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THE EFFECT OF STUDY TIME ON PRIMING POSSIBLE AND IMPOSSIBLE FIGURES IN THE OBJECT DECISION TEST

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Previous research demonstrated object decision priming for possible, but not impossible three-dimensional objects (e.g., Schacter et al. 1990; 1991). Subsequent research by Carrasco and Seamon (1996) found that when possible and impossible objects were equated for complexity, priming was observed for both object types. The present research extended the complexity results. Possible objects demonstrated object decision priming with greater classification accuracy for studied than nonstudied objects, following exposure durations of 900 ms to 30 s. The pattern for impossible objects was a function of their complexity. Highly complex impossible objects showed greater classification accuracy for nonstudied than studied objects, whereas moderately complex impossible objects showed no difference in classification accuracy, except following the longest duration where studied objects were classified more accurately than nonstudied objects. The conditions under which priming was observed for possible and impossible objects was discussed in terms of stimulus complexity and the ease of generating structural representations of the stimuli and the presence of a general response bias.

El efecto del tiempo de respuesta en el priming de figuras posibles e imposibles en la tarea de decisión del objeto. La investigación anterior ha mostrado la existencia de *priming* para objetos imposibles (Schacter et al. 1990, 1991). Un estudio posterior realizado por Carrasco y Seamon (1996) encontró que cuando se igualaron en complejidad los objetos posibles e imposibles el *priming* fue significativo para ambos tipos de objetos. Esta investigación extendió los resultados de complejidad. Se encontró *priming* para los objetos posibles en la tarea de decisión del objeto, con mejor precisión en la clasificación para objetos estudiados que para los no estudiados en duraciones entre 900 ms y 30 s. El patrón relativo a los objetos imposibles resultó depender de su complejidad. Los objetos imposibles muy complejos mostraron mayor precisión para los objetos no estudiados que para los estudiados mientras que los objetos imposibles moderadamente complejos no mostraron diferencia en la clasificación a excepción de la duración más larga en la que los objetos estudiados se clasificaron de manera más precisa que los no estudiados. Las condiciones en las que se observó el *priming* para objetos posibles e imposibles dependió de la complejidad del estímulo, de la familiaridad para generar representaciones tridimensionales de los objetos y de la presencia de un sesgo general de respuesta.

Explicit and implicit memory have received considerable attention from researchers during the past decade. Explicit memory is the conscious or intentional retrieval of past experience, whereas implicit memory is the nonconscious or unintentional retrieval of previously acquired information (Graf & Schacter, 1985; Schacter, 1987). Explicit memory is typically measured by direct

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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. In tests such as word identification, word-stem completion, and affective preference, implicit memory is indicated when subjects show a facilitation or change in performance that is attributable to information acquired during study. These different expressions of memory that have been dissociated by a wide variety of experimental variables. Examples of those variables include stimulus encoding instructions, study-test changes in the stimuli, and length of the retention interval. Graf (1994), Moscovitch, Goshen-Gottstein, and Vriezen (1994), Richardson-Klavehn and Bjork (1988), Roediger and McDermott (1993), and Schacter (1987) provide comprehensive reviews of this research.

One robust stimulus variable that has dissociated explicit and implicit memory involves possible and impossible three-dimensional objects used in the research of Schacter and Cooper and their colleagues (e.g., Cooper, Schacter, Ballesteros, & Moore, 1992; Schacter & Cooper, 1993; Schacter, Cooper, & Delaney, 1990; Schacter, Cooper, Delaney, Peterson, & Tharan, 1991). These researchers have consistently found explicit memory for possible and impossible objects, but implicit memory only for possible objects. For example, Schacter et al. (1990) presented subjects with unfamiliar possible and impossible objects in an incidental learning task. After encoding the objects, the subjects were given a surprise recognition or object decision test. The recognition test required the subjects to determine if each object had been presented during study, whereas the object decision test required them to classify each stimulus as a possible or impossible object. Half of the studied and nonstudied stimuli represented «possible» objects that could exist as three-dimensional forms, and half represented «impossible» objects that contained surface or edge violations that prevented them from existing as three-dimensional structures. Schacter and Cooper have repeatedly found that recognition was observed for both object types, whereas priming, indicated by greater object classification accuracy for studied than nonstudied objects, was found for possible, not impossible objects (Cooper et al., 1992; Schacter & Cooper, 1993; Schacter et al. 1990; 1991).

