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Dissociable neural subsystems underlie visual working memory for abstract categories and specific exemplars

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An ongoing debate concerns whether visual object representations are relatively abstract, relatively specific, both abstract and specific within a unified system, or abstract and specific in separate and dissociable neural subsystems. Most of the evidence for the dissociable subsystems theory has come from experiments that used familiar shapes, and the usage of familiar shapes has allowed for alternative explanations for the results. Thus, we examined abstract and specific visual working memory when the stimuli were novel objects viewed for the first and only time. When participants judged whether cues and probes belonged to the same abstract visual category, they performed more accurately when the probes were presented directly to the left hemisphere than when they were presented directly to the right hemisphere. In contrast, when participants judged whether or not cues and probes were the same specific visual exemplar, they performed more accurately when the probes were presented directly to the right hemisphere than when they were presented directly to the left hemisphere. For the first time, results from experiments using visual working memory tasks support the dissociable subsystems theory.

The nature of representations of visual objects remains a topic of debate. Some theories posit that such representations are relatively abstract, in that a common representation may be activated by multiple exemplars or by multiple views of the same object exemplar (see, e.g., Biederman, 1987; Biederman & Bar, 1999; E. E. Cooper, Biederman, & Hummel, 1992; Hayworth & Biederman, 2006; Hummel & Biederman, 1992; Hummel & Stankiewicz, 1996; Wagemans, Van Gool, & Lamote, 1996). Other theories posit that object representations are relatively specific, in that different representations are activated by different exemplars or by different views of the same object exemplar (see, e.g., Bülthoff & Edelman, 1992; Gauthier et al., 2002; Poggio & Edelman, 1990; Tarr, 1995; Tarr & Gauthier, 1998; Tarr, Williams, Hayward, & Gauthier, 1998; Ullman, 1996). Alternatively, both abstract and specific representations may exist along different points on a continuum in a single, unified processing system (see, e.g., Farah, 1992; Hayward & Williams, 2000; Tarr & Bülthoff, 1995). Finally, abstract and specific object representations may exist in separate and dissociable neural subsystems, with an abstract subsystem operating effectively in the left hemisphere (LH) and a specific subsystem operating effectively in the right hemisphere (RH) (see, e.g., Burgund & Marsolek, 2000; Marsolek, 1995, 1999; Marsolek & Burgund, 1997, 2003).

The bulk of the evidence for the dissociable neural subsystems theory comes from experiments in which familiar shapes were used. This may be cause for concern, as Curby, Hayward, and Gauthier (2004) recently suggested, since abstract effects in the LH could reflect semantic processing of postvisual information that is associated with the visual-shape information, rather than processing of (abstract) visual shapes only, as posited by the dissociable neural subsystems theory. A related concern is that abstract effects in the LH could reflect linguistic processing of names associated with the visual shapes, rather than processing of abstract visual-shape information. In addition, when objects are presented multiple times in an experiment, abstract effects in the LH could reflect episodic memory for previous trials in the experiment. In this article, we report results that indicate, in line with the dissociable neural subsystems theory, that abstract processing of visual shapes in the LH does not require semantic, linguistic, or episodic information. Abstract processing of visual shapes can occur effectively in the LH when the stimuli are novel objects viewed for the first and only time.

According to the dissociable neural subsystems theory, an abstract category subsystem and a specific exemplar subsystem operate relatively independently and in parallel. An abstract category subsystem encodes the visual category to which an input stimulus belongs (e.g., pen vs. cup). It uses

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a features-based strategy in which relatively invariant features of shapes can be used to indicate that different visual inputs belong to the same abstract category. In contrast, a specific-exemplar subsystem encodes the visual exemplar to which an input stimulus corresponds (e.g., my favorite pen vs. my least favorite pen). It uses a whole-based strategy in which complex distributed representations can be used to indicate that even visually similar inputs correspond to different exemplars (Marsolek, 2003, 2004).

