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IMPLICIT AND EXPLICIT MEMORY FOR FAMILIAR AND NOVEL OBJECTS PRESENTED TO TOUCH

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Two experiments examined implicit and explicit memory for familiar and unfamiliar objects presented haptically. Experiment 1 showed substantial priming for real world objects using a speeded naming task. Furthermore, priming was not affected by changes in the mode of exploration (with gloves or without gloves) from study to test. In contrast, explicit memory assessed by a recognition test was impaired when such a change occurred. Experiment 2 showed implicit memory for unfamiliar wooden objects when priming was evaluated with a symmetry judgment task. Structural encoding but not elaborative encoding produced priming whereas explicit memory was enhanced under elaborative encoding. These findings suggest similarities between memory for objects in vision and touch.

Memoria implícita y memoria explícita de objetos familiares y no familiares presentados a través del tacto. En dos experimentos examinamos la memoria implícita y explícita háptica. El Experimento 1 mostró priming similar para objetos familiares en una tarea de identificación tanto cuando la exploración no varió del estudio a la prueba de memoria (sin guantes) como cuando sí lo hizo (con guantes), mientras la memoria explícita fue inferior cuando se modificó el modo de exploración. El Experimento 2 mostró priming en una tarea de detección de la simetría en objetos no familiares cuando los objetos se codificaron estructuralmente pero no cuando se codificaron semánticamente. Por el contrario, la memoria explícita fue superior cuando los objetos se codificaron semánticamente que cuando se codificaron estructuralmente. Estos resultados sugieren semejanzas en la memoria de objetos presentados a la visión y a tacto.

Most of the studies on implicit and explicit memory have used words presented either visually or auditorily, and less frequently they have used visual objects as stimuli (for reviews, see Roediger & McDermott, 1993; Schacter, 1987; 1994). These studies have shown a large number of dissociations between both types of memory measures. Very little work has been conducted on other modalities.

Studies on active touch have shown that the haptic system is very efficient in identifying and detecting structural properties of 3-D objects (e.g., Ballesteros, Manga, & Reales, 1997; Klatzky & Lederman, 1987; 1992; Klatzky, Lederman, & Metzger, 1985). However, how tangible objects are represented in implicit memory has recei-

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ved very little attention. The present study was conducted to investigate how active haptic observers store and retrieve information about 3-D familiar and novel objects under implicit and explicit conditions.

The terms *implicit* and *explicit memory* are used to refer to two different ways of accessing prior acquired experience. Explicit memory for objects requires conscious recollection of previous experience with the objects, whereas implicit memory is shown when previous experience with stimuli do not require conscious or intentional recollection of previous information (see Tulving & Schacter, 1990; Schacter, 1987). Implicit memory is assessed by showing repetition priming effects; i.e. more accurate and/or faster responses for stimuli that have been previously encountered than for new stimuli.

Research on stimuli presented to vision and audition has shown striking dissociations between implicit and explicit memory tasks in normal subjects as well as in (heavily) amnesic patients (for reviews, see Roediger & McDermott, 1993; Shimamura, 1986; Schacter, 1990; Schacter, Chiu, & Ochsner, 1993). Several features of the visual studies deserve attention. First, the experimental results do suggest that the change in a number of perceptual variables from study-to-test produce strong effects on implicit memory tests but has little or no effect on explicit memory tests. For example, priming is dramatically reduced and sometimes eliminated when the stimulus format is manipulated from the study-phase to the test-phase. In the verbal domain, priming is considerably reduced when the case or the font of words (two physical attributes of written words) changed from study to test (e.g., Graf & Ryan, 1990; Roediger & Blaxton, 1987). Second, priming is reduced or eliminated when words are presented at study and pictures are presented at test, or vice versa (e.g., Durso & Johnson, 1979; Kirsner, Milech, & Stumpfel, 1986; Rajaran & Roediger, 1993; Srinivas, 1993). Third, it is important to note, however, that not all the perceptual variables are encoded in the mental representations that support implicit memory effects. Research on visual objects has shown that a number of perceptual variables of objects such as size, right-left reflection, location, color, surface pattern, contrast and illumination do not affect repetition priming. However, all these changes impaired explicit memory (e.g., Biederman & Cooper, 1991a, 1992; Cave & Squire, 1992; Cave, Bost, & Coob, 1996; Cooper, Schacter, Ballesteros, & Moore, 1992; Srinivas, 1996). These findings suggest that repetition priming is not sensitive to all the perceptual attributes of the objects but only to those that are relevant to detect object's shape and structure.