In subsequent studies, these researchers increased the number of exposures to the stimuli at study to enhance the strength of the memory representations, modified the instructions to give more equal weight to possible and impossible decisions, and equated the possible and impossible objects for overall size. Because none of these manipulations produced priming for impossible objects, the authors concluded that the failure to find priming for impossible objects may be an enduring characteristic of impossible objects (Cooper et al., 1992; Schacter & Cooper, 1993; Schacter et al., 1990; 1991). They suggested that the dissociation involving possible and impossible objects in the recognition and object decision tests reflected the output of different underlying memory systems used for the representation and retrieval of visual object information. One system, called the episodic system, is responsible for explicit memory. Because explicit memory for both possible and impossible objects has been observed, this system is able to encode representations for both object types. The other system, responsible for implicit memory, is the structural description system. The primary function of this system is to analyze the structural relations among the components of a visual object to compute a global three-dimensional representation. Representations from this system are assumed to be useful during the object decision test because this test requires subjects to make possible-impossible decisions about an object's three-dimensional structure. If subjects have already computed representations for objects during study, their performance on the object decision test should be more accurate for studied than nonstudied objects. The finding that priming was observed only for possible objects has been interpreted to mean that the structural description system either cannot compute or has great difficulty computing three-dimensional representations for structurally impossible objects (Cooper et al., 1992; Schacter & Cooper, 1993; Schacter et al., 1990; 1991).

However, subsequent research has demonstrated that possible and impossible objects do not always yield different implicit memory results. Seamon et al. (1995) demonstrated implicit memory for Schacter and Cooper's possible and impossible objects in an affective preference task, and Carrasco and Seamon (1996) obtained priming for both object types in the object decision test. Carrasco and Seamon's results are especially noteworthy because they used Schacter and Cooper's possible and impossible objects and their same general procedure to observe if subjective complexity differences between possible and impossible objects might be responsible for previous failures to find priming for impossible objects. Carrasco and Seamon found that Schacter and Cooper's impossible objects were higher in complexity than their possible objects. When impossible objects were more complex than possible objects, Carrasco and Seamon found priming only for possible objects. But when possible and impossible objects were systematically equated for complexity (moderate complexity for both), priming was observed for both object types. These findings suggested that the previously observed dissociation of object type and explicit and implicit memory (Cooper et al., 1992; Schacter & Cooper, 1993; Schacter et al., 1990; 1991) were due to a confound of object type and subjective complexity. When stimuli are equated for complexity, object decision priming can be observed for both possible and impossible objects in the object decision test.

The goal of the present research was to examine further the conditions that allow priming for impossible objects. Carrasco and Seamon (1996) suggested that the lack of priming for structurally complex impossible objects may be due to insufficient study time and resources available for encoding these stimuli. More complex stimuli may require greater study time and resources at encoding than less complex stimuli. Because none of Schacter and Cooper's possible objects are structurally complex, this issue applies primarily to their impossible objects. Past research has shown that manipulating stimulus study time has dissociated explicit and implicit memory by affecting recognition memory more than priming (e.g., Jacoby & Dallas, 1981; Musen, 1991; Schacter et al., 1991; Seamon, Marsh, & Brody, 1984). However, study time can influence implicit memory. For example, Ganor-Stern, Seamon and Carrasco (1998) used Schacter and Cooper's possible and impossible objects in their recognition and object decision paradigm to study the effects of limited attentional resources and study time on explicit and implicit memory. In their first study, Ganor-Stern et al. found that when attention at study was limited by a flanking digits procedure, object recognition was diminished but object decision priming for possible objects was unaffected. The possible and impossible objects were not equated for complexity, so priming was found only for possible objects. In their second study, when object study time was reduced from 5 to 3 s in the limited attention condition, object recognition was impaired and object priming was eliminated. The degree to which object priming was influenced by attentional resources was determined by the intervening variable of study time. Because implicit memory was sensitive to an attentional manipulation when study time was short (see also Hawley & Johnston, 1991), Ganor-Stern et al. (1998) suggested that the quality of the object representations was less stable following shorter than longer study times.