These subsystems have been dissociated in several ways. One way has been to measure hemispheric asymmetries through divided visual field experiments, from which causal inferences about the neural implementations of functions can be made, in the following way: Presenting test shapes directly to one hemisphere (i.e., briefly in one visual field) gives subsystems in that hemisphere timing and representational quality advantages over subsystems in the other hemisphere. Thus, finding evidence of abstract representations when test stimuli are presented directly to the LH (such that the stimuli presentations benefit one set of neural subsystems) and evidence of specific representations when test stimuli are presented directly to the RH (such that the stimuli presentations benefit a different set of neural subsystems) affords the conclusion that at least weakly independent neural subsystems are involved. For example, when test objects are presented directly to the RH, repetition priming for objects is greater when the same exemplars are repeated between initial encoding and subsequent test than when the prime and test objects are different exemplars in the same abstract category. In contrast, when test objects are presented directly to the LH, same-exemplar priming and different-exemplar/same-category priming are equivalent (but both are greater than priming when the printed names of objects are the primes and depictions of those objects are the test stimuli; Marsolek, 1999).

This type of dissociation of abstract and specific subsystems has been observed using familiar objects (see, e.g., Burgund & Marsolek, 2000; Marsolek, 1999), letter forms (Marsolek, Nicholas, & Andresen, 2002), letter-like forms (Marsolek, 1995), word forms (see, e.g., Deason & Marsolek, 2005; Marsolek, Kosslyn, & Squire, 1992), and pseudoword forms (Burgund & Marsolek, 1997). In addition, these subsystems may differentially process high and low spatial frequency information (Marsolek & Burgund, 1997); their differential proficiencies in the left and right cerebral hemispheres depend on stimulus and task demands (Marsolek, 1999; Marsolek & Burgund, 2003; Marsolek & Hudson, 1999); they are differentially affected by serotonin levels in the brain (Burgund, Marsolek, & Luciana, 2003); they can be selectively impaired following visual cortical damage (Beeri, Vakil, Adonsky, & Levenkron, 2004; Vaidya, Gabrieli, Verfaellie, Fleischman, & Askari, 1998); they are associated with different areas of activation in functional magnetic resonance imaging (Koutstaal et al., 2001); they rely on neurocomputationally contradictory processing strategies (Marsolek & Burgund, 1997); and they are associated with different event-related-potential components (Pickering & Schweinberger, 2003).

However, a limitation of this extant evidence for dissociable subsystems is that the studies cited above mostly used familiar visual shapes. This is important, because the purported evidence for effective abstract processing in the LH could be due to LH advantages in postvisual processing. Familiar shapes are associated with familiar semantic, phonological, and episodic memory information. Thus, evidence that categories of shapes are processed effectively following direct presentations to the LH could reflect top-down processing of postvisual information that is common to the shapes in one category, rather than abstract visual processing per se. By contrast, the dissociable neural subsystems theory posits that an abstract subsystem stores abstract yet visual representations (i.e., relatively invariant visual shape features) that are needed to recognize the category of a visual shape.

Curby et al. (2004) recently reported evidence in line with the hypothesis that abstract processing in the LH may be partially attributable to top-down semantic processing. When no semantic associations for novel object stimuli had been learned previously, viewpoint-specific processing in a sequential matching task (in which matches were more accurate, the greater the correspondence of two views) was observed following either LH or RH test presentations. These results are in line with Burgund and Marsolek's (2000) suggestion that, unless task demands cause abstract processing to be performed, the use of novel objects typically benefits the specific subsystem and often causes viewpoint-specific processing effects to be observed. In another experiment, however, Curby et al. found significantly reduced viewpoint-specific processing when the objects were presented directly to the LH compared with when they were presented directly to the RH, but only after the participants had learned new semantic associations (e.g., "this shape is friendly") for the preexperimentally novel shapes.