The wealth of experimental dissociations obtained in studies with normal as well as with neurologically impaired patients led some theorists to propose different underlying memory systems which are neurophysiologically and computationally different (e.g., Schacter, 1992; Schacter, Cooper, & Delaney, 1990; Schacter, et al., 1993; Tulving & Schacter, 1990; Tulving, 1983). These memory systems are composed of several domain-specific subsystems in charge of processing modality-specific information about the form and the structure but not the meaning and other properties of the stimuli. Schacter and his associates (e.g., Cooper et al., 1992; Schacter et al., 1990; Tulving & Schacter, 1990) have proposed that priming on implicit memory tests is mediated by a presemantic perceptual representational system, whereas explicit recognition depends on an episodic memory system that encodes perceptual as well as spatial, temporal, contextual and semantic information about objects. In other words, all kinds of information that differentiates one object from another is represented in the episodic memory system. According to Schacter (1994), a structural description contains a representation of the relations among the different parts of an object that specifies its global shape and structure. These structural descriptions are believed to be computed by the structural-description brain system (cf. Riddoch & Humphreys, 1987). The presemantic representational subsystem is considered by Schacter and his colleagues as part of the structural-description system. A series of studies conducted by Schacter and his colleagues and associates using unfamiliar line drawing depicting 3-D novel possible and impossible objects supported the multiple memory systems framework and found priming only for possible but not for impossible objects. However, Carrasco and Seamon (1996) reported significant priming for possible and for impossible objects when both were equated at a moderately level of complexity (see also Seamon & Carrasco, in this number).

The experiments reported in this article explored the possibility that objects presented tactually would create or activate mental representations that later would produce facilitation for studied compared to nonstudied objects. We begin with a brief review of the active touch literature.

The haptic system

Active touch is conceptualized as a complex perceptual system that encodes inputs from cutaneous and kinesthetic receptors (e.g., Loomis & Lederman, 1986; Millar, 1994). The importance of active haptic exploration was recognized by pioneers in the field of touch (Gibson, 1962; Katz, 1925; Révész, 1950). According to Gibson (1966), the haptic system is composed by the cutaneous, the haptic, the dynamic, the temperature, and the pain subsystems which provide different and complex information. Researchers on touch are aware of the importance of the movements performed by the hands during haptic exploration of objects and surfaces (e.g., Klatzky & Lederman, 1992; Locher & Simmons, 1978; Millar, this volume; Zinchenko & Lomov, 1960).

In haptics, structural properties of shape such as bilateral symmetry have received little attention. In a series of experiments, Ballesteros et al., (1997) investigated the accuracy of touch in detecting bilateral symmetry of simple four-five raised line shapes and unfamiliar 3-D objects made from a piece of wood. Experiments conducted with raised shapes showed that touch was moderately accurate at detecting bilateral symmetry but symmetric judgments were systematically less accurate than asymmetric judgments with a finger scanning. However, exploring the small patterns with the two forefingers (bimanual exploration) facilitated the detection of symmetric shapes without improving necessarily asymmetric judgments. In contrast, bimanual exploration of 3-D unfamiliar objects was very accurate and, as in vision, symmetric judgments were more precise than asymmetric judgments. These findings were consistent with the hypothesis that the advantage of symmetric shapes depends on the availability of spatial reference (Millar, 1981). A new series of experiments were designed to test the hypothesis that bilateral symmetry is an encoding property for both modalities, vision and touch, even when the task does not require the detection of symmetry explicitly. The findings suggested that symmetry facilitated processing in vision although the task did not require explicitly the detection of symmetry. Symmetry was also part of the early shape encoding in touch but only when body-axis reference cues for spatial organization were provided (Ballesteros, Millar, & Reales, 1998).

A number of attempts from our laboratory failed to show priming when blindfolded observers explored five-six raised-line small (2 x 2 cm) novel shapes under structural and semantic encoding conditions (for a description of the shapes, see Ballesteros et al., 1997). The procedure included a study-phase in which observers explored the stimuli with the forefinger of their preferred hand followed by implicit and explicit memory tests. Implicit memory was assessed by a symmetry detection task. We attributed the lack of priming for these novel shapes to the difficulty of encoding spatial information under reduced kinesthesic feedback (the shapes were small) as well as to the lack of a spatial reference frame under blindfolded conditions. However, other researchers (Easton, Greene, & Srinivas, 1997) were successful in finding priming for haptically encoded simpler three-line raised patterns. Differences in the simplicity of the shapes (three-line shapes) as well as in the experimental procedure (e.g., participants had to give an accurate description of the presented shapes) might account for their success in getting implicit memory for 2-D patterns.

It is well known that blindfolded sighted observers perform quite poorly not only with unfamiliar shapes but also with raised line drawings of familiar objects (e.g., Ikeda & Uchukawa, 1978; Klatzky, Loomis, Lederman, Wake, & Fujita, 1993; Lederman, Klatzky, Chataway, & Summers, 1990; Loomis, Klatzky, & Lederman, 1991; Magee & Kennedy, 1980). However, people with vision as well as visually impaired observers interact continuously with real objects in their daily experience. We all have evidence that in everyday life haptic identification of objects out of sight is quite easy (e.g., when we introduced our hand in the pocket to get a handkerchief, or when we reach our hand to get a drink while talking to a friend). Vision and touch are both modalities specially adapted to extract shape and structure information from 3-D objects.

