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Selective attention affects implicit and explicit memory for familiar pictures at different delay conditions

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Three experiments investigated the effects of two variables –selective attention during encoding and delay between study and test– on implicit (picture fragment completion and object naming) and explicit (free recall and recognition) memory tests. Experiments 1 and 2 consistently indicated that (a) at all delays (immediate to 1 month), picture-fragment identification threshold was lower for the attended than the unattended pictures; (b) the attended pictures were recalled and recognized better than the unattended; and (c) attention and delay interacted in both memory tests. For implicit memory, performance decreased as delay increased for both attended and unattended pictures, but priming was more pronounced and lasted longer for the attended pictures; it was still present after a 1-month delay. For explicit memory, performance decreased as delay increased for attended pictures, but for unattended pictures performance was consistent throughout delay. By using a perceptual object naming task, Experiment 3 showed reliable implicit and explicit memory for attended but not for unattended pictures. This study indicates that picture repetition priming requires attention at the time of study and that neither delay nor attention dissociate performance in explicit and implicit memory tests; both types of memory require attention, but explicit memory does so to a larger degree.

La atención selectiva afecta a la memoria implícita y a la memoria explícita de dibujos familiares en diferentes condiciones de retraso. En tres experimentos se estudiaron los efectos de dos variables —atención selectiva durante la codificación y retraso entre estudio y prueba— en pruebas de memoria implícita (compleción de dibujos fragmentados e identificación de dibujos) y explícita (recuerdo libre y reconocimiento). Los experimentos 1 y 2 mostraron consistentemente que: a) en todos los retrasos estudiados (inmediato hasta un mes), el umbral de identificación de dibujos fue inferior para los estímulos atendidos que para los no atendidos; b) los dibujos atendidos fueron recordados y reconocidos mejor que los no atendidos; y c) atención y retraso interactúan en los dos tipos de pruebas. En las de memoria implícita la actuación empeoró a medida que aumentaba el retraso tanto para los estímulos atendidos como para los no atendidos, pero el *priming* fue más fuerte y duró más para los dibujos atendidos que para los no atendidos, estando todavía presente después de un mes desde la fase de estudio. Para la memoria explícita la actuación empeoró en función del retraso para los estímulos atendidos, mientras que para los no atendidos la actuación fue consistente a través de todos los retrasos. El experimento 3, utilizando una tarea perceptiva de identificación rápida de dibujos, mostró memoria implícita y explícita para los dibujos atendidos, pero no para los no atendidos. Este estudio indica que la memoria implícita requiere atención durante la fase de codificación del estímulo y que ni el retraso ni la atención disocian la actuación en las pruebas de memoria implícita y explícita; ambos tipos de memoria requieren atención pero la explícita más que la implícita.

It is widely accepted that there are two manifestations of memory, explicit and implicit. However, the role of some variables considered to dissociate these two types of memory has been questioned. In particular, the role of attention and of delay between study and test in implicit memory remain controversial. Attention is required for the formation of enduring memory traces in explicit memory (e.g., Craik, Govoni, Naveh-Benjamin and Anderson, 1996; Mulligan, 1998; Rock and Gutman, 1981). However, the role that attention plays in implicit memory is not well understood. Its effects may depend on stimulus duration at study (e.g., Ganor-Stern, Seamon and Carrasco, 1998;), type of stimuli (Smith and Oscar-Berman, 1990), attentional load (Mulligan, 1997) and the way attention is manipulated (Crabb and Dark, 1999; MacDonald and MacLeod, 1998; Wood, Stadler and Cowan, 1997).

Divided attention studies use dual tasks in which participants must respond to both, target stimuli and distractor stimuli. On the other hand, selective attention studies require participants to direct attention to the target stimuli; those to which they have to respond. A number of studies using the *divided attention* paradigm at

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encoding have shown that whereas attention impairs performance on explicit and conceptual implicit memory tests (e.g., Mulligan, 1997, 1998; but see Isingrini, Leroy and Vazou, 1995), it has little or no effect on perceptual implicit memory tests (e.g., Parkin and Russo, 1990; Parkin, Reid and Russo, 1990). On the other hand, *selective attention* studies in the verbal domain have found attentional effects in both explicit and implicit memory (e.g. Crabb and Dark, 1999; MacDonald and MacLeod, 1998; Stone, Ladd, Vaidya and Gabrieli, 1998). However, the role of selective attention in implicit memory for pictures has not been studied.

The goal of this study was to investigate the role of selective attention at encoding on implicit and explicit memory tests for visual objects using a novel overlapping-picture task. To our knowledge, this is the first study to evaluate the effects of selective attention at encoding on two good examples of implicit tests (Roediger and McDermott, 1993) –picture fragment completion and speeded object naming– and in two explicit tests –free recall and recognition– for pictures. Furthermore, to examine whether attention and delay interact, both implicit and explicit memory were assessed at several delays between study and test –from immediate to a month. Because attention at encoding strengthens stimulus representation (e.g. Carrasco, Penpeci-Talgar and Eckstein, 2000; Ganor-Stern et al, 1998; Rock and Gutman, 1981), we hypothesized that attended material may be more resilient to the passage of time so that performance in both implicit and explicit memory tasks would be superior and last longer for attended than unattended pictures. The main questions we asked in the study are, How does selective attention at encoding affect perceptual priming for pictures assessed by two good examples of implicit memory tests?, Is perceptual implicit memory automatic or requires the deployment of attention? Is there a dissociation between implicit and explicit memory tests? How affects delay between study and test to both, implicit and explicit performance?

Explicit versus implicit memory

Explicit memory is typically assessed by direct tests of memory such as free recall, cued recall, and recognition, whereas implicit memory is measured by indirect memory tests that do not ask subjects to recollect specific prior experiences. Implicit memory is inferred when subjects show facilitation in performance that is attributable to information acquired during the study phase. This facilitation, often referred to as repetition priming, has been found in several tests using verbal materials. More recently, a number of visual studies have focused on nonverbal materials, such as possible/impossible judgments of 3-D novel visual patterns (e.g., Carrasco and Seamon, 1996; Schacter, Cooper and Delaney, 1990), object naming (e.g., Biederman and Cooper, 1991; Reales and Ballesteros, 1999), or judgments of affective preference (e.g., Seamon et al, 1995). Implicit memory is also manifested in audition (Schacter and Church, 1992) and touch (Ballesteros and Reales, 2004; Ballesteros, Reales and Manga, 1999). A number of experimental variables dissociates explicit and implicit memory; e.g., stimulus encoding instructions (e.g., Schacter et al, 1990) and study-test changes in the stimuli (e.g., size, orientation, mode of exploration; Cooper, Schacter, Ballesteros and Moore, 1992; Seamon et al, 1995). Research on functional memory dissociations has been comprehensively reviewed (e.g., Roediger and McDermott, 1993; Schacter, 1987). However, a series of studies has questioned the generalizability of these dissociations (e.g., Bentin, Moscovitch and Nirhod, 1998; Carrasco and Seamon, 1996; Ganor-Stern et al, 1998; MacDonald and MacLeod, 1998; Reales and Ballesteros, 1999; Wood et al, 1997). In this study, we assessed whether selective attention, delay, and/or their interaction dissociate implicit and explicit memory performance.