The effect of study time on priming was addressed in the present experiment by presenting subjects with possible and impossible objects to study for different exposure durations, followed by an object decision test. If priming in the object decision test is determined by the opportunity to generate object representations during encoding, then priming for possible and impossible objects should be dependent on stimulus exposure duration during study and stimulus complexity. Specifically, possible objects, because they are low to moderate in complexity, should demonstrate priming at shorter as well as longer study times. But impossible objects, because they are moderate to high in complexity, should demonstrate priming only at longer study times. Schacter et al. (1991) previously considered whether increasing object study time might lead to priming for impossible objects. However, over a range of study times that varied from 1 to 20 s, they found priming for possible but not impossible objects. Of course, a collection of impossible objects might be of such high complexity that study times greater than 20 s per stimulus are needed to demonstrate priming. Alternatively, it may be that priming cannot be observed for the most complex impossible objects, even after extended study times. Such a result would suggest that highly complex objects may be too difficult to encode within the constraints of an experimental session to generate usable object representations. To explore these possibilities, we examined the effect of an extended range of study times, from 900 ms to 30 s, on the priming of possible and impossible objects in the object decision test.

Experiment

Method

Subjects and Design. The subjects, 80 Wesleyan University students who received introductory psychology credit, took part in a 2 x 2 x 2 mixed factorial design. Stimulus Exposure Duration at Study (900 ms, 3 s, 9 s, and 30 s) was manipulated as a between-subject variable, and Object Type (Possible and Impossible Objects) and Item Type (Studied and Nonstudied Objects) were manipulated as within-subject variables. The Exposure Duration variable yielded four experimental groups, each comprised of 20 subjects.

Materials and Apparatus. The stimuli consisted of line drawings of three-dimensional possible and impossible objects used previously by Ganor-Stern et al. (1998) and obtained from Schacter and Cooper (see Schacter et al., 1990, for examples). A total of 44 object figures were used: 22 possible objects and 22 impossible objects. The object figures subtended a visual angle of approximately 5 deg when viewed from a distance of 2.25 m. They were photographed as negative slides and projected on a screen by a Gerbrands projection tachistoscope, where they appeared as red objects on a dark surround when shown through a red photographic filter attached to the lens shutter of the tachistoscope. The experiment was conducted under conditions of low room illumination.

Procedure. The subjects were told that they were participating in a perceptual decision making experiment in which they would have to decide if three-dimensional object figures faced predominantly left or right. Prior to the experimental trials, two possible and two impossible object examples were shown to emphasize the subjective nature of the perceptual judgments. These stimuli were not used in any subsequent conditions. Following the instructions and examples, the subjects were presented with 66 trials consisting of 11 possible and 11 impossible objects shown three times each in three random orders of 22. Each object figure was individually shown in the center of the visual field for a fixed exposure duration of 300 ms, 1 s , 3 s, or 10 s, followed by a 3.5 s interstimulus interval, yielding total exposure durations at study of 900 ms, 3 s, 9 s, and 30 s per stimulus when exposure duration and repetition were combined. The subjects were required to look at each figure for the full length of the exposure duration, then indicate by marking their answer sheets whether the object faced left or right. This structural encoding condition encouraged the subjects to view the figures as three-dimensional objects, and it was the same judgment task that was used previously by Schacter et al. (1990; 1991) and the present researchers (e.g., Carrasco & Seamon, 1996; Ganor-Stern et al., 1998). The subjects, who were tested in groups of up to 6 and monitored during study to ensure that they looked at the object figures for the entire exposure duration, were not informed of the possible-impossible stimulus dimension or the subsequent object decision test.