Present study

The two experiments reported in this paper were designed to examine whether haptic priming for familiar and novel tangible objects can be obtained and whether it is sensitive to different forms of encoding and changes in the mode of exploration. We were interested to find out whether these experimental manipulations would affect the mental representations of objects that are created after the encounter with the objects. A second aim of the study was to find out whether these manipulations would affect implicit and explicit ways of retrieving objects information differently. The work can be of interest for the visually impaired as it can revealed the organization of haptic memory for objects and can be of help in the development of new sensory substitution devises. In Experiment 1 haptic priming for familiar objects was assessed by a speeded naming task. We further studied the effect of introducing study-test changes in the way in which observers performed the task. Explicit memory was evaluated by a recognition test. In Experiment 2, unfamiliar wooden objects were used to test implicit memory for stimuli without previous mental representations. We investigated also whether haptic priming depends on presemantic structural descriptions, as suggested by studies in the visual domain, and explored how this manipulation influences episodic recognition.

Experiment 1

Wippich and Warner (1989) conducted an early study in which they found implicit memory for objects presented tactually. They assessed implicit memory by subtracting the time needed to answer questions related to an haptic dimension between the first (study-phase) and the second (test-phase) presentation of each object. Our first experiment examined whether haptic priming is documented in a situation in which different tasks were used at study and test. The experiment also explored the influence of sensory-perceptual factors in haptic implicit and explicit memory (Ballesteros, 1993). We hypothethized that if priming is supported by the construction of a structural description of the object during study (e.g., Schacter et al., 1990; Tulving & Schacter, 1990), having participants wearing gloves at performing the implicit memory test should not reduce priming compared to the condition in which they did not use gloves while performing the implicit memory test (as in the encoding phase). The idea is that interfering the sensory mechanoreceptors will not deteriorate the structural description of the object activated at study. On the other hand, if episodic representations that support explicit memory include perceptual, semantic and contextual information as Schacter and his colleagues have argued (e.g., Cooper et al., 1992), the use of gloves during haptic recognition will impaired explicit memory.

Three main issues about memory for tangible real world objects were addressed in this experiment. First, whether haptic priming will be shown given the differences between the visual and the haptic modalities. In contrast to the large number of studies directed at finding out the mechanisms we use to encode information about 3-D visual objects, the paucity of research on how the mental system deals with object information perceived haptically is striking. Second, we explored the specificity of priming. Memory systems theories based on visual and auditory findings suggest that implicit measures of memory tap structural representations of objects that are necessary for object decision and object identification (e.g., Tulving & Schacter, 1990). However, it is important to find out whether under tactual exploration sensory low-level perceptual features are crucial for accessing the identity of objects. The third issue was to find out whether implicit and explicit measures of haptically encoded objects would dissociate experimentally.

Results suggesting that haptic priming is not reduced after changing the sensory accessed information would favor the interpretation that implicit memory is not sensitive to all the physical attributes of objects but only to those that are involved on object identification (e.g., its shape and its spatial structure). This outcome would be against the interpretation that implicit memory is a reflection of (low-level) sensory processes.

We anticipated that exploring objects by active touch would create or activate a mental representation of its shape and structure, and that this representation would be reactivated in a second encounter with the object. The finding of no perceptual specificity in priming would be against the processing view and would favor the memory systems view. In addition, we were interested in exploring the influence of this manipulation on explicit recognition. According to the memory systems view, the low-level perceptual features of objects that make them special are encoded in the episodic memory system that support explicit memory performance. A dissociation between the implicit and the explicit memory tests will strengthen the memory systems view and extend it to the haptic domain.

Method

Participants. Eighty Universidad Nacional de Educación a Distancia (UNED) students participated in partial fulfillment of a course requirement. Twenty participants were randomly assigned to the each of four experimental conditions described below. All participants were naive as to the purpose of the experiment.

Materials and Equipment. The target stimuli were 40 familiar objects. Five additional objects were used as practice trials and its results were not included on the data analysis. Twenty of the target stimuli were natural objects defined as objects that can be encountered in the real world whereas the other 20 were manufactured or man-made objects (artificial objects). Figure 1 displays a sample of the natural and the man-made objects used in the experiment. The objects were selected from several basic-level categories such as vegetables, household objects, tools, etc.

The apparatus consisted of a piezoelectric board interfaced with an IBM System/2 computer that recorded the data. The board was placed on the table at which the participant was seated. A pizoelectric force sensitive sensor was located underneath the board. The relevant stimulus was selected automatically by a computer program which recorded the data for the relevant variables. To stop the internal clock of the computer, a vocal Lafayette key was attached to the collar of the participant.

Design. A 2 mode of exploration (with gloves or without gloves) x 2 type of tests (object naming or recognition) x 2 type of objects (natural or artificial) x 2 item type (studied objects or nonstudied objects) mixed factorial design was used. The first two factors, mode of exploration and type of test, were manipulated between-subjects, whereas type of object and study condition were manipulated within-subjects. In addition, the 20 natural and the 20 artificial experimental objects were divided randomly in two subsets, 1 and 2. Each subset contained 10 natural and 10 artificial objects. Subsets 1 and 2 appeared equally often as studied and nonstudied objects and they were rotated through all the experimental conditions. The result was a completely counterbalanced design in which each subset appeared equally often as studied and nonstudied in each cell of the main design.