As Curby et al. (2004) discussed (see also Gauthier, James, Curby, & Tarr, 2003), this intriguing finding may indicate that semantic processing (and,we would add, perhaps linguistic and episodic memory processing) directly affects performance in the LH during the matching task. Alternatively, this finding may indicate that interactive feedback from postvisual systems may help an abstract subsystem learn the relatively invariant visual shape features for new visual categories during the semantic learning task, which was subsequently evidenced by reduced viewpoint-specific processing in an abstract visual subsystem during the matching task. The present study was conducted to provide a strong test of the hypothesis, derived from the dissociable neural subsystems theory, that abstract visual processing can be observed even when novel objects are viewed for the first and only time.

The main difficulty in setting up such a test is generating novel objects that likely have never been viewed by the participants and are not easy to verbalize but can be visually discerned as belonging to the same abstract category. The shapes shown at the bottom of Figure 1 are examples of the stimuli that we generated to serve this purpose. Each of the visual object categories that we created was formed from a prototype object that served as the base

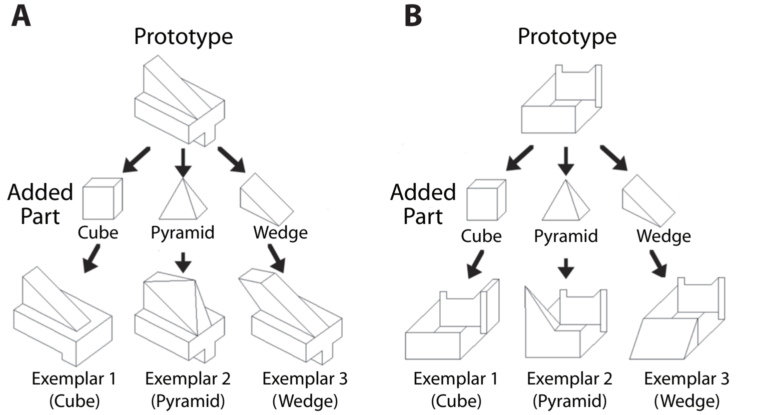

Figure 1. Examples of novel visual stimuli used in the study. (A) How one possible-object category was generated from a prototype/base. (B) How one impossible-object category was generated.

for the three novel objects in the category; a cube or brick shape was attached to the base to generate one exemplar, a pyramid was attached to generate another exemplar, and a wedge was attached to generate a third exemplar. The resulting category of objects was visually discernible as a category, even upon first viewings, because the three objects shared a large number of common visual features. To increase the likelihood that these stimuli were novel, half of them were structurally impossible (i.e, they could not exist in three dimensions), whereas the other half were structurally possible. Using such stimuli, we administered abstract and specific visual working memory tasks. In the abstract category task, participants compared whether a probe object presented briefly in the left or the right visual field belonged to the same abstract category as the cue object that had previously been presented in the central field (Figure 2A). In the specific exemplar task, participants compared whether a probe object presented briefly in the left or the right visual field corresponded to the same specific exemplar as the cue object that had previously been presented in the central visual field (Figure 2B).

These tasks have the following virtues: The putative specific-exemplar subsystem should not have been useful for performing the abstract category task, given that the cue and probe objects always differed at the specific exemplar level (see Figure 2A). Also, the putative abstract category subsystem should not have been useful for performing the specific-exemplar task, given that the cue and probe objects always belonged to the same abstract category (see Figure 2B). Another virtue of this study is that we generated enough stimuli to ensure that no one object was presented more than once to one participant. In this way, episodic memory for the objects presented in previous trials of the experiment could not be involved in performance.

The dissociable neural subsystems theory posits that purely visual shape representations (uninfluenced by top-down semantic, phonological, or episodic processing) can be utilized when performing the abstract category task in the LH, as well as when performing the specific exemplar task in the RH. If so, the abstract category task should be performed more accurately when probe stimuli are presented directly to the LH than when they are presented directly to the RH, and the specific exemplar task should be performed more accurately when probe stimuli are presented directly to the RH than when they are presented directly to the LH. Alternatively, top-down semantic, phonological, or episodic processing may be required for abstract object processing in the LH. Since the visual objects are novel and each is viewed only once in the experiment (thus disallowing effects from memory for previous trials), no semantic, episodic, or phonological information should be associated with the stimuli. Thus, by the alternative theory, no LH advantage should be observed with the abstract category task.