The role of attention in perceptual implicit memory for verbal materials

Verbal studies disagree as to whether perceptual implicit memory requires the participation of attention. Some authors have asserted that attention is not necessary for implicit memory. They base their conclusion on studies using selective attention and shadowing prose (Eich, 1984) and lexical decision (Szymanski and MacLeod, 1996) tasks, or divided attention and word-fragment completion (Parkin et al, 1990). In contrast, other verbal studies have concluded that attention is necessary for the emergence of perceptual implicit memory (Mulligan and Horstein, 2000; Rajaram, Srinivas and Travers, 2001; Stone et al, 1998). This conclusion has been reached by using tasks such as lexical decision (Bentin et al, 1998), word-identification priming (Stone et al, 1998), word-stem completion, word fragment completion and perceptual fluency (Crabb and Dark, 1999; Rajaram et al, 2001), rapid reading (MacDonald and MacLeod, 1998; Mulligan and Hornstein, 2000), and words-digits flanking (Hawley and Johnston, 1991), as well as a divided attention paradigm and a shadowing task with a rapid presentation rate (Wood et al, 1997). These studies on verbal implicit memory tests indicated that attention is necessary at encoding to establish a lasting representation that can support repetition priming. These verbal perceptual priming studies indicate that implicit and explicit memory for words can no longer be distinguished on the grounds that attentional manipulations affect performance on explicit but not on implicit tests.

The role of attention in perceptual implicit memory for object pictures

Most studies of attention and memory have used words as stimuli; very few studies have used pictures. As is the case with verbal studies, object pictures studies are inconsistent with regard to the role of attention in implicit memory. Whereas some authors have reported that attention dissociates explicit and implicit memory (e.g., Parkin and Russo, 1990), some have reached the opposite conclusion (Ganor-Stern et al, 1998).

It has been suggested that attention can have qualitatively similar but quantitatively different effects on explicit and implicit memory; implicit memory is less sensitive to attentional manipulations than explicit memory, but that does not imply that implicit memory is attention free (Ganor-Stern et al., 1998). By studying the effects of limited attentional resources at study time on explicit and implicit memory, these authors found that when attention at study was limited by a flanking-digits procedure, object recognition was diminished but object decision priming for possible pictures was unaffected. However, when study time was reduced from 5 to 3 s, object recognition was still diminished and object priming was eliminated. Hence, the degree to which priming is affected by attentional resources was determined by the intervening variable of study time; implicit memory was more sensitive to an attentional manipulation when study time was short.

The effect of delay in implicit and explicit memory

Delay between study and test has often been used to explore the functional dissociation between implicit and explicit memory tests (Roediger and McDermott, 1993). Although a number of studies have reported that such a dissociation has emerged as a function of delay (e.g., McAndrews, Glisky and Schacter, 1987; Reales and Ballesteros, 1999; Sloman et al, 1988), there is no consensus on this topic (e.g., Snodgrass and Surprenant, 1989).

For familiar pictures, there is stable repetition priming but diminished recognition between 1 and 6 weeks (Mitchell and Brown, 1988). Similarly, even for nonsense patterns, perceptual priming remains approximately constant from a few hours to a week delay. Likewise, both within-modal (vision/vision) and cross-modal (touch/vision) priming are both unaffected at a 30 min delay, whereas explicit recall decreases significantly at such a delay (Reales and Ballesteros, 1999).

Snodgrass and Supranant's study (1989), however, did not provide evidence for the dissociation of implicit and explicit memory as a function of delay. Performance for a picture-fragment completion implicit memory task and for a yes/no recognition explicit task showed approximately equal rates of forgetting up to a delay of 14 days (for similar results see Lachman and Lachman, 1980).

In short, the functional dissociation between implicit and explicit memory as a function of retention interval is not unequivocal. To further evaluate this dissociation, in this study we explored whether selective attention at encoding affects explicit and implicit memories similarly at different delays.

The present study

We investigated whether the effects of selective attention and study-test delay interact on explicit and implicit memory. Studies that have investigated the role of attention in implicit and explicit memory have measured performance a few minutes after study. So, it is important to study the role of attention at encoding for longer retention intervals on memory performance. We hypothesized that if attended information attains a stronger representation than unattended information (e.g., Desimone and Duncan, 1995; Ganor-Stern et al, 1998; Rock and Gutman, 1981; Yeshurun and Carrasco, 1998, 1999), then attended information should be more resilient to time passage and consequently delay should affect it less. Furthermore, if priming for unattended pictures occurs, it should diminish or disappear earlier than for attended pictures. Note that even if the representation of both attended and unattended pictures decays at a similar rate, the representation would fall below identification threshold earlier for the unattended than for the attended pictures because the initial representation for the attended pictures is stronger.

Divided attention studies have some methodological limitations. A slow rate of presentation could allow subjects to switch attention between attended and unattended information thus enabling performance in implicit but not in explicit memory tests (Bentin et al, 1998; Cowan, 1995; Crabb and Dark, 1999; MacDonald and MacLeod, 1998). In addition, most of the studies reporting no effect of attention in implicit memory have used tasks in which target and distracting stimuli were presented in different sensory modalities –audition and vision, (e.g., Parkin et al, 1990; Parkin and Russo, 1990)– and it is likely that attention may tax resources more within than between modalities. We predicted that the effects of selective attention at encoding would result in the reduction or even the elimination of repetition priming for unattended pictures on the implicit picture fragment completion (Experiments 1 and 2) and speeded picture naming (Experiment 3) tests.

To evaluate the implicit/explicit dissociation while circumventing these methodological problems, Experiments 1 and 2 explored the effects of *selective attention* at encoding on implicit and explicit memory at several delay conditions (immediate, 5 min, 1 day, 1 week, and 1 month) while attention at encoding was manipulated within the visual modality. In this selective attention paradigm with overlapping figures, participants are directed to attend to the figure of a given color; no information was provided regarding the figure of the other color. Using this paradigm, it has been found that attended pictures are highly recognized but unattended ones are not (Goldstein and Finke, 1981; Rock and Gutman, 1981). In order to maximize the effect of selective attention, attended and unattended pictures were shown centrally overlapped at the same spatial position and at the same modality. The question we asked was whether repetition priming disappeared or diminished for unattended pictures.