Procedure. The participants were tested individually in a quiet room under incidental conditions. They were informed that they were participating in an experiment on object perception. The experimenter told participants that he was interested in knowing how they perceived different dimensions of real objects through touch without vision. As they entered the laboratory, participants were blindfolded; they did not see the objects at any time during the experiment.

The experimental session always started with a study-phase in which participants were allowed 10 seconds to explore each object with both hands. They were told that a series of objects would be presented at the center of the board, one at a time, and they had to judge a series of salient properties of the object in dichotomous terms: Its weight (e.g., heavy or light), its temperature (e.g., warm or cold), its size (e.g., large or small), its shape (e.g., round or sharp) and its texture (e.g., soft or rough). The computer program generated a random presentation order for each participant. An auditory signal from the computer alerted the participant that the exploration time was over and he or she had to judge verbally as many of the above mentioned properties as possible. Participants were informed that there were not correct or incorrect answers. A 5-minute distractor task was performed between study and test consisting of marking all the words in a page that included the letter «e».

At test, half of the participants (40) performed an implicit memory test consisting of naming the objects as quickly and accurately as possible while the other half (40) participated in an «old-new» recognition test. In this phase of the experiment, 20 new objects were added to the set of 20 objects previously studied. At each trial, the experimenter placed a randomly selected object at the center of the piezoelectric board. A tone from the computer alerted the blindfolded participant that the object was ready to be

