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The role of the cerebral hemispheres in specific versus abstract priming

Michal Schnaider Beeri
Mount Sinai School of Medicine, New York, USA

Eli Vakil
Bar-Ilan University, Ramat-Gan, Israel

Abraham Adonsky and Shalom Levenkron
Sheba Medical Center, Ramat-Gan, Israel

The present study examined specific and abstract priming for pictures in unilateral brain-damaged patients using a picture fragment identification task. Participants were 10 posterior right hemisphere (RH) damaged patients, 11 posterior left hemisphere (LH) damaged patients, and 30 healthy normal controls. Results reveal that RH patients perform specific priming tasks significantly worse than healthy participants ($p < .005$). There was a trend ($p < .1$) towards worse abstract priming in LH patients when compared to healthy participants. These results are additional evidence that specific priming depends on normal functioning of the posterior right cerebral hemisphere, while abstract priming depends on normal functioning of the posterior left cerebral hemisphere, and extend this finding from verbal to non-verbal stimuli.

Memory for previous experiences can be expressed in several ways. Explicit memory refers to intentional or conscious recollection of recent experiences, as expressed on standard recall and recognition tests. In contrast, such phenomena as skill learning, classical conditioning, and priming are examples of implicit memory (Graf & Schacter, 1985; Schacter, 1987), which refers to unintentional retrieval of previously acquired information in tasks that do not require conscious recollection of specific learning experiences. Priming itself is subdivided into conceptual and perceptual priming (Blaxton, 1989). Conceptual priming reflects the degree to which analysis of stimulus meaning is recapitulated at test. Thus, conceptual priming is greater following semantic than non-semantic

Address correspondence to Michal Schnaider Beeri, PhD, Department of Psychiatry, Mount Sinai School of Medicine, One Gustave Levy Place, New York, NY, 10029-6574, USA. Email: michal.beeri@mssm.edu

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processing of the input (e.g., category exemplar generation; Srinivas, 1993). In contrast, perceptual priming reflects the degree to which analysis of stimulus form is recapitulated at test. Perceptual priming is greater, for example, when study and test stimuli are presented in the same perceptual modality. In perceptual priming there is encoding of the form and structure of the stimuli but there is no access to their meanings or other associative properties (Tulving & Schacter, 1990).

In the last decade two new subsystems of perceptual priming have been examined thoroughly, one representing form-specific information and the other representing abstract form information (Marsolek, Kosslyn, & Squire, 1992). Form-specific representations preserve specific characteristics of the lines of the stimuli themselves. Thus, in the case of verbal stimuli, a form-specific system produces different output representations when a particular stimulus is presented as input in different fonts. Abstract representations specify the identity of the stimulus. Accordingly, an abstract form system produces the same representation independently of the variance in the stimulus input. The line of reasoning leading to the idea that the two types of form representation cannot be encoded in a single system is that, on the one hand, a system that computes abstract representations of stimulus forms must provide a single output for different instances of the same stimulus. On the other hand, a system that computes form-specific representation of stimulus form must produce a different output for each different instance of the stimulus. These two goals seem incompatible, which suggests that separate systems should perform the computations more efficiently than one system (Kosslyn & Koenig, 1992; Marsolek et al., 1992).

The hypothesis of the existence of these two systems was originally based on verbal stimuli only and took advantage of findings about cerebral laterality. Although it has been known that the left hemisphere plays a special role in language and in verbal processing, there is evidence that visual representation of verbal material can be perceived and sustained better in the right hemisphere than in the left. Some of this evidence comes from divided visual studies, in which stimuli are presented to participants briefly in their left or right visual fields to ensure that visual input reaches one hemisphere before crossing brain commissures to reach the other hemisphere (Chiarello & Richards, 1992; Faust & Chiarello, 1998; Marsolek et al., 1992; Marsolek, Squire, Kosslyn, & Lulenski, 1994). For example, in a study investigating the semantic priming of words that are members of the same category but are not strongly associated, findings support the view that a broader range of related meanings is activated during word recognition in the right than in the left hemisphere (Chiarello & Richards, 1992). In addition, there is evidence that specific properties of many kinds of verbal visual input are processed better in the right hemisphere than in the left (Kosslyn, 1987; Kosslyn & Koenig, 1992). More recently, accumulating findings indicate that abstract and specific visual-form systems operate independently in the brain (Marsolek et al., 1992; Marsolek, Schacter, & Nicholas, 1996).