Experiments

In the first two experiments, we manipulated selective attention at encoding by using superimposed outlines of pictures (Rock and Gutman, 1981) and we tested implicit memory by using fragmented pictures of the same objects (Snodgrass, Smith, Feenan and Corkin, 1987; Snodgrass and Supranat, 1989). In Experiment 3, we manipulated selective attention at encoding in the same way but implicit memory was assessed by using a speeded object naming task. Explicit memory was assessed either by a recall (Experiment 1) or a recognition (Experiment 2 and 3) test.

Like Rock and Gutman (1981) we used overlapped pictures, but unlike them we used familiar pictures. Research using overlapped figures has shown that the representations activated by the attended stimuli are stronger than those activated by the unattended pictures. Note that, even though we used overlapped figures, our procedure is not related to that of Tipper (1985). We used no probes, and for the same observer a figure could only be attended, unattended or nonstudied; i.e. an attended figure could have not been unattended in the previous trial. Consequently, no negative priming could be expected (see Procedures).

Observers were presented with two overlapping pictures of two different colors and were required to name the object of one specific color. Observers were asked to maintain fixation in the center of the two figures. Even if eye movements were to occur, the pictures overlapped so that the attended one would not have an advantage in terms of retinal location (Rock and Gutman, 1981). Furthermore, the two overlapping pictures had different colors so that the outlines could be easily discriminated as belonging to different pictures. Color is known to facilitate the organization of items; groups of items resulting from color similarity are often treated as units (e.g., Bundesen and Pedersen, 1983).

EXPERIMENT 1

Most of the previous studies on the effects of attention in repetition priming have used verbal materials but we used pictures in this experiment to assess the role of selective attention on implicit and explicit memory tasks at several delays ranging from

0min to 1month. The implicit test of speeded-picture fragment completion was administered before the explicit test of free recall at all delays.

Method

Participants

Sixty males, 18 to 21 years old, voluntarily participated in one or two 45-min experimental sessions, depending on the delay condition they were assigned to. Because they were fulfilling the Spanish Obligatory Military Service and they lived in an assigned barrack, the experimenter could recruit them as experimental conditions required, without previous notice. All had normal or corrected to normal vision and were naive as to the purposes of the study. They had never participated in any other perception or cognition experiment.

Apparatus

The stimuli were presented on a 14" color monitor of a Compatible PC 486 computer, whose resolution was 640 × 480 pixels. The system was interfaced with a voice-key (Lafayette 63040) to record the level of fragment completion at which the picture was named.

Stimuli

Ninety stimuli were selected from the Snodgrass and Vanderwart (1980) picture set. The pictures were approximately 10 × 10 cm subtending a visual angle of approximately 4 × 4°. During the study phase, the pictures were depicted with a continuous green or blue outline (Figure 1); during the test phase, the stimuli were fragmented black outlines of the stimuli (Snodgrass et al, 1987) presented on a white background.

The pictures were digitized, saved in graphic BMP format, and presented on the computer monitor. A 16 × 16 grid was superimposed on the projected image. All of the 16 × 16 pixel blocks that contained some black pixels were identified. This information was stored in an array and was randomly permuted. The deleted block rate of the image followed from the exponent function: P= 0.7 × $e^{8.0}$. Each picture was stored as a fragmented image at eight different levels of completion (Figure 2). Level 1 corresponded to the most fragmented image; level 8 was the complete picture. The proportions of deleted pixel blocks were 0.91, 0.88, 0.83, 0.76, 0.65, 0.51, 0.30, and 0 from levels 1 to 8, respectively.

Figure 1. *This diagram depicts the overlapped pictures used in the study phase of all four experiments. The outline of one picture was green (here shown in black) and the outline of the other picture was blue (here shown in gray). The pictures were taken from Snodgrass and Vanderwart (1980)*

Design

A mixed-factorial design was used: 2 within-subject factors –3 study conditions (attended, unattended, and non-studied pictures) × 2 types of test (implicit vs. explicit)– and 1 between-subject factor: 5 delay conditions (non-delayed, 5 min, 1 day, 1 week, and 1 month).

Procedure

The 90 stimuli were randomly divided into three groups of 30 pictures. For counterbalancing purposes, each of these groups appeared as the attended (green), unattended (blue), or non-studied (black) pictures for 4 observers in each delay condition. Previous research has shown that the particular color of the attended or unattended object is not a critical variable for object perception and recognition (see Rock and Gutman, 1981).

During the *study phase*, participants performed a speeded-naming task –they were asked to name as quickly as possible the identity of the green picture. The participant pressed the mouse button when he or she was ready. After 1500 ms, two overlapped pictures appeared at the center of the screen, one in blue and the other in green. Then, the participant named the green picture as quickly as possible. The pictures disappeared from the screen as soon as the response was made. Finally, the experimenter recorded the object's name to see later whether it was correct. There were 30 experimental trials. In addition, to avoid primacy and recency effects, observers performed 5 extra trials at the beginning and 5 at the end from the same set of pictures. Participants correctly identified all the pictures. This study phase lasted approximately 5 to 6 min.

After completing the study phase, according to the delay condition they performed the *test phase*, consisting of a speeded fragment completion task (Snodgrass et al, 1987). Observers were presented with progressively less fragmented pictures. Once each fragmented picture appeared on the screen, if participants did not respond for 1.5 s the next more completed level was shown. They were asked to identify each object as soon as possible, by pressing the space key of the keyboard as soon as they identified the object. A prompt on the screen indicated that they should type the object's name. There were 90 trials in which the pictures were sequentially presented for 1.5 s at each of the eight-fragmented levels. The sequence stopped when the observers started to type the name of the object.