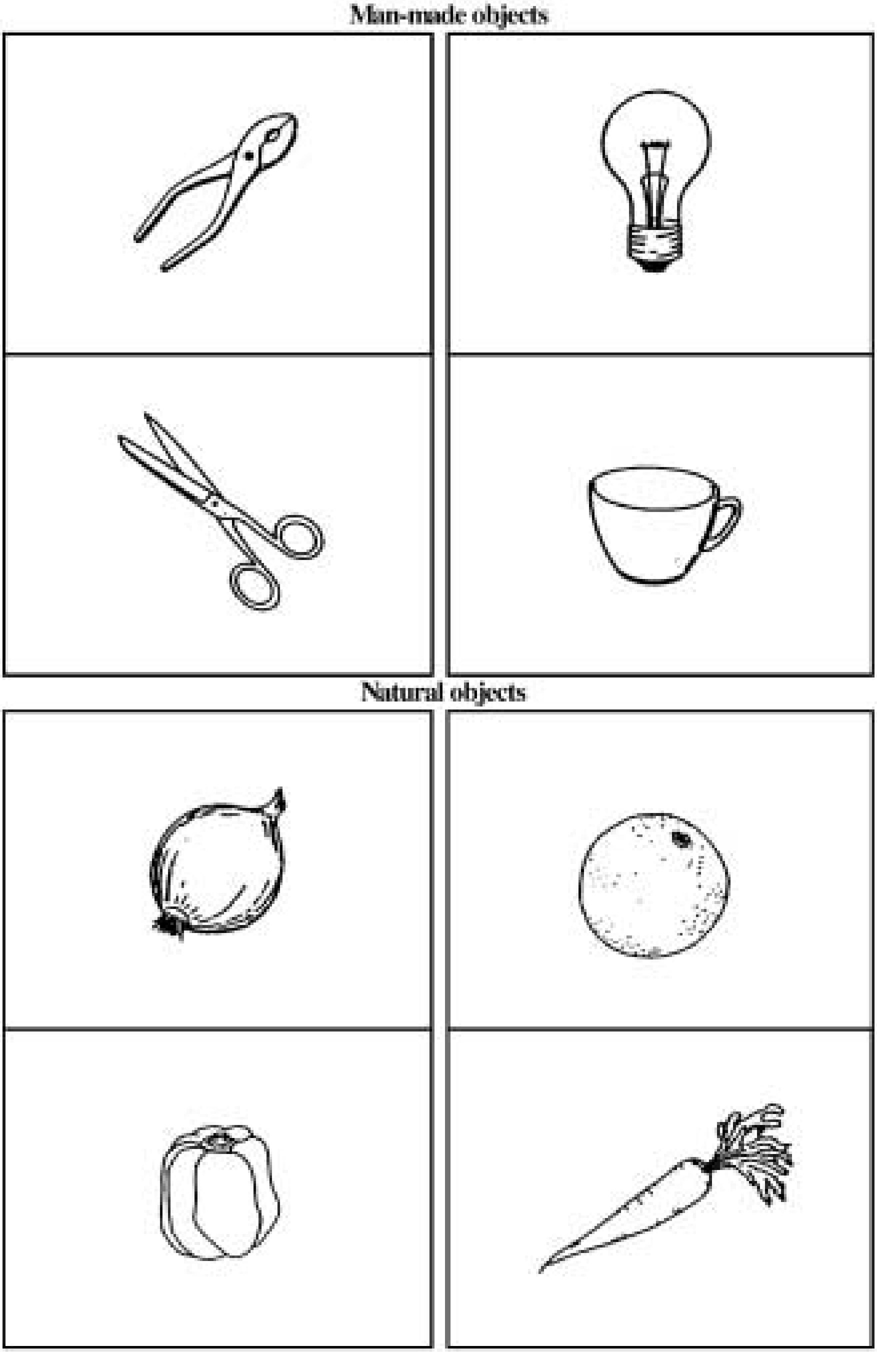

Figure 1. Examples of man-made and natural objects used in Experiment 1

explored. Observers participating in the implicit memory test moved the fingers from a placeholder and named the object using a basic-label term (e.g., «bottle») as quickly as possible. The experimental session always started with 5 practice trials followed by 40 experimental trials (20 objects presented during the study-phase and 20 new objects). Accuracy was also recorded. The experimenter introduced the oral responses on the key board, recorded falsely triggered responses as well as technical errors. The implicit task made no reference to a previous exposure to the objects.

Participants who performed the explicit memory test were presented with the 40 objects (20 presented during the study-phase and 20 new objects) and were asked to make «old-new» judgments for each object. They were informed that some of the objects were shown during the first part of the experiment and some of them were new objects. The explicit test started with 5 practice trials followed by the 40 experimental trials. On each trial, the computer program displayed a random number on the screen and the experimenter selected the corresponding object locating it at the center of the haptic board. An auditory signal informed the participant that the object was ready.

A further manipulation was the way in which participant explored the objects. Half of the participants in the implicit and in the explicit memory tasks performed the tests wearing latex gloves (the study-test changed condition). The rest of the participants performed the implicit and explicit memory tasks without gloves, as they did during the study phase (the study-test unchanged condition).

Results and Discussion

The data corresponding to the performance on the implicit and the explicit memory tasks were analyzed separately. Object identification results are reported first, followed by the explicit memory results.

Object identification. The main dependent variable was latency. Accuracy was very high (95 % correct). Most of the incorrect trials were due to technical problems. Figure 2 shows latency means corresponding to correct responses as a function of mode of exploration (with gloves vs. without gloves), type of object (natural vs. artificial object) and item type (studied vs. nonstudied object).

Note that the perceptual similar condition that matched the mode of exploration at study was the 'without gloves' condition while the 'with gloves' condition corresponded to the perceptual dissimilar (changed) condition. The main results can be summarized as follows: First, studied natural and man-made objects were identified faster than nonstudied objects. Second, naming familiar and man-made objects wearing gloves required more time that naming the objects without gloves. Third, the magnitude of facilitation was not reduced, in fact, it somehow increased when participants identified the objects wearing gloves (the study-test dissimilar condition) compa-

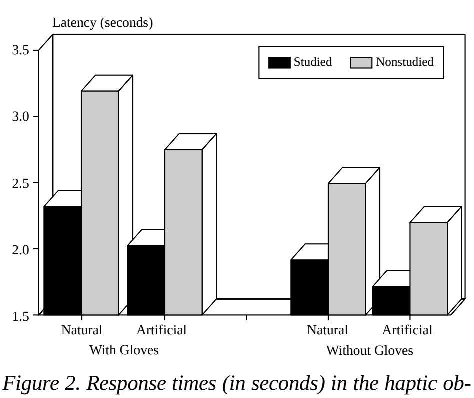

Figure 2. Response times (in seconds) in the haptic object identification task for studied and nonstudied stimuli as a function of object type (natural or artificial) and mode of exploration (with gloves or without gloves)

red to the condition in which participants did not use gloves (the study-test similar condition). Finally, the identification of the natural objects took longer than the identification of the man-made objects. The picture that emerged from the implicit memory test suggests that priming is substantial in the two modes of exploration conditions -the same mode of exploration and the different mode of exploration conditions for both, natural and artificial objects. The statistical analysis confirmed these observations. The three-factor mixed ANOVA with mode of exploration as the between-subjects variable and type of object and item type as within-subjects variables performed on latencies corresponding to correct responses confirmed the results described above. Analysis of the main effect of item type indicated a significant difference between studied and nonstudied objects [F (1,38)= 89.09, MSe= 70.8030, p <.0001]. Studied objects were named approximately 0.6 s faster than nonstudied objects (1.99 s vs. 2.65 s, respectively), This main effect showed the repetition priming effect. Mode of exploration was also significant [F(1,38)= 13.800, MSe= 70.8030, p <.001]. Naming objects wearing gloves produced a delay of about 0.5 s compared to naming objects without gloves (2.56 s vs. 2.10 s, respectively). In addition, the main effect of type of object was significant [F(1,38)= 20.40, MSe= 17.4570, p <.0001], manufactured or man-made objects were named about 0.3 s faster than natural objects (2.47 s vs. 2.16 s, respectively).

