious aspect of the present results is that in the *no-label* condition, within-category search was actually faster than between-category search – a finding that seems at odds with work showing a superiority for between-category search for colors (Daoutis et al., 2006; Gilbert, Regier, Kay, & Ivry, 2006). Although it is possible that

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this difference was due to a speed-accuracy tradeoff, as indicated by significantly lower accuracy for between-category compared to within-category search, a possible alternative explanation is that the activation of the category representation by the category labels acted as a sustained prime, leading to overall faster processing of b's overall (even while making it more difficult to discriminate between B's and b's). A replication of Experiment 3 without auditory cues ($N = 23$) provided tentative support for this interpretation. While search was still highly efficient (<5 ms/item), overall RTs were significantly slower than in Experiment 3 ($M = 586$ ms $SD = 104$ ms versus $M = 521$ ms, $SD = 58$ ms), $t(32) = 2.65$, $p = .01$. Consistent with the idea that faster within-category search in Experiment 3 was due to the presence of labels, there was now no difference between within- and between-category search (within-category: $M = 590$ ms, $SD = 26$ ms; between-category: $M = 583$ ms, $SD = 20$ ms), $F < 1$. It appears then, that hearing the category name not only facilitated search on between-category *label* trials, but may have also had a more sustained impact of making the processing of b's more efficient, perhaps by making their representations more informationally redundant (Garner & Clement, 1963; Rauschenberger & Yantis, 2006).

5. General discussion

Conceptual categories affected visual search performance as revealed by faster search times through within-category (conceptual homogeneous) N-T's compared to between-category (conceptual heterogeneous) N-T's – the *conceptual grouping effect*. Although the present results do not show conclusively that within-category non-targets are rejected simultaneously as a group (cf. Treisman, 1982), they indicate faster processing of non-targets belonging to the same conceptual category, thus confirming that faster processing of similar non-targets is not confined to perceptual similarity (Duncan & Humphreys, 1989). The more efficient search through non-targets from the same conceptual category suggests that the non-target exemplars are being grouped based on their conceptual category.

The conceptual grouping effect seems to arise on-line, possibly through top-down feedback of category-level representations onto lower-level visual representations (Lupyan, in press) rather than through pre-existing differences in similarities between stimuli in the same versus different conceptual categories. Consistent with this claim, Experiment 2 failed to find differences between responses to within-category B–b pairs and between-category B–p pairs, lending support to the idea that the conceptual grouping effect observed in Experiment 1 emerges on-line during the search task rather than a result of prior experience with the letters permanently changing the perceptual space (Kuhl, 1994). In further accord with this interpretation, verbal labels enhanced the degree to which conceptual categories penetrated perceptual processing. In Experiment 3 it was shown that in a mixed-trial design, search times were reduced when a target was labeled compared to trials on which it was not (with

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target-identity always known). This facilitation due to labels was highly specific to stimuli that had pre-existing associations with the label – B and b, but not p or ᗺ.[2]

What mechanism might be responsible for the finding that simply hearing labels – which contribute no additional knowledge – facilitates between-category search? Compatible with the present results are theories that stress the fluid interaction between higher- and lower-levels of visual processing such as Hochstein and Ahissar's (2002) Reverse Hierarchy Theory. In accord with this theory, verbal labels may engage higher-levels of visual representations than are engaged in the absence of labels. These more categorical representations facilitate search by dynamically collapsing low-level differences within a category (conceptual grouping), while exaggerating the representational differences between the named category and other stimuli.

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[2] The finding that hearing "find the b" also facilitates searching for a ᗺ among b's, suggests that explicitly labeling the non-targets (e.g., "ignore the b's") should also facilitate search. This has been confirmed by Lupyan (2007) who found reduced search slopes on label trials in a more difficult task (searching for a 2 among 5's).

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