The order of presentation of the 90 pictures –30 attended, 30 unattended, and 30 non-studied– was randomized for each participant. Performance was assessed by the fragmentation level at which the pictures were correctly identified, which the computer recorded. If the name was incorrect, the computer beeped and the next more completed level automatically appeared. After a 2 s interval, another picture was randomly selected. There were 5 practice trials at the beginning. Even though participants did not know that a second phase would follow, to prevent rehearsal, participants assigned to the 5-min condition were asked

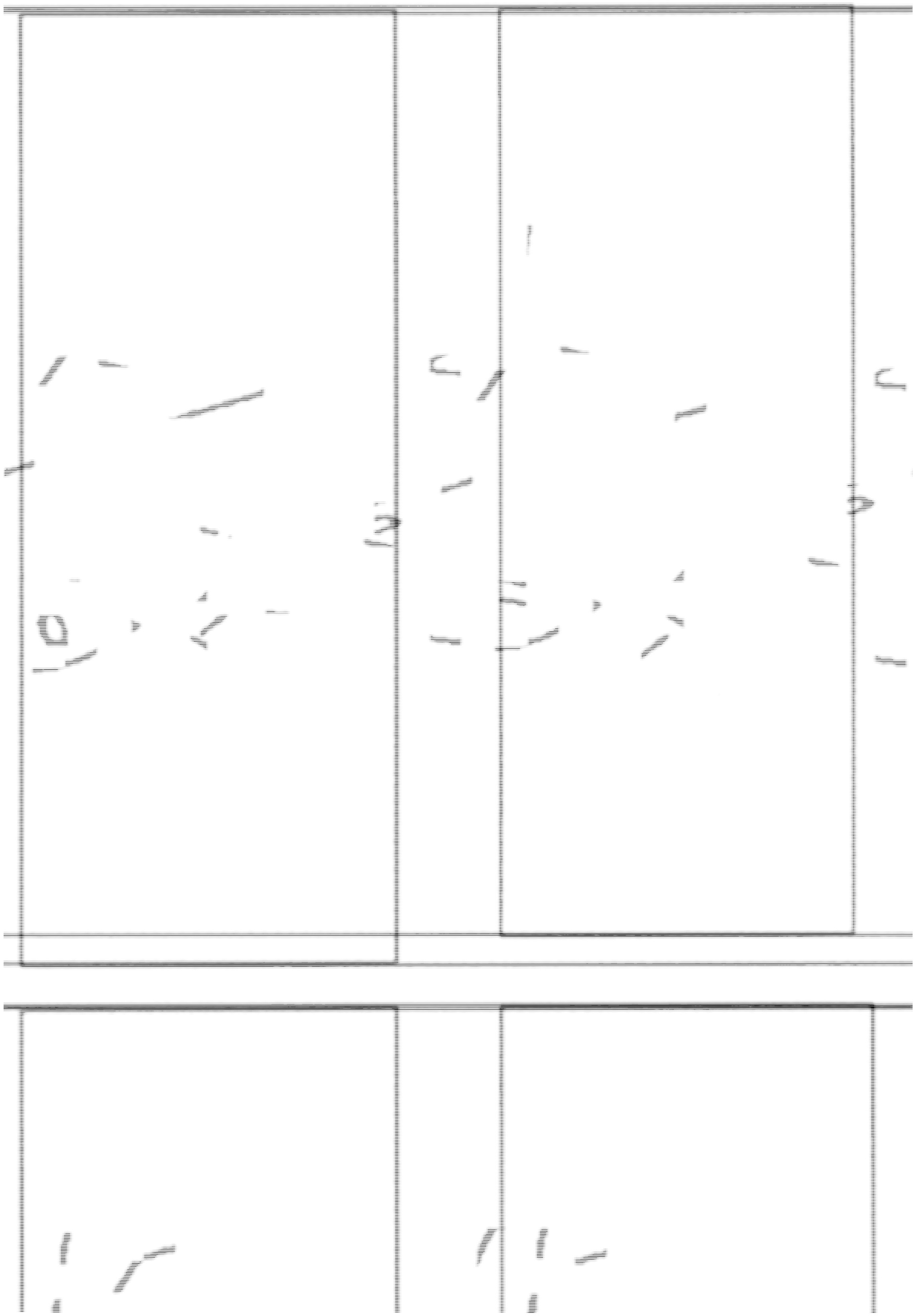

Figure 2. *This diagram depicts the 8 different levels of one of the 90 fragmented pictures used in the speeded picture fragment completion test. These fragmented pictures were obtained using Snodgrass et al (1987) fragmentation algorithm*

to write down as many names of Spanish soccer players as possible. This test phase lasted approximately 40 min.

Lastly, explicit memory was evaluated by asking participants to type on the keyboard the names of as many pictures as possible that they had seen during the study phase. Participants were required to complete this free-recall task in 5-min. Performance was assessed by the total number of correct attended pictures, correct unattended pictures, and intrusions (non-studied pictures).

Results and discussion

Picture fragment completion test

Absolute identification thresholds. The superior performance for the attended pictures is evident by the lower threshold for picture identification (Figure 3). The pictures were identified under more degraded conditions when observers had named the pictures during the study phase than when they had either not named them (unattended) or not seen them (non-studied). This result was confirmed by a factorial ANOVA: 3 study conditions × 5 delays on the absolute identification thresholds. The main effect of study condition was significant, $F(2,110)= 158.40$; MSe= 0.059; $p<.001$. A post-hoc test indicated that the identification threshold was lower for the attended (4.75) than for the unattended (5.30) pictures [$p<.001$], which in turn was lower than that for the non-studied pictures (5.52); [$p<.001$]. The effect of delay was not significant, $F(4,55)= 1.11$; MSe= 0.286; $p>.1$. There was a marginally significant interaction of condition × delay, F(8,110)= 1.96; p= .058. This interaction emerged because priming was present for the attended pictures at all delays ($p<.01$) but was significant for the unattended pictures when tested immediately, at 5-min and 1-day, but not when tested at 1-week and 1-month ($p>.1$).

These results indicate that when had observers named the pictures the identification threshold was lower than when they had not, and that priming remained significant for attended but not for unattended pictures at the longest delay. These findings confirm the hypotheses that selective attention affects implicit memory and that this effect interacts with delay.

Standard priming scores. Given that the goal of the present experiment was to compare performance for attended and unattended pictures, we calculated priming for each study condition. Conventionally priming is assessed by calculating the difference between studied and non-studied items. Table 1 (upper panel) displays the priming for the attended-studied and unattended-studied pictures at each delay. For all delays, the ratio indicates that the difference between attended-studied and non-studied pictures was greater than the difference between unattended-studied and non-studied pictures. This ratio was very large for the 0-min and 5-min delays and diminished for the longer delays of 1-day, 1-week, and 1- month.