METHOD

Participants

Forty-eight male undergraduate students at the University of Minnesota volunteered to participate for payment or course credit. All but one were right-handed, as assessed by the Edinburgh Handedness Inventory (mean laterality quotient = .79; Oldfield, 1971),

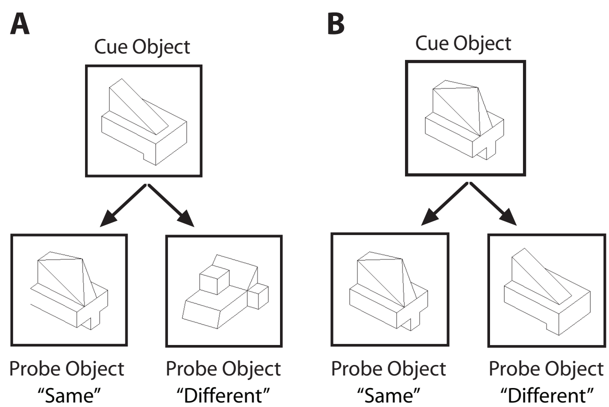

Figure 2. Examples of the cue and probe objects and the correct responses for the given cue–probe combinations in the abstract category (A) and the specific exemplar (B) visual working memory tasks.

and all had normal or corrected-to-normal vision.[1] Right-handed males were tested because they generally exhibit more reliable hemispheric asymmetries than do females and left-handed males (see, e.g., Hellige, 1993).

Design

A 2 × 2 × 2 factorial design was used, with visual working memory task (abstract vs. specific), object type (possible vs. impossible), and hemisphere of direct presentation of the probe object (LH vs. RH) as within-participants independent variables.

Materials

Stimuli were line drawings of 240 objects (120 possible and 120 impossible). Eighty base/prototype objects (40 possible and 40 impossible) were collected from various sources, including L. A. Cooper, Schacter, Ballesteros, and Moore (1992), Cowan (1977), Draper (1978), Huffman (1971), Marsolek and Burgund (2005), Penrose and Penrose (1958), Schacter and Cooper (1993), Schacter, Cooper, and Delaney (1990), Schacter, Cooper, Delaney, Peterson, and Tharan (1991), and Sugihara (1982). Each base/prototype was used to generate a category of three exemplar objects, and each exemplar in a category was formed by attaching a cube (or brick), pyramid, or wedge to the base/prototype (see Figure 1). In this way, 80 categories, visually discernible even on first viewings, were generated. Note that only the 240 exemplars were used in the experiment, not the bases/prototypes.

The 40 possible-object categories and the 40 impossible-object categories were divided into four lists of 10 categories each. Lists were equated so that they did not differ significantly from each other in terms of mean proportion or mean confidence in judgments of possible or impossible, as assessed via independent raters. Counterbalancing assured that each of the 80 categories and each of the 240 exemplars represented each of the conditions formed by crossing task (abstract vs. specific) and hemisphere of probe object presentation (LH vs. RH) an equal number of times across participants. Also, each of the 240 exemplars served as a cue and as a probe an equal number of times per task and was involved in *same* and *different* trials an equal number of times per task across all participants. Each cell of the main experimental design (task × object type × hemisphere) was represented by 10 trials per participant, with no object presented more than once per participant.

Stimuli were presented with an Apple Power Macintosh 7600/132 using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). The objects were presented in black lines against a white background, and each object subtended 7.5º–6.7º of widest (horizontal or vertical) visual angle. A 2-mm dot (subtending 0.23º of visual angle) served as the central fixation point that indicated the beginning of a trial. Cue objects appeared in the center of the display, and probe objects were presented in the left or right visual field such that the center of each object was 7.7º from the center of the display, and the inner edge of an object never appeared closer than 4.0º from the center. This virtually assured that probe objects were presented directly to only one hemisphere—participants erroneously fixate more than 1º from the central fixation point on less than 1% of trials when given instructions similar to ours (Jordan, Patching, & Milner, 1998). Finally, a chinrest was employed to keep participants' eyes approximately 50 cm from the monitor.