The interaction of item type x mode of exploration was marginally significant [F (1,38)= 3.718, MSe= 19.5021, p < .06]. The facilitation was larger when participants identified the objects wearing gloves than without gloves (0.8 s vs. 0.5 s). No other interaction approached significance.

In summary, the results showed that haptic priming was highly significant under both modes of exploration. The finding suggests that low-level (skin) sensory information does not play a crucial role in repetition priming assessed by an object naming task and that haptic, like visual priming, is not highly perceptually specific (e.g., Biederman & Cooper, 1991a; Snodgrass, Hirsman, & Fan, 1998). As said in the Introduction, visual studies have shown that implicit memory is not sensitive to all the perceptual characteristics of the stimuli. For example, changes in size or right-left orientation from study-to-test do not reduce priming but impair recognition for familiar and unfamiliar objects (cf., Biederman & Cooper, 1992; Cooper et al., 1992). Moreover, priming is not reduced when other visual dimensions of objects such as color, contrast or illumination changes (Cave & Squire, 1992; Cave et al., 1996; Srinivas, 1996).

Recognition memory. Figure 3 shows the results of the recognition test, expressed as the difference in accuracy between hits (correct «old/yes» decisions) minus false-alarms (incorrect «new/yes» decisions) as a function of mode of exploration (with gloves/without gloves) and type of objects (natural/artificial).

Explicit memory for objects actively explored was excellent. Overall mean correct

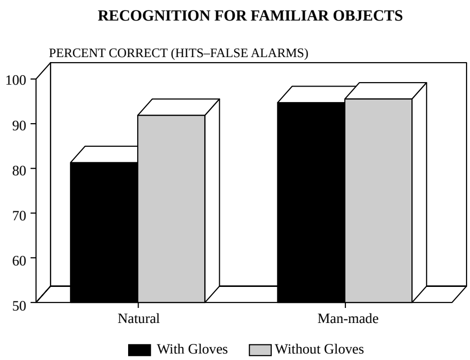

Figure 3. Recognition results expressed as percentage correct (hits-false alarms) for natural and man-made objects, as a function of mode of exploration (with gloves or without gloves)

recognition was 90%. The ANOVA performed on the hits minus false-alarms corrected recognition measures showed the main effect of mode of exploration [F(1,38)= 4.94, MSe= 0.4572, p <.04]. Recognition performance wearing gloves was significantly worse than without gloves (88% vs. 94% correct, respectively). The effect of type of object was also statistically significant [F(1,38)= 7.471, MSe= 1.521, p <.002]; man-made objects were recognized more accurately than natural objects (95% vs. 87% correct, respectively).

Experiment 2

Experiment 1 has shown implicit memory for familiar objects and little influence of low-level sensory factors in object identification. The question addressed in Experiment 2 was whether repetition priming would be shown for unfamiliar objects as well. To assess implicit memory, we employed the symmetry detection task used in our visual priming (Ballesteros & Cooper, 1992) and haptic perceptual experiments (Ballesteros et al., 1997). The experiment had three main goals. First, to investigate whether repetition priming exists for 3-D unfamiliar objects for which we have not mental representations prior to the encoding episode. The second goal was to investigate whether the mental representations supporting implicit memory for haptic objects are presemantic as it has been shown for visual objects (e.g., Reales & Ballesteros, 1999, Schacter et al., 1990) and verbal stimuli (e.g., Hamann, 1990; Hirshman, Snodgrass, Mindles, & Feenan, 1990). In vision, Schacter, et al., (1990) using an object decision task and unfamiliar depiction's of 3-D lineal objects reported that implicit memory is unaffected whether participants encode the stimuli semantically (elaborative encoding) or structurally (structural encoding). Conversely, the explicit measures were positively affected by elaborative encoding compared to conditions involving the encoding of local visual features (Schacter et al., 1990). The third goal was to look for possible dissociations between implicit and explicit measures of memory.

Method

Participants. Eighty new observers from the same pool participated in the experiment. Twenty observers were randomly assigned to each of the four experimental conditions described in the design section.