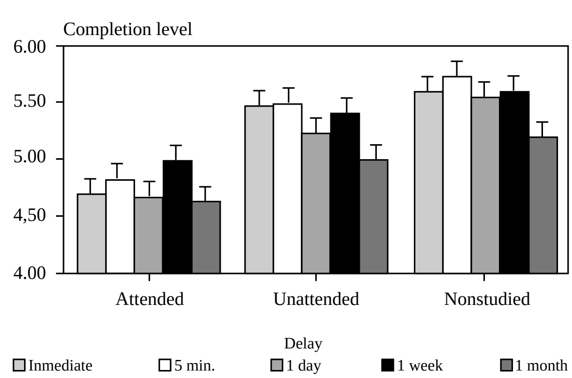

Figure 3. *Experiment 1: mean completion level necessary for picture identification for the immediate, 5-min, 1-day, 1-week and 1-month delay conditions as a function of study condition: attended, unattended, or non-studied). The error bars show the standard error of the mean*

Free recall test

Overall free recall. The superior performance for the attended than the unattended pictures and intrusions, and the highly similar performance for unattended and intrusions are readily apparent in Figure 4. A derived measure of overall free-recall (studied - non-studied and studied - intrusions) showed a much higher recall ratio for the attended (6.80) than for the unattended (0.65) pictures. This result was confirmed by a mixed-factorial 3x5 ANOVA, whose main effect of study condition was significant $F(2,110)= 81.75$, MSe= 10.33, $p<.0001$. A post-hoc test indicated that recall was higher for the attended (11.03) than for unattended (4.88) pictures [$p<.001$], which did not differ from the non-studied pictures (4.23); [$p= .10$].

The main effect of retention interval was also significant, $F(4,55)= 5.17$, MSe= 5.08, $p<.001$. Post-hoc tests indicated that participants wrote down more words at 1-week than at all other delays (p<.05). This difference, however, does not reflect better performance for the 1-week interval than for the other four delay conditions because there were also more intrusions than at all other intervals which did not differ (all *p*s >.10). Study condition × retention interval interacted significantly, [$F(8,110)= 4.34$; MSe= 10.33, $p<.001$, because performance for the attended pictures gradually diminished as a function of delay, but this orderly pattern did not emerge either for the unattended pictures or for the intrusions. Simple tests showed that for the attended pictures recall was significantly lower at the longest delay (1-month) than at all the other delay conditions (all *p*s <.01). For the

Table 1
Experiment 1: derived measures of priming (top panel) and free-recall (bottom panel) for the attended and unattended overlapped pictures

	Priming |Studied-nonstudied|		
Delay conditions	**Attended**	**Unattended**	**Ratio**
0 min	.89	.13	6.85
5-min	.88	.22	4.00
1-day	.87	.31	2.80
1-week	.59	.18	2.27
1-month	.59	.22	2.68
	Free-recall Studied-nonstudied		
Delay conditions	**Attended**	**Unattended**	**Ratio**
0 min	10.50	0.25	42.00
5-min	9.83	0.75	13.10
1-day	6.42	1.25	5.14
1-week	4.09	0.34	12.02
1-month	3.17	0.67	4.73

unattended pictures, however, recall was significantly higher for 1-week delay than for immediate and for 5-min delay (p<.01).

Relative free recall. Table 1 (lower panel) shows the derived measures of free recall for the attended studied and unattended studied pictures at each delay. For all delays, the ratio indicates that the difference between attended-studied and non-studied pictures was greater than the difference between unattended-studied and non-studied pictures. This ratio was very large for the 0-min delay and diminished for the longer delays.

The results of this experiment suggest that attention does not dissociate explicit and implicit memory. Performance for attended pictures was superior in both speeded picture fragment completion (implicit task) and free-recall (explicit task). Furthermore, we hypothesized that if attended stimuli attain a stronger representation than unattended stimuli, the former should be less vulnerable to time passage and delay should affect it less. According to the hypothesis, attention and delay interacted in both implicit and explicit tests. First, and remarkably so, attended pictures still showed a priming effect at the longest delay –1 month– but this effect was no longer present for the unattended pictures. Second, recall for attended pictures decreased as delay increased, but recall for unattended pictures was poor at all delay conditions, possibly because there were a floor effect. The priming found for the unattended pictures indicates that unattended information undergoes some form of psychological processing. This is consistent with studies using diverse paradigms that show that unattended information is processed, albeit to a lesser degree; e.g., contextual scenes in object identification, the Garner- and Stroop- interference effects, the effects of irrelevant information in object and pattern recognition, and the flanker compatibility effect (for a review see Ballesteros and Manga, 1996).

Intrusions may have occurred because observers performed the implicit before the explicit memory tasks. The presence of contamination would pose a problem for test interpretations and would question the dissociation between explicit and implicit memory tests. Note that because in the present experiment all participants completed the implicit memory test before the explicit one, it is quite unlikely (although not impossible) that explicit memory would have contaminated the implicit results. In any case, Experiment 2 was conducted, in part, to assess this issue.

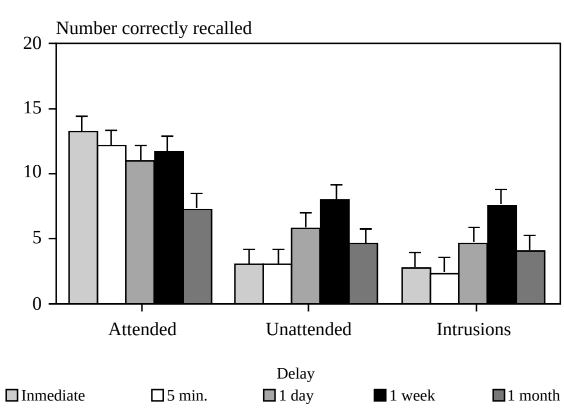

Figure 4. *Experiment 1: mean total number of free-recalled picture names for the immediate, 5-min, 1-day, 1-week and 1-month delay conditions as a function of study condition: studied attended, studied unattended and non-studied (intrusions) pictures. The error bars show the standard error of the mean (the maximum possible number of pictures attended and unattended pictures correctly recalled is 30)*

Furthermore, in Experiment 3 we used a picture naming test and equated retrieval cues for limiting retrieval strategies in order to address further this issue.

EXPERIMENT 2

This experiment assessed the role of selective attention in both implicit and explicit memory tasks at several delays ranging from 5-min to 1-month. To avoid explicit contamination, after encoding, participants performed either the implicit or the explicit memory test. We used the same priming test as in Experiment 1, but replaced the free-recall explicit test with a recognition test. In this way, a different pattern of results between the implicit and explicit tests could not be attributed to differences in the nature of the task. In doing so, in the present experiment the match in retrieval cues between the implicit and the explicit tests was closer. We predicted less explicit contamination.

Method

Participants

Seventy-two males from the same pool, 18 to 21 years old, voluntarily participated in one or two 45 min experimental sessions, depending on the delay condition that they were assigned to.