Procedure

Participants were tested individually. Abstract task trials and specific task trials were blocked (with order of blocks counterbalanced across participants).

The sequence of events for both the abstract and the specific tasks was the same: (1) presentation of a fixation point in the center of the display for 500 msec, (2) 1-sec presentation of a cue object in the center, (3) 10-sec blank display, (4) 500-msec presentation of a fixation point in the center, and (5) presentation of a probe object for 183 msec in the left or the right visual field. During each 1-sec intertrial interval, the display was blank. In both tasks, participants stored the cue object in visual working memory until the probe appeared, then they made a comparison between the cue and the probe. Pilot research indicated that a 10-sec blank display between cue and probe presentations enabled effective performance of both tasks that was not too close to ceiling, whereas shorter delays before probe presentations caused near ceiling levels of performance for both tasks.

The abstract and specific tasks differed with respect to the cue–probe comparisons. In the abstract category task, participants responded "same" if they judged the cue and the probe to be similar enough (i.e., to share enough features or parts) to belong to the same visual category; they responded "different" if they judged the cue and the probe to belong to different categories (Figure 2A). In *same* trials, the cue and probe belonged to the same category, but they were never the same exemplar. In *different* trials, the cue and probe belonged to different categories, but they were always both possible or both impossible. In the specific exemplar task, participants responded "same" if they judged the cue and probe to be exactly the same shape (albeit in different spatial locations of the display) and "different" if they judged them to be different shapes (Figure 2B). In *same* trials, the cue and the probe were the same exemplar. In *different* trials, the cue and the probe always belonged to the same category but were different exemplars. When the participants were instructed about the experiment, they were shown examples of comparison stimuli to which they should respond "same" and stimuli to which they should respond "different"; these example stimuli were not presented in the actual experiment. For both tasks, participants made "same" and "different" responses via buttonpresses, using the index and middle fingers of their right hands. Participants rested their fingers on the response keys throughout the trials, and they were encouraged to respond as accurately and quickly as possible.

Trials were presented in orders that were random but with the following constraints: Neither the object type (possible or impossible) nor the visual field in which the probe object was presented (left or right) would be the same on more than three consecutive trials, and the correct response ("same" or "different") would also not be the same on more than three consecutive trials.

RESULTS

Two repeated measures ANOVAs were conducted, one with sensitivity (d_L) as the dependent measure and the other with response times (RTs) for correct responses as the dependent measure.[2] The sensitivity measure derived with logistic distributions d_L was used because Snodgrass and Corwin (1988) demonstrated mathematically and empirically that signal detection theory using logistic distributions and the measures d_L and C_L produces an index of sensitivity that is independent of bias. Since estimates of d_L and C_L are undefined when hit or false alarm proportions are 0 or 1, proportions of 0 were converted to $1/(8N)$ and proportions of 1 were converted to $1 - [1/(8N)]$. In both ANOVAs, visual working memory task (abstract vs. specific), object type (possible vs. impossible), and hemisphere of direct presentation of the probe object (LH vs. RH) were within-participants independent variables.

Sensitivity

Figure 3 displays the important results from the sensitivity (d_L) ANOVA. As predicted, the interaction between task and hemisphere of direct presentation of the probe was significant [$F(1,47) = 6.20$, $MS_e = 4.806$, $p < .05$]. In the abstract task, sensitivity was significantly greater when probes were presented directly to the LH (3.44) than when probes were presented directly to the RH (2.93) [$t(47) = 2.05$, $p < .05$]. Contrastingly, in the specific task, sensitivity was significantly greater when probes were presented directly to the RH (3.65) than when probes were presented directly to the LH (3.05) [$t(47) = 2.02, p < .05$]. This pattern of results did not differ between possible and impossible objects; the three-way interaction between object type, task, and hemisphere did not approach significance ($F < 1$).