Following the exposure to the study stimuli, the subjects were presented with an object decision test. This test consisted of 44 test trials involving 22 figures from the study portion of the experiment and 22 comparable figures not previously studied. Half of the studied and nonstudied figures were possible objects and half were impossible objects. These figures were presented individually for 100 ms, followed by a 3.5 s intertrial interval, in a random order. The subjects were told to classify each test figure as a possible or impossible object by marking their answer sheets accordingly. Prior to the test, the subjects were given detailed instructions about possible and impossible objects, including four possible and four impossible object examples to classify, and they were told that half of the test figures to be shown represented possible objects and half represented impossible objects.

Finally, the particular stimuli designated as studied and nonstudied objects in this experiment were previously shown by Ganor-Stern et al. to yield equivalent levels of classification accuracy. In that study, 20 subjects in a control condition were given the object decision test with these same stimuli, but without prior study. Ganor-Stern et al. found that possible objects were classified more accurately than impossible objects, but there was no difference in classification accuracy for possible or impossible objects designated as studied or nonstudied and no interaction of these variables. Thus, object decision priming in the present experiment may not be attributed to the particular objects used as stimuli.

Results and Discussion

Table 1 presents the mean percent object classification scores for studied and nonstudied possible and impossible objects following study at different exposure durations. Several important observations can be made. First, studied objects were classified more accurately than nonstudied objects when those objects were possible, at each of the stimulus exposure durations. Greater classification accuracy for studied than nonstudied objects demonstrates object decision priming for possible objects that was independent of exposure duration. Second, nonstudied objects were classified more accurately than studied objects when they were impossible at all but the longest exposure duration. Clearly, increasing total stimulus exposure duration from 900 ms to 30 s per stimulus at study was not sufficient to produce object decision priming for these impossible objects. Instead, prior stimulus exposures generally had opposing effects on possible and impossible objects in the object decision test. The greater classification accuracy for nonstudied than studied impossible objects at all but the longest exposure duration suggests the presence of a response bias.

These results were supported by the results of an analysis of variance that showed an interaction of possible and impossible objects and studied and nonstudied objects, $\underline{F}$ (1, 76)= 72.61, MSe= 198.45, $\underline{p}$ <.0001. For possible objects, studied objects were classified more accurately than nonstudied objects, $\underline{F}$ (1, 76)= 99.82, MSe= 166.06, $\underline{p}$ <.0001, there was no effect of stimulus exposure duration, F= 1.0, and no interaction of these variables, $\underline{F}$ (1, 76)= 1.01, MSe= 1.67, $\underline{p}$ >.25. For impossible objects, nonstudied objects were classified more accurately than studied objects, $\underline{F}$ (1, 76)= 20.14, MSe= 50.75, $\underline{p}$ <.0001, there was a marginal effect of stimulus exposure duration, $\underline{F}$ (3, 76)= 2.33, MSe= 9.59, $\underline{p}$ <.09, and no interaction of these variables, $\underline{F}$ (3, 76)= 1.35, MSe= 3.41, $\underline{p}$ > .25.

The finding of greater classification accuracy for studied than nonstudied possible objects provides another demonstration of object decision priming for possible objects in this task. This demonstration has been made numerous times by Schacter and his colleagues (e.g., Schacter et al., 1990, 1991, 1992) as well as other researchers (e.g., Carrasco & Seamon, 1996; Ganor-Stern et al., 1998). However, the demonstration of greater classification accuracy for nonstudied than studied impossible objects has typically not been demonstrated in individual experiments by Schacter and his coworkers, but it was found in two experiments with the present stimuli by Ganor-Stern et al., and it was observed in a meta-analysis of studied and nonstudied impossible objects over many of Schacter et al.'s experiments by Ratcliff and McKoon (1995). Table 2 de-

Table 1

Object Classification Accuracy for Possible and Impossible Objects

Total Study Time	Possible: Studied	Possible: Nonstudied	Impossible: Studied	Impossible: Nonstudied
900 ms	.86	.67	.60	.70
3 s	.86	.67	.55	.70
9 s	.87	.64	.53	.66
30 s	.89	.74	.67	.71

Note. Data are mean proportions. Chance performance is .50.