Apparatus and stimuli

These were the same as in the previous experiment.

Design

A mixed-factorial design was used: 1 within-subject factors –3 study conditions (attended, unattended, and non-studied pictures) and 2 between-subject factors: 2 types of test (implicit vs. explicit) and 3 retention interval (5-min, 1- week, and 1-month).

Procedure

The study-phase and the implicit task were exactly the same as in Experiment 1. The explicit task was different; instead of free recall a recognition task was used. Participants were presented with 90 pictures one at a time and were asked to indicate whether each picture was «old» or «new», i.e., whether they had seen them in the study phase. Each picture remained on the screen until the participant responded or for a maximum of 5 s. Half of the observers performed the implicit task and the other half performed the explicit task. After encoding, but before test participants performed a distractor task consisting of writing down as many names of soccer players as possible.

Results and discussion

Picture fragment completion

Absolute identification thresholds. Figure 5 illustrates performance on the implicit task as a function of study conditions (attended, unattended, and non-studied pictures) and retention interval (5-min, 1-week, and 1-month). The pictures were identified under more degraded conditions when observers had named the pictures during the study phase (attended) than when they had either not named them (unattended) or not seen them (nonstudied).

This result was confirmed by a mixed 3-within (study conditions) × 3-between (delays) ANOVA. The main effect of study condition was significant, $F(2,66)= 51.34$; $MSe= 0.08$; $p<.001$. Post-hoc tests showed that the identification threshold was lower for attended (4.44) than for unattended (4.92), $p<.01$, which in turn had a lower threshold than for non-studied pictures (5.06), $p<.05$. The main effect of delay was also significant, F (2,33)= 17.149, MSe= 0.172; $p<.001$. Post-hoc tests showed that 5- min (5.00) did not differ from 1-week (5.18), $p>.10$, but that it was lower than for 1-month (4.25), $p<.001$. Although it is surprising that the lowest identification threshold was attained at 1-month, this result is due to an overall superior performance of this group of participants at all study conditions (attended, unattended, and non-studied).

The interaction of delay × study condition was significant, $F(2,33)= 5.45$; $p<.009$. Figure 5 illustrates that the difference in priming between attended and unattended stimuli diminished as a function of delay. The reliable difference between studied-attended and non-studied pictures at all delay conditions ($p<.002$) demonstrates perceptual implicit memory for attended pictures even after 1 month; in contrast, there was no significant implicit memory for unattended pictures after 1 month. Moreover, priming for attended pictures was greater at 5-min than at 1-week delay, which in turn was greater than at 1-month ($p < .002$). However, for unattended pictures, priming did not differ among conditions ($p>.10$).

Table 2 shows that for all delays, the priming for attended pictures was greater than for unattended pictures, and that the attended/unattended ratio diminished with delay.

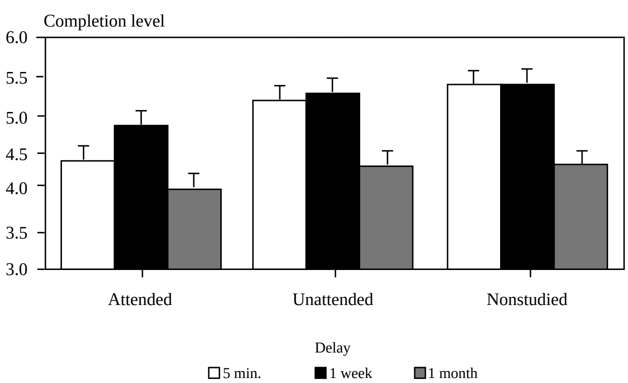

Figure 5. *Experiment 2: mean completion level necessary for picture identification for the 5-min, 1-week and 1-month delay conditions as a function of study condition: attended, unattended or non-studied). The error bars show the standard error of the mean*

Table 2
Experiment 2: derived measures of priming for the two orders for the attended and unattended overlapped pictures

	Priming |Studied-nonstudied|		
Delay conditions	**Attended**	**Unattended**	**Ratio**
5 min	.44	.003	146.6
1-week	.57	.05	11.4
1-month	.38	.04	9.5

Recognition

Figure 6 illustrates recognition performance expressed in terms of a corrected recognition measure of hits – false alarms, as a function of study condition and delay. These data clearly show that, for attended pictures, recognition decreased as a function of delay from 5-min to 1-week, and that at 1-month recognition was virtually non-existent. In contrast, for unattended pictures, recognition was only above chance at 5-min.

The mixed-model ANOVA performed on the corrected recognition measure of hits–false alarms as a function of study condition (attended, unattended) and delay (5-min, 1-week, 1-month) showed that the main effect of study condition was reliable, F (1,33)= 243.45, MSe= 10.259, $p<.001$. Attended pictures (13.20) were recognized better than unattended pictures (.42). The main effect of delay was reliable too, $F(2, 33)= 39.94$, MSe= 13.62, $p<.001$; recognition at 5 min (13.75) was better than for the 1-week (7.87) and 1-month (0.32) delays.

The significant interaction of study condition × delay, F (2,33)= 55.74, MSe= 10.26, $p<.001$, revealed that for attended pictures the corrected recognition measure decreased rapidly as a function of delay; performance was at its maximum at the 5-min delay, decreased sharply at 1-week, and disappeared at the longest delay of 1- month (all ps<.01). However, for unattended pictures, performance was at chance at all delay conditions except the 5-min delay ($p<.05$).

The main finding indicates that attention matters not only for explicit but also for implicit memory. With regard to explicit memory, the data clearly showed that whereas for the attended pictures recognition decreased as a function of delay, for the unattended pictures recognition was very poor at all delays; it only differed from chance at 5-min. With regard to implicit memory, the reliable differences between attended and non-studied pictures, as well as between unattended and non-studied pictures, demonstrate perceptual implicit memory for both attended and unattended pictures. Furthermore, implicit memory was more pronounced for attended than for unattended pictures (Figure 5 and Table 2).

In sum, the results replicate those from Experiment 1. This confirms that the results of Experiment 1 were not due either to explicit contamination of the implicit test nor to the specific explicit task (recall).