In these experiments, participants read a list of printed words and subsequently completed word stems (three-letter beginnings of words) to form the first words that came to mind which began with the present stem (stem completion test). In so doing, participants tended to report words they read as completions. This priming effect was greater when initially presented words and subsequently presented word stems were presented in the same letter-case than when they were presented in different letter-cases. However, although the same letter-case advantage was found when stems were presented briefly in the left visual field (directly to the right hemisphere—RH), this advantage was not found when they were presented briefly in the right visual field (directly to the left hemisphere—LH). These results indicate that a specific visual form system operates more effectively in the right hemisphere than in the left. Moreover, one study found that amnesic patients show normal form-specific and abstract priming while a patient (MS) who suffered a right occipital lobectomy failed to exhibit font-specific priming but showed normal abstract priming (Vaidya, Gabrieli, Verfaellie, Fleischman, & Askari, 1998). These results indicate that perceptual specificity in visual priming depends on visual processes mediated by the right occipital lobe. In contrast, abstract visual priming is most probably best represented in the LH (Marsolek, 1995). In Marsolek's study, abstract priming was examined for new types of forms (i.e., forms without any meaning). After learning those forms, participants rapidly classified previously unseen prototypes of the newly learned types more efficiently when the prototypes were presented to the LH than when they were presented directly to the RH. These results indicate that an abstract visual-form system operates more effectively in the LH and stores information that remains relatively invariant across the different instances of a type of form.

In summary, most of the above findings derive from divided visual field studies using healthy participants and indicate that abstract priming operates more effectively in the LH while specific priming operates more effectively in the RH. In the present study, this lateralised effectiveness found by Marsolek and colleagues was re-examined using right and left hemisphere injured patients and non-verbal stimuli. We hypothesised that left hemisphere injured patients would perform abstract priming tests less well than normal participants and would perform normally on specific priming tests. The opposite profile was hypothesised for the right hemisphere injured patients, i.e., worse than normal participants' performance in specific priming tests and normal performance in abstract priming tests. These hypotheses may be summarised as an interaction of group and type of priming (LH patients impaired on abstract priming and RH patients impaired on specific priming) in addition to the group differences (impairment of head-injured patients compared to healthy participants).

METHOD

Participants

A total of 21 patients suffering from a first ischaemic cerebro-vascular accident (CVA)—10 in the right posterior cortex (RH) and 11 in the left posterior cortex (LH)—participated in this study. Of these, 20 patients were examined during their hospitalisation in three geriatric departments in central Israel. One patient was examined at home 1 week after discharge. The inclusion criteria were: (1) All patients were examined at least 2 months after and not later than 1 year after occurrence of the CVA. (2) CT scan results indicated the presence of a single ischaemic infarct in the posterior cortex of one of the hemispheres. A radiologist in each of the hospitals interpreted the scans. (3) Patients had no history of cerebral infarct, or any other psychiatric or neurologic disease or alcoholism. (4) Patients had sufficient level of intellectual and speech functioning to allow response capability to the study tasks.

As the control group 30 healthy elderly people participated in this study. All control participants lived in different institutions for the independent elderly in central Israel, and were free of any neurological or psychiatric disease; they were independent in activities of daily living and mentally healthy as reported by the social worker of the institution.

All the participants were right-handed. The groups were matched on age and education. The right CVA sample consisted of 5 men and 5 women, average age of 70.2 (SD = 10.8) and 9.5 (SD = 4.7) years of education. The left CVA sample consisted of 4 women and 7 men, average age of 71.4 (SD = 10.4) and 11.2 (SD = 4.9) years of education. Finally, the control sample consisted of 11 women and 19 men, 73.8 (SD = 9.4) years of age and 10.3 (SD = 4.1) years of education. Age and education were compared using ANOVA. No significant differences were found between the groups in these sociodemographic variables.

Materials

A pre-test was conducted using the 260 pictures of Snodgrass and Vanderwart (1980), to select the pictures that would be included in the tests and to overcome cultural differences. Those pictures were shown to 22 students who were asked to identify them. The 80 pictures with the highest identification rate were included in this study (the lowest identification rate being 82% of the participants). These 80 pictures were divided into two lists of 40 pictures each (list A and list B). In the study phase and in the testing phase 20 pictures each were presented while only 20 pictures were presented in the testing phase. From the 20 pictures presented in the study phase, 10 were presented exactly in the same form as in the testing phase (to test for specific priming) while the other 10 were presented in a subtly deformed form (to test abstract priming). Deformation was done by means of the Paint Shop Pro software. Each picture was stretched vertically or horizontally by 30–60% of its original form. In a pre-test 15 students identified all deformed pictures. (An example of an original and a deformed camel is presented in Appendix A.)