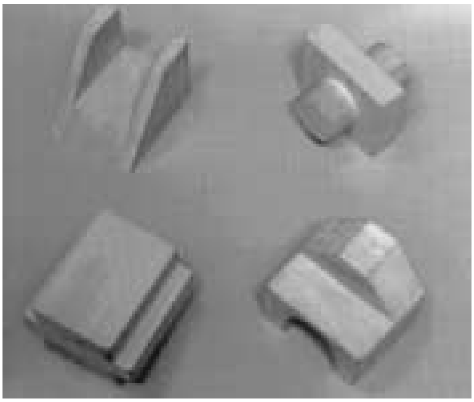

Figure 4. Examples of symmetric unfamiliar objects used in Experiment 2

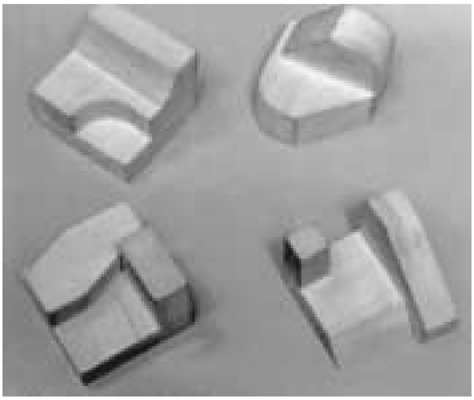

Figure 5. Examples of asymmetric unfamiliar objects used in Experiment 2

Materials and Equipment. The stimuli were forty unfamiliar symmetric and asymmetric wooden objects. Four additional objects, 2 symmetric and 2 asymmetric, were used for practice trials. Twenty of the experimental objects were bilaterally symmetric and the other 20 were asymmetric. They were made from a cubic piece of wood approximately 7 cm long x 7 cm wide x 6 cm high. Figures 4 and 5 display a sample of the symmetric and asymmetric objects used in this experiment. The equipment used was the same as in Experiment 1.

Design. A 2 encoding conditions (physical or semantic encoding) x 2 types of test (symmetry/asymmetry judgment test or haptic recognition test) x 2 type of objects (symmetric or asymmetric) x 2 item types (studied or nonstudied objects) mixed factorial design was used. The first two variables, encoding conditions and type of test, were manipulated between-subjects whereas type of object and item type were manipulated within-subjects. Moreover, the 20 symmetric and the 20 asymmetric experimental objects were randomly divided into two sets. Each set contained 10 symmetric and 10 asymmetric objects. These two sets were rotated through all the experimental conditions, producing a total counterbalanced design in which each stimulus set appeared equally often as studied and nonstudied stimuli in each cell of the design.

Procedure. At study, blindfolded participants were presented one at a time with 20 unfamiliar objects made of wood, 10 symmetric and 10 asymmetric. They were informed that the experiment was about shape perception by touch. Participants in the elaborative encoding condition were allowed 10 seconds to explore the object and provide the name of a familiar object that each wooden structure reminded them of. Participants in the structural encoding condition were also allowed 10 seconds for judging the complexity of the wooden object using a 5 point scale in which 1 means no complex at all and 5 most complex.

At test, observers participating in the implicit memory task were presented with the 40 objects, one at a time (the 20 studied plus the 20 nonstudied during the first phase of the experiment) in a different random order. On each trial, an object was presented at the center of the piezoelectric board aligned to the observer’s body midline. Participants explored the object with both hands for 1.5 s. An auditory signal informed that the object was ready for exploration while a second signal advised them to stop touching the object and to say clearly into the attached vocal key as quickly and accurately as possible whether the object was bilaterally «symmetric» or «asymmetric». They were not allowed to pick up or to rotate the object during exploration. Response times were recorded automatically by the computer since the hands first contacted the object to the verbal response. The experimenter monitored participant’s performance to ascertain that the hands stop touching the object right after the second beep. Accuracy was also recorded.

Participants at the recognition test were presented with the same 40 objects in a random order; the 20 previously presented at the study phase plus 20 new objects. The presentation time was 10 seconds. Subjects had to indicate whether or not they had explored the objects during the study-phase.

Results and Discussion

As in Experiment 1, the results corresponding to the performance on the implicit and the explicit memory tasks were analyzed separately.

Symmetry/asymmetry judgment test. Overall accuracy was 80% correct. Studied objects were classified as symmetric or asymmetric only slightly more correctly (80%) than nonstudied objects (78%). Observers were more accurate in detecting symmetric than asymmetric objects (84% and 75%). The result replicates previous findings from our laboratory (Ballesteros, et al. 1997, Exp. 3). Moreover, structural encoding produced better performance (82%) than semantic-elaborative encoding (77%).

The ANOVA on latency for correct responses showed that the main effect of type of encoding was highly significant [F(1,39)= 9.763, MSe= 0.6491, p <.002]. Objects encoded structurally (1.655 s) were judged as symmetric or asymmetric faster than objects encoded semantically (2.057 s). The main effect of studied (1.852 s) versus nonstudied objects (1.865) was not significant (F <1). Symmetric objects (1.822 s) were detected marginally faster(p <.08) than asymmetric objects (1.895 s.). These results were qualified by the interaction type of encoding x item type [F(1,36)= 5.029, MSe= 0.294, p <.04] which was significant (see Figure 6). Planned comparisons indicated that objects encoded structurally were judged faster than nonstudied objects, but those encoded semantically were not.