Table 2

Comparative Object Classification Results for Possible and Impossible Objects

Experiment	Possible: Studied	Possible: Nonstudied	Impossible: Studied	Impossible: Nonstudied
Present Experiment	.87	.68	.59	.69
Ganor-Stern et al. (1998, Exp 1)	.80	.68	.57	.67
Ganor-Stern et al. (1998, Exp 2)	.82	.67	.58	.67
Schacter et al. (1991, Exp 2)	.75	.64	.57	.60

Note. Data are mean proportions. Data from Ganor-Stern et al (1998, Experiment 1, five 1 s exposures, and Experiment 2, three 1 s exposures, full attention conditions; Schacter et al. (1991, Experiment 2, five 1 s exposures). The data from the present experiment and both experiments from Ganor-Stern et al. are based on the same possible and impossible objects. Chance performance is .50.

monstrates that the percent correct object classification means over all exposure durations from the present experiment are generally similar to those observed by Ganor-Stern et al. and Schacter et al. when possible and impossible objects are individually shown for 1 s either three times (Ganor-Stern et al., Experiment 2) or five times (Ganor-Stern et al., Experiment 1; Schacter et al., 1991, Experiment 2).

Because Carrasco and Seamon (1996) observed object decision priming for impossible objects only when they were of moderate complexity, we performed a post-hoc analysis of the object classification results for impossible objects. Based on Carrasco and Seamon's subjective complexity ratings of Schacter and Cooper's possible and impossible objects, we separately rank-ordered the 11 studied and 11 nonstudied impossible objects used in the present experiment in terms of their subjective complexity. Median-split analyses of the studied and nonstudied rankings yielded four stimulus categories, each composed of five impossible objects: less complex studied objects, less complex nonstudied objects, more complex studied objects, and more complex nonstudied objects. The median studied and nonstudied impossible objects were not used in this analysis.

The object classification results for less complex and more complex studied and nonstudied impossible objects are shown in Table 3 for each exposure duration at study. For the more complex impossible objects, nonstudied objects were classified more accurately than studied objects at all exposure durations. However, a different pattern was observed for less complex impossible objects. For these stimuli, classification accuracy was similar for studied and nonstudied objects, except at the longest exposure duration where studied objects were classified more accurately than nonstudied objects.

Table 3
Object Classification Accuracy for Less Complex and More Complex Impossible Objects

	Impossible Objects			
	Less Complex		**More Complex**	
Total Study Time	**Studied**	**Nonstudied**	**Studied**	**Nonstudied**
900 ms	.59	.62	.55	.71
3 s	.60	.61	.50	.74
9 s	.61	.58	.44	.73
30 s	.72	.61	.61	.77

Note. Data are mean proportions. Chance performance is .50.

These results were supported by the results of analyses of variance. There was an interaction of studied and nonstudied impossible objects and stimulus complexity level, $\underline{F}$ (1, 76)= 22.65, MSe= 29.50, $\underline{p}$ <.0001, as greater classification accuracy for nonstudied than studied objects was observed for more complex, $\underline{F}$ (3, 76)= 28.90, MSe= 45.91, $\underline{p}$ <.0001, but not less complex, $\underline{F}$ < 1, objects. No other main effects or interactions were significant. For less complex impossible objects studied for 30 s total study time, studied objects were classified more accurately than nonstudied objects, $\underline{t}$ (19)= 2.28, $\underline{p}$ <.04, demonstrating object decision priming for these objects.