Procedure

All participants were individually tested. They were told that their perceptual speed was being tested. Two experimental sessions were conducted. The first included a picture identification test (for priming) and the second a parallel picture recognition test (for explicit memory). Both tests (partial picture identification and recognition) have been extensively used in similar forms (e.g., Hirshman, Snodgrass, Mindes, & Feenan, 1990; Vakil & Sigal, 1997). Both sessions were conducted in two phases: In the learning phase participants were asked to name aloud the 20 stimuli presented. Between the learning and test phases a distractor task was performed in which participants were asked to look at a furniture magazine and decide on the most beautiful furniture. This task lasted approximately 10 minutes and it was chosen as a task that is not cognitively effortful for participants. Immediately after completion, participants started the test phase. The perceptual identification test was introduced by telling the participants that it was a task measuring the speed of picture identification, and no hint was given concerning the stimuli presented during the learning phase. Fragments of the stimulus appeared in the centre of the screen and increased in number until the participant said aloud the name of the stimulus, then the examiner pressed a computer key freezing the process. If the participant identified the stimulus incorrectly, he or she was told so and the gradation process continued until the stimulus was correctly identified. The fragmentation was completed to the full stimulus after 15 seconds. Percent exposure (PE) to correct identification was recorded, ranging from 0 to 100. Following the correct identification of the stimulus, the full stimulus was presented on the screen for 1 second and then the next stimulus was presented. The measurement of PE of the participant by the examiner (and not by the participant him/herself) was done for the following reasons: (1) LH patients had partial or complete paralysis of the right hand and thus could not press the computer key. We employed a procedure that makes possible comparison between all groups; (2) reduction of variance under the assumption that the examiner's reaction time is consistent.

An explicit memory task was administered to confirm that the effect of the priming task was on implicit and not on explicit memory. The explicit and implicit tasks were absolutely parallel in an effort to make them comparable (see, as an example of comparable tasks, Graf, Squire, & Mandler, 1984). Participants who received picture list A in the priming session, received picture list B in the explicit memory session, and vice versa. The procedure of the explicit memory task was exactly the same as the priming procedure aside from the instructions, which included a clear explanation that some of the stimuli presented in the test phase were the same as the stimuli presented in the study phase.

We attempted to produce a parallel task for verbal stimuli but in a preliminary analysis it was found that the task did not yield either priming or explicit memory. Thus the performance on this task is not reported.

Data analysis

A two-way ANOVA was conducted to compare type of priming (specific versus abstract) in the three participant groups (RH patients, LH patients, and control). The type of priming factor was a within-participant variable, while the groups factor was a between-subjects variable. The dependent variable was the PE required to identify the stimulus (ranging from 0% to 100% of exposure, where the higher the percentage, the poorer the performance). The same analysis was done to compare type of explicit memory (specific versus abstract). The reaction time for new stimuli differed for the three groups: mean = 68.3% (SD = 7.0), 76.9% (13.0), and 78.3% (11.5) for the normal, LH patients, and RH patients groups, respectively; $F(2) = 6.09$, $p = .004$. Thus priming and explicit memory effects (i.e., the difference between new and old pictures) were calculated relative to the PE required identifying new pictures. This was adjusted for the participant's reaction times. The following are the operational definitions of the variables:

Standard picture (SP): Subject's average exposure percentage required to identify pictures that were presented in exactly the same form in both the testing and learning phases.

Distorted picture (DP): Subject's average exposure percentage required to identify pictures that were presented in a slightly distorted form in the testing phase compared to the learning phase.

New picture (NP): Subject's average exposure percentage required to identify new pictures (i.e., pictures that were presented for the first time in the testing phase).

Specific priming effect: [(NP-SP)/NP]*100.

Abstract priming effect: [(NP-DP)/NP]*100.

RESULTS

Implicit memory

Table 1 presents the mean priming effect in the different groups. The analysis revealed main effects for group, $F(2, 48) = 6.41$, $p < .005$, and for type of priming, $F(1, 48) = 35.57$, $p < .005$, with higher abstract priming effect than specific priming effect. The interaction between Group and Type of priming was also statistically significant, $F(2, 48) = 6$, $p < .05$.

To analyse the source of the interaction, post hoc analyses using Tukey's procedure were conducted separately for specific and abstract priming. The

TABLE 1
Perceptual priming by group and type of priming, mean (SD)

	Left hemisphere patients	*Right hemisphere patients*	*Healthy participants*
Specific priming	18.7 (7.9)	8.2 (8.4)	23.7 (9.0)
Abstract priming	21.4 (13.4)	22.5 (10.2)	29.3 (10.5)

analysis revealed that RH patients performed specific priming tasks significantly less well than healthy participants ($p < .005$). LH patients also performed significantly better than RH patients ($p < .05$) but were not significantly different from healthy participants ($p = .243$). In contrast, there was a blend ($p < .1$) towards differences between the three groups in abstract priming tasks, where healthy participants tended to perform better than LH patients ($p < .1$).