The only other significant effect in the sensitivity ANOVA was the main effect of object type [$F(1,47) = 7.41, MS_e = 3.232, p < .01$]. Overall, and not surprisingly, sensitivity was greater for possible objects (3.52) than for impossible objects (3.02). No other effects approached significance (all other ps $> .10$).[3]

The findings of greater sensitivity in the abstract task when probe objects were presented directly to the LH and greater sensitivity in the specific task when probe objects were presented directly to the RH support the dissociable subsystems theory, in part because the objects were novel and viewed for the first and only time during the experiment. However, one could argue that some of these objects could be given names or short verbal descriptions and that, therefore, the LH advantage in the abstract task could have been due to an LH advantage in naming or using verbal descriptions to perform the task. To the extent that possible objects are more easily named or described than impossible objects, our finding that object type (possible vs. impossible) did not affect the results supports our hypothesis that naming or verbally describing objects was not responsible for the results. However, to provide a stronger test, we collected ratings of the nameability of our objects on a scale of 1–7 from 16 independent raters and used these ratings in an additional ANOVA. As expected, these ratings did correlate significantly with object type (possible vs. impossible) ($r = .81, p < .001$). More important, within each experimental condition for each participant, we split the trials to form a new independent variable, *nameability of the cue object* (easy vs. hard). We added this variable in place of the object type variable (possible vs. impossible) in a new three-way ANOVA on sensitivity, and we found that the significant interaction between task and hemisphere of direct presentation of the probe [$F(1,47) = 4.97, MS_e = 3.691, p < .05$] was not qualified by ease of naming of the cue object in a three-way interaction [$F(1,47) = 1.19, MS_e = 2.543, p > .25$]. We concluded that the ability to name or verbally describe objects was not responsible for the hemispheric asymmetries in the abstract and specific tasks.

Response Times

No effect achieved significance in the RT ANOVA. The only effect that approached significance was the interaction between task and object type [$F(1,47) = 3.96, MS_e = 17{,}059.8, p < .06$]. Responses in the specific task were faster for possible objects than for impossible objects (968 vs. 997 msec, respectively), but responses in the abstract task were not (1,001 vs. 976 msec, respectively). Most important for the RT analysis, the interaction between task and hemisphere of direct presentation of the probe did not approach significance ($F < 1$), thus belying a trade-off between speed and sensitivity with regard to that critical interaction.