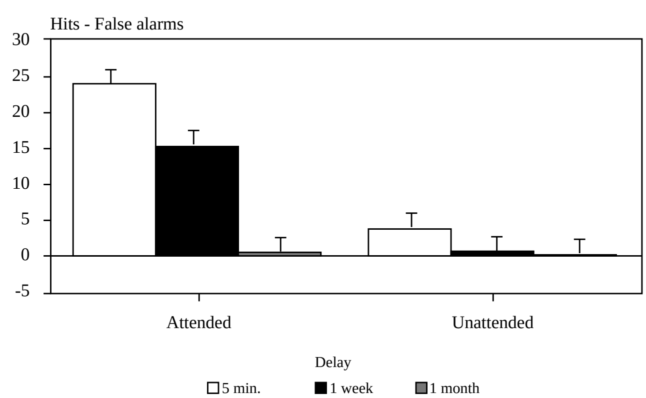

Figure 6. *Mean total number of hits-false alarms for recognized picture names for the 5-min, 1-week and 1-month delay conditions as a function of study condition: studied attended, studied unattended pictures (Exp. 2). The error bars show an estimate of the standard error of the mean*

EXPERIMENT 3

As in the previous experiments, we investigated the role of selective attention and delay in both implicit and explicit memory tasks. However, in this experiment we provided exactly the same retrieval cues in the implicit and in the explicit memory tests. The idea was to limit at maximum retrieval strategies (retrieval specificity criteria). We assessed implicit memory with a speeded picture naming test and explicit memory, as in Experiment 2, with a recognition test. In both tasks, the physical retrieval cues provided to participants were exactly the same, and only the test instructions varied (Schacter, Bower and Booker, 1989): Participants were asked to name the object as fast as possible in the implicit memory test and to judge whether the picture was «old» or «new» in the explicit memory test. Presenting the same external cues in the implicit and the explicit memory tasks and only varying test instructions ensured that a different pattern of results between the implicit and explicit tests could not be attributed to differences in the nature of the task or to the use of different retrieval cues. The lack of priming for unattended pictures would be interpreted as supporting the idea that implicit memory requires attention at encoding.

Method

Participants

Twenty-four students at the *Universidad Nacional de Educación a Distancia* voluntarily participated in a 30-min experimental session. All had normal or corrected to normal vision and were naive as to the purpose of the study. They had not participated in any other perception or cognition experiment.

Apparatus and stimuli

These were the same as in the previous experiments.

Design

A mixed-factorial design was used: 1 within-subject factor –3 study conditions (attended, unattended, and non-studied pictures) and 1 between-subject factor –2 types of test (implicit vs. explicit).

Procedure

The study phase was exactly the same as in the previous experiments. Participants performed a filler task consisting of writing down names of famous people during a 5-min delay between the study and test phases. Then, half of the participants performed a speeded picture naming test as the implicit memory task. They were asked to name the picture as soon as possible. They were presented with 30 attended-studied pictures (green), 30 unattended-studied pictures (blue), and the 30 non-studied pictures (half green and half blue) in a random order. Half of the non-studied pictures were green and the other half were blue. We thought that this was a good strategy as participants could not associated color with condition. However, to find out whether the color of new pictures added to obtain baseline (implicit test) and performance with «new» pictures (recognition test), we conducted a within-subject analysis for response times corresponding to new stimuli as a function of color (blue, green) and found that this variable was not significant ($F(1,11)= .0009$, MSe= .0286, $p= .93$). So, there is not a confound of color with condition.

The other half of the participants performed the recognition test as the explicit memory task. They were presented with 90 pictures one at a time, in a random order, and were asked to indicate whether the pictures were «old» or «new»; i.e., whether they had seen them during the study phase. The color of the attended and unattended pictures in the recognition test was the same as in the implicit test. The pictures remained on the screen until participants responded or for a maximum of 5 s.

Results and discussion

Picture naming

Pictures on the implicit test were identified faster when observers had named the pictures during the study phase (attended) than when they had either not named them (unattended) or not seen them (non-studied). A within-subjects ANOVA confirmed this result. There was a significant main effect of study condition, $F(2,22)= 16.90$, MSe= 5946.95, $p<.0001$. A post-hoc test indicated that the mean response time was lower for attended (841 ms) than for unattended (1017 ms), $p<.0001$, and non-studied (973 ms), $p<.0012$, pictures, and that unattended and non-studied pictures did not differ significantly ($p>.1$).

Recognition

The within-subjects ANOVA performed in terms of the correct recognition measure of hits - false alarms showed that the effect of study condition was reliable, $F(1,11)= 279$, MSe= 10.314, $p<.001$. Attended pictures (25) were recognized better than unattended pictures (3.1). Recognition for unattended pictures was very poor, practically at chance.

In consonance with our previous results, this experiment clearly indicates that attention at encoding matters not only for explicit but also for implicit memory tests. The explicit memory test showed that whereas for the attended pictures recognition was good, for the unattended pictures it was very poor. The implicit memory test also showed reliable differences between attended and non-studied pictures. Perceptual priming was large for attended but not present for unattended pictures. This result showed that the speeded naming test requires attentional encoding processes; pictures must be attended during encoding to facilitate performance on this implicit memory test. Interestingly, in a recent haptic study, the same conclusion has been reached. Participants held two objects simultaneously, one in each hand, and were instructed to identify the object in one hand. Their speeded response was faster for the attended than unattended objects, and priming only appeared (Chiang, Bushnell and Ballesteros, 1999) for the attended objects.

General discussion

The present study was designed to investigate the effects of selective attention at encoding, and delay of between study and test, on implicit (picture-fragment completion in Experiments 1 and 2 and object naming in Experiment 3) and explicit (free recall in Experiment 1 and recognition in Experiments 2 and 3) memory tests. The experiments consistently indicated that: (a) at all delays (ranging from immediate to 1 month), the identification threshold was lower for attended than for unattended pictures; (b) attended pictures were recalled and recognized better than unattended pictures; (c) attention and delay interacted for implicit memory –performance decreased with delay for both attended and unattended pictures, but priming was more pronounced and lasted longer for attended pictures and was still present at 1-month; (d) attention and delay interacted for explicit memory –performance decreased with delay for attended pictures in both free-recall (Experiment 1) and recognition (Experiments 2 and 3), but for unattended pictures was consistently poor regardless of delay; and (e) when the perceptual cues where held constant for the implicit (object-naming) and the explicit (recognition) memory tests, significant priming and recognition did exist for attended pictures but not for unattended pictures.

Attention affects both implicit and explicit memory

Participants in the three experiments could effectively select and process one of two superimposed stimuli using color as the selective cue. This result is concordant with studies that have used this procedure in explicit memory. For instance, Rock and Gutman (1981) reported that recognition was good for attended but not for unattended unfamiliar drawings.