Explicit memory

Table 2 presents the mean effects of explicit memory in the different variables. The analysis reveals no significant difference between groups' performance on explicit memory tasks, $F(2, 46) = 2.5$, $p = .11$. As in the implicit memory analysis, PE needed to recognise deformed stimuli was significantly lower than the PE needed to recognise identical stimuli, $F(1, 46) = 5.73$, $p < .05$. The interaction between Group and Type of priming was not significant, $F(2, 46) = 0.83$, $p = .442$.

The effect of regular versus deformed stimuli in the learning phase of the priming task. To verify if the origin of the surprising result indicating larger abstract than specific priming effect is a real larger abstract priming effect or an artifact of the specific type of deformation done in this study, 10 more control subjects were tested. Subjects were 74 years old on average (SD = 2.8), had 12.5 years of education (SD = 2.5), and included four males and six females. The test was based on the same procedure detailed in the ‘‘Procedure’’ section but with the following change: 20 slightly deformed pictures were presented in the learning phase, including the 10 deformed

TABLE 2
Explicit memory by group and type of explicit memory, mean (SD)

	Left hemisphere patients	*Right hemisphere patients*	*Healthy participants*
Specific priming	9.0 (5.2)	10.9 (4.8)	11.7 (5.6)
Abstract priming	10.6 (5.7)	12.2 (6.6)	15.3 (5.4)

pictures used in the learning phase of the original study. Thus the 40 stimuli in the test phase were identical to the ones used in the original study—10 deformed stimuli (for specific priming), 10 regular stimuli (for abstract priming, a slight change compared to the learned pictures, and 20 new pictures. Results were consistent with those found in the main analysis of this study: using a paired *t*-test, abstract priming (mean = 25.35; *SD* = 6.69) was again significantly higher than the specific priming effect (mean = 22.04; *SD* = 7.51; $t = 2.95$, $df = 9$, $p = .016$).

DISCUSSION

The objective of this study was to examine the role of the cerebral hemispheres in specific and abstract priming in head-injured patients as opposed to healthy participants. The results of the present study examining head-injured patients reinforce those of previous studies (Marsolek, 1995; Marsolek et al., 1992, 1994) examining normal participants indicating that specific priming depends on normal functioning of the posterior right cerebral hemisphere while abstract priming depends on normal functioning of the posterior left cerebral hemisphere. Moreover, our results extend the idea of different levels of efficiency of specific and abstract priming in the hemispheres from verbal stimuli to pictures (Koutstaal, Wagner, Rotte, Maril, Buckner, & Schacter, 2001; Marsolek, 1999). This strengthens the idea that the efficiency of the hemispheres is not stimulus-dependent but process-dependent. Moreover, the pattern of the results for the priming tasks is different from this pattern in the explicit tasks, in that in the first there is a significant interaction between type of priming and group while in the second the interaction is not significant. This is consistent with Marsolek's argument for a difference between visual subsystems supporting priming and hippocampal subsystems supporting explicit memory (Marsolek et al., 1996).

The finding that PE needed for abstract priming is lower than that needed for specific priming is quite surprising. A common finding on implicit memory tests is that maximal priming is obtained when study and test items share the same perceptual attributes and the amount of priming declines as a function of similarity between studied and tested items (Roediger & Blaxton, 1987; Srinivas, 1993). Moreover, in Marsolek's studies, the amount of abstract priming was consistently lower than the amount of specific priming. A possible explanation for this discrepancy is that the deformation done to the original pictures emphasises some critical characteristics of the stimulus (for example, the hump of the camel) facilitating its identification in a similar way to what happens with caricatures (Lee, Byatt, & Rhodes, 2000). To test this, the supplemental study of control subjects applied the same paradigm but using deformed pictures in the learning phase. If PE for deformed pictures were consistently lower than PE for original pictures, this would confirm the explanation of the deformed pictures being easier to perceive. However, the obtained results showing amount of abstract priming higher than amount of specific priming (i.e., lower PE when a slightly different stimulus was presented, whichever version was presented first), confirms some form of negative priming for specific picture information.