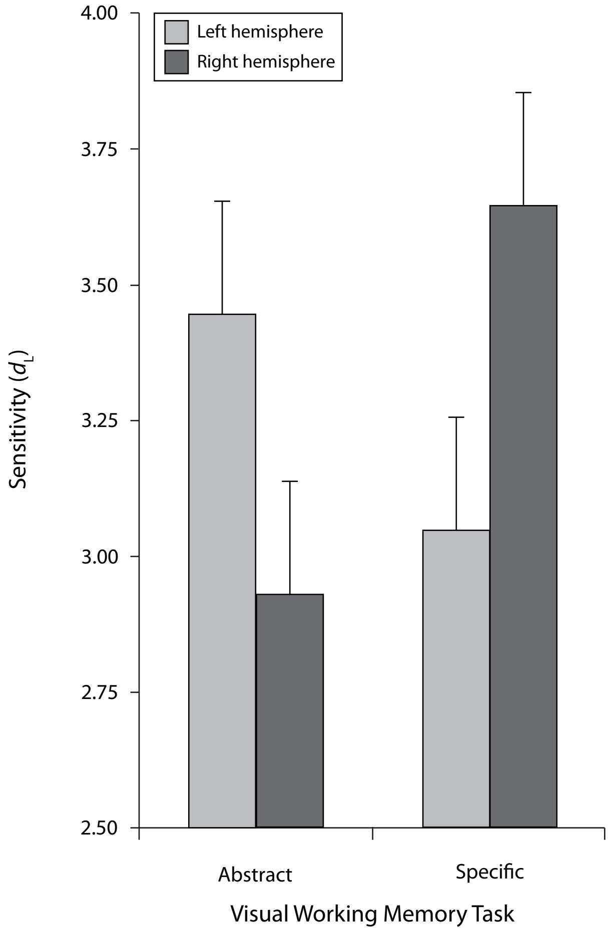

Figure 3. Main results from abstract category and specific exemplar visual working memory tasks. In the abstract category task, participants judged whether lateralized probe objects belonged to the same abstract visual category as the preceding centralized cue objects. In the specific exemplar task, participants judged whether lateralized probe objects corresponded to the same specific visual exemplars as the preceding centralized cue objects. Sensitivity (d_L) is displayed as a function of visual working memory task (abstract vs. specific) and hemisphere of direct presentation of probe objects (left vs. right). Error bars indicate standard errors of the mean.

Control Experiment Results

We also conducted a control experiment to test whether working memory maintenance processes were critical to obtaining the main experiment's results. We tested an additional set of 48 right-handed male participants in an experiment conducted and analyzed in the same manner as the main experiment, with the exception that the 10-sec delay between cues and probes was replaced with a 0.5-sec delay so that performance would not be highly dependent on working memory maintenance processes. Most important, performance was generally very high, and no effects approached significance in the analyses of sensitivity or of RTs for correct responses (all ps $> .10$). This indicates that the hemispheric asymmetry results from the main experiment were not due solely to encoding of probe objects (which occurred in the same manner in the main experiment and in the control experiment) and were instead due at least in part to visual encoding of cue objects and maintenance of these items in visual working memory.

DISCUSSION

Neuroimaging and neurophysiological research indicate that the posterior cortical systems that underlie visual shape recognition are also utilized during storage of those shapes in visual working memory (for reviews, see Jonides, Lacey, & Nee, 2005; Ranganath & D'Esposito, 2005; Smith & Jonides, 1997; Wager & Smith, 2003). If this is the case, the dissociable abstract category and specific exemplar subsystems that have been evidenced primarily in shape identification experiments (Deason & Marsolek, 2005) and in long-term priming and memory experiments (for reviews, see Marsolek, 2003; Marsolek & Burgund, 1997) should also be dissociable in visual working memory tasks. The results presented here support this prediction.

In the present study, participants compared cue and probe objects in two different visual working memory tasks. In the task that required judging whether or not the cue and the probe belonged to the same visual category, participants performed more accurately when the probes were presented directly to the LH than when they were presented directly to the RH. In contrast, in the task that required judging whether the cue and the probe were the same visual exemplar, performance was more accurate when the probes were presented directly to the RH than when they were presented directly to the LH.

This study provides evidence for the abstract and specific subsystems—evidence that allows for a causal inference about the implementation of these subsystems. Our findings that (1) abstract performance is enhanced when stimulus presentation benefits subsystems in the LH and (2) specific performance is enhanced when stimulus presentation benefits subsystems in the RH lead to the conclusion that the stimulus presentation variable causes different patterns of behavioral performance due to asymmetric neural implementations of abstract and specific visual subsystems. Such a causal inference supplements the kinds of correlational inferences that are typically made when different patterns of neuroimaging or neurophysiological signals are correlated with behavioral effects. These results are the first from visual working memory experiments to support the theory that abstract and specific subsystems are neurally dissociable.