To our knowledge, this is the first study to report that perceptual implicit memory for pictures is affected by attention at encoding, and that without selectively attending to the pictures neither explicit nor implicit long-term memory is possible. In all three experiments, we consistently found stronger priming as well as better performance in explicit memory tests for attended than unattended pictures. Note that although the attentional effect was more pronounced for the free-recall and recognition tests than for the picture-completion and object-naming tests, explicit and implicit memories were *not* functionally dissociated. On the other hand, Gabrieli et al (1999) did not find effects of the division of attention on a picture-naming test. The contrasting results obtained by Gabrieli and his colleagues and ours findings is interesting as it suggests that whereas divided attention studies often produced the same perceptual priming, selective attention manipulations often disrupt perceptual facilitation.

The present results also differ from those of Parkin and his colleagues (e.g., Parkin et al, 1990; Parkin and Russo, 1990) who found that divided attention significantly impaired recall but did not affect implicit memory. This inconsistency may stem from methodological reasons. Several authors have noted that Parkin's encoding task was not particularly designed to prevent attention 'leaking' to the unattended items, such that nominally unattended or ignored information may have been subjected to further processing (e.g., Bentin et al, 1998; MacDonald and MacLeod, 1998). In addition, their primary and secondary tasks were presented in different modalities, which may have not taxed attention as much as when information is presented within modalities. As point it out above, attention effects are more likely to be observed in those conditions in which attention is manipulated within the same modality and both stimuli (the attended and the unattended stimuli) are presented together at the same spatial location than when attention is diverted to different modalities and attended and unattended items are presented at different moments or very infrequently (for the same argument, see Mulligan and Hornstein, 2000).

Our results also differ from those of Mulligan and colleagues who have consistently found an attentional effect for implicit memory with conceptually-driven tasks, but not with a verbal perceptual implicit memory test (Mulligan, 1997, 1998). For instance, they found that inducing a heavy attentional load while encoding words reduced performance on a conceptual implicit memory test (category exemplar production, Mulligan, 1997), but not on a perceptual implicit memory test (word-fragment completion; Mulligan, 1998). In any case, methodological differences between Mulligan's studies and the present one may explain the disagreement regarding attentional participation in perceptual priming. For instance, whereas they used words, we used pictures, and whereas they manipulated divided attention, we manipulated selective attention. As noted in the introduction, these two ways of manipulating attention do not always yield consistent results.

More recently, Mulligan and Hornstein (2000) using a Stroop-like task found that dividing attention within the visual modality impaired repetition priming in a perceptual identification task. Identifying the color reduced priming even when participants identified the words overtly. Similarly, Rajaram et al. (2001) using also the Stroop task showed significantly reduced perceptual priming effects in word fragment completion and word stem completion tests when attention was directed to color not to the word itself.

Indeed, several studies assessing the effect of selective attention on implicit memory for words have concluded that attention plays a role in implicit memory and that attention is necessary at encoding so as to establish a lasting representation that can support repetition priming (Bentin et al, 1998; Crabb and Dark, 1999; MacDonald and MacLeod, 1998; Stone et al, 1998; Stone, Ladd and Gabrieli , 2000). These verbal perceptual priming studies indicate no dissociation for implicit and explicit memory. Furthermore, recent haptic studies have shown that a speeded implicit identification test (object naming of familiar objects) was faster for the attended than the unattended objects and that priming only emerged for the former not only in young adults (Chiang, Bushnell and Ballesteros, 1999) but also in older adults and Alzheimer's disease patients (Ballesteros and Reales, 2004).

In sum, the results of the three experiments reported here using pictures as stimuli are in close agreement with findings from several recent verbal studies in which attention at encoding was manipulated in a selective or divide paradigm. The findings support the idea that attention at encoding is required not only for explicit memory tests and conceptual implicit tests but for perceptual implicit tests as well.

The effect of attention and delay interact in both implicit and explicit memory

The present results showed no functional dissociation of implicit and explicit memory tests as a function of delay, supporting Snodgrass and Surprenant's (1989) conclusions. Although implicit memory does persist over time, it does not seem to be as completely resistant to forgetting as previously supposed (Bentin et al, 1998). However, its persistence over long periods of time is remarkable.

This study also indicated that delay is an intervening variable affecting the degree of attentional effect on implicit memory: (1) Explicit memory for attended pictures decreased with delay, but performance was consistently poor for unattended pictures regardless of delay; (2) the shorter the delay, the greater the difference between the number of attended and unattended recalled (Experiment 1) or recognized (Experiment 2) pictures; and (3) priming was more pronounced and lasted longer for the pictures that were selectively attended at study than for those that were not. At the longest delay of 1-month, implicit memory was only present for the attended pictures. Note that this interval is longer than the interval of 1-week at which many studies using word-fragment and word-stem completion show significant losses of perceptual priming (see Roediger and McDermott, 1993). It is important to note that these results were the same whether the explicit test was recall or recognition·

In short, using an *object* perceptual priming task, in all three experiments implicit memory was much more pronounced for selectively attended than for unattended pictures, and the priming was present for longer time for the former than for the latter. We attribute these results to the fact that the named pictures at encoding, which were selectively attended, may have had an enhanced processing and attained a stronger representation than unattended information (e.g., Carrasco et al, 2000; Desimone and Duncan, 1995; Ganor-Stern et al, 1998; Rock and Gutman, 1981; Yeshurun and Carrasco, 1998, 1999).

In this study, delay emerged as an intervening variable determinig the effects of attention on priming. Ganor-Stern and colleagues (1998) reported that study time is another intervening variable affecting the degree to which priming is affected by attentional resources. These two studies support a limited-capacity model for both explicit and implicit memory for visual stimuli whether these stimuli are unfamiliar (in the Ganor-Stern et al, 1998, study) or familiar (in the present study). The present results are consistent with the central-bottleneck model (Pashler, 1998). When the system is processing the attended stimulus, priming for the unattended stimulus is reduced (picture fragment completion test) or eliminated (speeded picture naming test).

Conclusion

Using a new overlapping-pictures encoding task to manipulate selective attention, we found that attention at encoding matters. The three experiments reported here convergently showed that neither attention nor delay dissociated performance in explicit and implicit memory tests. Furthermore, these two variables interacted. Attention at encoding enabled a better stimulus representation that was more resilient to the passage of time. Thus, the hampering effect of delay was minimized when information had been selectively attended as opposed to when it had not. The findings that both implicit and explicit manifestations of memory lasted longer for attended than unattended pictures indicate that the way in which information is encoded has some long lasting effects. Selectively attended stimuli are processed more fully than unattended stimuli occupying the same spatial position. We conclude that attention has qualitatively similar but quantitatively different effects on explicit and implicit memory. Implicit memory, as indicated by perceptual priming of picture outlines, is less sensitive than explicit memory to limited attentional resources, but neither expression of memory is attention free.

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