Some methodological pitfalls should be addressed. Some recent studies suggest that temporal-occipital areas are more important for object priming than the parieto-occipital areas used in this study (Koutstaal et al., 2001; Yasuno et al., 2000). This may explain the lack of significant impairment in abstract priming in LH-damaged patients. The size of the brain lesion was not controlled and may have had some influence on the results. It may be, for example, that the statistically significant interaction in the priming analysis was obtained because the brain damage of the RH patients was larger than that of the LH patients. Nevertheless, the disadvantage of the RH patients should also be consistent in the explicit memory task, and this difference did not occur. Further, the inclusion criteria of the CVA patients (good level of cognitive functioning, specifically posterior damage, etc.) were chosen in an attempt to improve homogeneity of the sample, enhancing the likelihood of significant statistical effects despite the small number of participants and the possible neuroanatomical differences. Finally, the sample sizes limited the power of the statistical tests. A larger sample of LH patients would be necessary to draw firm conclusions if the LH effect size is smaller than the RH effect size.

In sum, Tulving (1995) argued that priming effects depend to a large extent on the perceptual representation system (PRS) that is in turn composed of several domain-specific subsystems. A number of researchers have suggested that the PRS involved in multiple memory systems corresponds to different anatomical regions of the brain (e.g., Petersen, Fox, Snyder, & Raichle, 1990; Schacter, Reiman, Uecker, Polster, Yun, & Cooper, 1995). The present study indicates that the structural description subsystem involved in the PRS is further subdivided into specific and abstract systems that have an asymmetrical distribution between right and left hemispheres.

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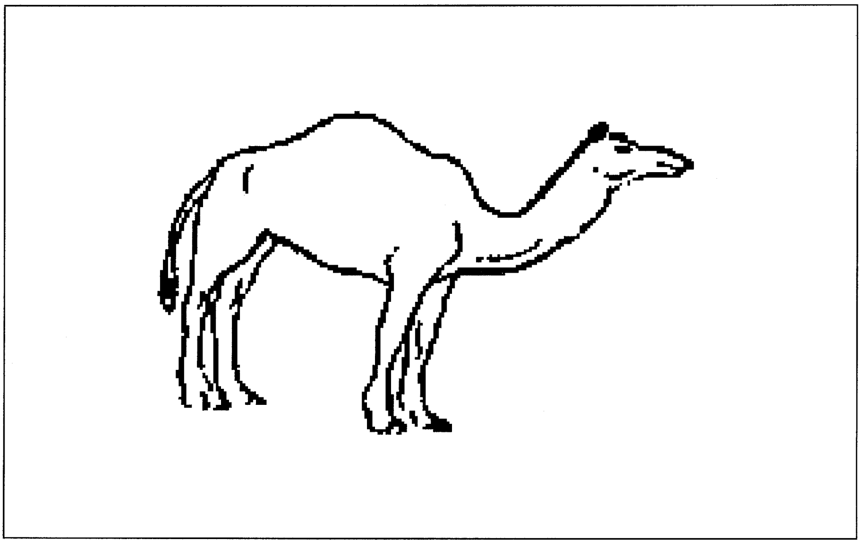
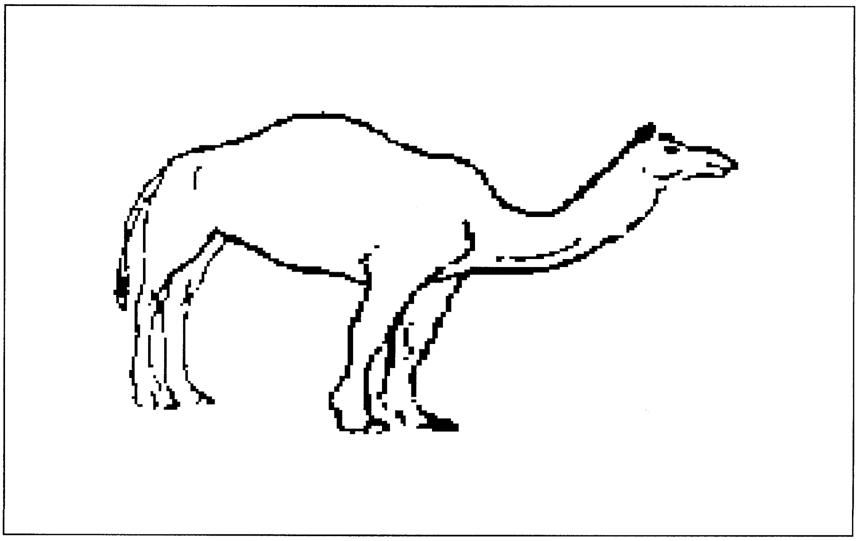
APPENDIX

An example of an original and a deformed stimulus



An original camel



A *slightly deformed* camel