The evidence for asymmetric neural implementations of abstract and specific visual subsystems is also evidence against unified or single-system theories of visual object representation. Different single-system accounts posit that object representations are relatively abstract (see, e.g., Biederman, 1987; Biederman & Bar, 1999; E. E. Cooper et al., 1992; Hayworth & Biederman, 2006; Hummel & Biederman, 1992; Hummel & Stankiewicz, 1996; Wagemans et al., 1996), relatively specific (see, e.g., Bülthoff & Edelman, 1992; Gauthier et al., 2002; Poggio & Edelman, 1990; Tarr, 1995; Tarr & Gauthier, 1998; Tarr et al., 1998; Ullman, 1996), or both abstract and specific at different points on a continuum in a single system (see, e.g., Farah, 1992; Hayward & Williams, 2000; Tarr & Bülthoff, 1995). In contrast, our theory is that object representations are abstract and specific in parallel and dissociable neural subsystems (see, e.g., Burgund & Marsolek, 2000; Marsolek, 1995, 1999; Marsolek & Burgund, 1997, 2003). The present results provide support for the latter perspective for the first time from investigations of working or short-term memory. In contrast with how single-system abstract and single-system specific theories conceptualize these representations, our results show that abstract and specific representations of the same objects exist in the brain, and that these representations are implemented in different brain areas.

These results also are crucial for ruling out explanations for prior studies' results that differed from explanations derived from the dissociable neural subsystems theory. These previous studies largely utilized familiar shape stimuli, thus the purported evidence of an LH advantage for abstract visual processing could have been due to LH advantages in top-down semantic (Curby et al., 2004), phonological, or episodic memory processing. The asymmetries in the present study were found when novel objects were used that likely had never been viewed before, were not easy to verbalize, and were viewed for the first and only time during the experiment. In addition, the asymmetries in the present study were not affected by the relative nameability of the objects stored in working memory. Thus, the asymmetries likely were due to visual processing per se, unaffected by top-down semantic, phonological, or episodic processing.

We conclude that the present results are not due to top-down semantic processes, but this conclusion may depend in part on how one defines *semantic*. One could argue that simply appreciating an abstract category of visual shape (which is required to perform the abstract task) is a kind of semantic processing. However, any such appreciation of an abstract category of visual shape in our experiment (with novel objects viewed for the first and only time in the experiment) necessarily would entail visual-form information and could not be due to postvisual meanings associated with the shapes. Such postvisual meaning information is what is typically understood to be semantic information in cognitive psychology (and is what was manipulated in the Curby et al. [2004] study that was used to motivate our study); thus, we conclude that semantic information processing did not underlie performance in our study.

A final important point to take from these results is that they provide further support for the perspective that task demands are crucial to investigations of hemispheric asymmetries of visual processing. Even when the stimuli and some aspects of different visual tasks remain constant, not every visual task will yield the same evidence of a particular pattern of lateralization. This perspective has been supported for years. For example, when the task is low-level visual detection of low and high spatial frequency gratings, no hemispheric asymmetries are observed. However, when higher level memory comparison processes (identification and discrimination tasks) are performed with the same stimuli, LH advantages are found for processing high spatial frequency information, and RH advantages are found for processing low spatial frequency information (see, e.g., Christman, Kitterle, & Hellige, 1991; Kitterle, Christman, & Hellige, 1990; Kitterle & Selig, 1991). Similarly, and in line with our previous research (Marsolek, 1999; Marsolek & Burgund, 2003; Marsolek & Hudson, 1999), the results presented here indicate that even when the same visual stimuli and similar visual working memory tasks are used, different patterns of hemispheric asymmetries can be observed. The demands of performing an abstract category comparison or a specific exemplar comparison appear to be responsible for the findings of opposite patterns of hemispheric asymmetries in visual working memory, with abstract category processing most effective in the LH and specific exemplar processing most effective in the RH.

AUTHOR NOTE

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NOTES

1. One participant claimed to be right-handed but then scored as left-handed on the Edinburgh Handedness Inventory (−.37). None of the statistical effects in the analyses changed as a function of not including this participant's data, and the results reported here are from analyses that included data from this participant.

2. A third ANOVA that used the bias toward responding "same" or "different" as the dependent measure (C_L) did not yield any significant effects; all $ps > .20$.

3. In addition to analyzing sensitivity, we also analyzed performance without using signal detection theory, in terms of proportions of trials with correct responses. All of the effects that were significant and nonsignificant in the sensitivity analysis were also significant and nonsignificant, respectively, in the proportion-correct analysis.

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