Implicit memory

Symmetry detection task

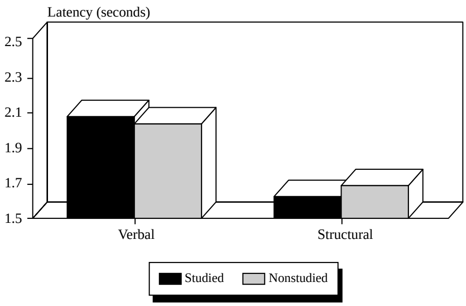

Figure 6. Response times (in seconds) in the object symmetry detection task for studied and nonstudied objects, as a function of type of encoding (verbal or structural)

Explicit old-new recognition performance. The ANOVA performed on the hits-false alarms data contrasted entirely with the symmetry detection performance. Objects encoded semantically were recognized much more accurately (.66 correct) than objects encoded structurally (0.39 correct) [F(1,35)= 24.190, MSe= 0.0508, p <.0001]. Moreover, symmetric objects were recognized more accurately (0.63) than asymmetric objects (.42) [F(1,35)= 24.190, MSe= 0.0255, p <.0001]. Neither other effect nor any interaction were significant.

Experiment 2 showed that haptic recognition for unfamiliar objects was significantly enhanced by elaborative encoding whereas the implicit symmetry detection task showed opposite results. Structural encoded objects were detected faster and marginally more accurately than elaboratively encoded objects.

General Discussion

The present study has revealed several main results. First, implicit memory for familiar objects evaluated by a speeded naming task showed repetition priming for objects explored haptically. Second, the change of the mode of exploration from study-to-test did not reduced haptic priming but impaired recognition (Exp.1). Modifying the conditions of the cutaneous sensory information pick up, while observers were free to perform hand-movements, had no effects on the implicit memory test; priming did not decrease when at test participants had to identify the objects using gloves. However, the same manipulation impaired explicit recognition. Third, for unfamiliar objects, priming was found under structural encoding but not under semantic encoding. In clear contrast, semantic encoding produced better explicit memory as assessed by higher recognition (Exp. 2).

Results have shown a robust haptic priming that resist sensory study-to-test changes. Hence, it can be inferred that haptic object naming would be mediated by structural information. Whereas explicit retrieval was clearly impaired when observers wore gloves, priming was not reduced. It seems as if the kinesthesic information provided by the moving hands during haptic exploration suffices to tap implicit representations of objects. Although priming scores were marginally larger in that condition, naming objects required more time wearing gloves than not wearing them. The finding suggests that the mental representations tapped by the implicit naming task do not rely on cutaneous-sensory mechanisms, or at least, not exclusively. Conversely, explicit recognition was impaired when haptic explorers used gloves compared to the without gloves condition. This pattern of haptic recognition performance suggests that explicit memory representations of real objects relies on cutaneous sensory factors more heavily that implicit memory representations. These results converge with findings reported by Wippich (1990) using a very different procedure.

This study has shown that implicit and explicit memory measures for objects presented to touch without vision can be experimentally dissociated. The double dissociation suggests that the two measures tap different objects representations; the implicit test seems to rely on structural, shape-based representations of objects while explicit recognition appears to tap low-level, cutaneous sensory information. Why is explicit memory influenced by such sensory attributes? Possibly, because, as in vision, the haptic representations that support explicit memory for 3-D objects include all of distinctive useful information, such as texture, temperature, softness, hardness, as well as shape and structure. The results are congruent with the memory systems account (cf., Schacter & Tulving, 1990). Maximal priming was obtained when studied and tested stimuli showed the same physical features; when studied and test stimuli shared the same form (physical attributes) and the same modality (visual or auditory). The same conclusion seems to extend to nonverbal stimuli; when the object exemplar or the fragment contour is changed from study to test, priming diminished (e.g., Biederman & Cooper, 1991b; Srinivas, 1993). However, other studies in the visual domain have shown that priming is not sensitive to all the perceptual attributes of studied familiar and unfamiliar objects. For example, changing objects size and their right-left orientation, do not have any effect on implicit memory but impair recognition (Biederman & Cooper, 1991a; Cooper et al., 1992). Moreover, Cave et al., (1996) have shown no influence of naming times on priming when color and surface pattern of the pictures were changed from study-to-test. These researchers interpreted these findings as suggesting that physical attributes that are not central to the formation of a shape representation do not affect repetition priming in the naming paradigm.

The two main theoretical accounts of implicit and explicit memory, the multiple memory systems and the transfer appropriate processing views, assume that priming is also modality specific. However, these theories are based on studies which have normally used words and visual or auditory stimuli (e.g., Bassili, Smith, & McLeod, 1989; Blaxton, 1989; Roediger & Blaxton, 1987; for a review, see Kirsner, Dunn, & Standen, 1989). In a recent study, we (Ballesteros & Reales, 1995; Ballesteros, Reales & Manga, this volume; Reales & Ballesteros, 1999) showed total cross-modal transfer between vision and touch for real-world objects. Vision and touch are two modalities finely tuned to process object shape and structure. The finding suggests that repetition priming is not totally modality specific but it is sensitive to high-level, structural features that define object shape and structure. Furthermore, given that semantic encoding did not affect priming in either cross-modal or within-modal conditions, the mental representations that support priming across and within modalities seem to be presemantic. Conversely, the mental representations that support explicit memory are sensitive to perceptual, contextual, spatial, and semantic information. These findings indicate that the mental representations of objects accessed via vision or active touch are similar.

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