The finding of priming for less complex impossible objects is similar to Carrasco and Seamon's (1996) observation. In the present experiment, this demonstration was made only for the 5 least complex impossible objects from a set of 22 possible and impossible objects that varied in complexity and were studied for the longest exposure duration. In Carrasco and Seamon's experiment, object decision priming was found for 6 moderately complex impossible objects from a set of 12 moderately complex possible and impossible objects studied for 1 s. In addition, Carrasco and Seamon's moderately complex impossible objects were somewhat less complex than the less complex impossible objects used in the present experiment. Thus, while object decision priming for impossible objects may be influenced by both the number of study stimuli and their exposure duration, stimulus complexity remains critically important as indicated by the present and previous findings that object decision priming is limited to objects of moderate complexity. Priming for impossible objects rated high in perceived complexity was not demonstrated, even when those objects were studied for 30 s.

Because space limitations did not permit us to report all relevant data in Carrasco and Seamon (1996) regarding different measures of complexity for Schacter and Cooper's possible and impossible objects, pertinent results from that research are reported here. In the present study, we report the raw data for the subjective and objective complexity measures for each of the 48 objects of the Schachter and Cooper set, as well as the correlations between objective measures of complexity and subjective ratings of complexity and impossibility. Carrasco and Seamon gathered subjective ratings from 80 Wesleyan University students, who were presented with line drawings of 36 possible and 36 impossible objects provided by Schacter and Cooper (see Schacter et al. 1990; 1991 for examples). Half of the subjects rated the objects for «complexity,» and half rated them for «possibility-impossibility» on a 7-point scale.

To measure the relationship between the subjective ratings of complexity or possibility-impossibility with the objective assessments of complexity, Carrasco and Seamon (1996) estimated the complexity value of each figure according to several indexes of complexity (Attneave, 1955, 1957; Chipman, 1977; Fehrer, 1935; French, 1954; Hochberg & Brooks, 1960; see Table 4): Number of lines (defined as the number of straight lines needed to construct the figure), number of line segments (defined as distances from one intersection to another), number of angles, number of points (defined as the number of intersections of two or more segments), number of elements (defined as the number of 'puzzle pieces' or planar shapes needed to form the figure). We classified the 48 objects into five groupings of stimuli: all stimuli (48), equated or extreme stimuli (24 each) and possible or impossible stimuli (24 each). Table 4 shows the values for the 12 objects of each group as well as the mean and standard error for each group.

In addition, we calculated intercorrelations among these complexity indexes and the subjective ratings for all the objects of the Schachter and Cooper set. In general, impossible objects were perceived as more complex than possible objects. Moreover, there were significant positive correlations among all of the objective complexity indexes for all 5 groupings of stimuli (all p's < .001). Subjective ratings of figure complexity increased with increases in objective complexity measures. The subjective ratings for the possible and impossible objects revealed that possible objects were rated less complex, $t(35) = 7.92$, $p < .001$, and more possible, $t(35) = 26.55$, $p < .001$, than impossible objects.

Table 5 also shows the Pearson correlations obtained among the four different objective measures used to assess complexity. These intercorrelations were highly significant for all three groupings ($p<.001$). Correlations were also obtained between objective measures of complexity and subjective ratings of complexity of possibility-impossibility. The correlations between the objective measures of complexity were more numerous for subjective ratings of complexity than for subjective ratings of impossibility. We have shown that this is also the case for both groupings of possible and impossible objects (Carrasco & Seamon, 1996; Table 1).

Table 4
Subjective Measures of Complexity and Possibility-Impossibility and Objective Measures of Complexity for Schacter and Cooper's Stimuli Used in This Study

Object Code	Item Type	Complexity Rating (Subjective Measures)	Poss-Imposs Rating (Subjective Measures)	Lines (Objective Measures)	Segments	Angles	Points	Elements
Equated Possible								
LP12	non-studied	3.45	2.73	19	23	29	17	7
LP14	non-studied	4.18	2.25	21	25	36	17	9
LP15	non-studied	4.10	3.68	17	21	27	16	8
LP18	non-studied	3.68	1.60	23	25	34	18	8
LP19	non-studied	3.90	2.33	26	30	39	23	9
LP22	non-studied	3.50	1.85	29	32	38	25	8
LP11	studied	4.00	1.80	28	30	34	24	7
LP13	studied	4.13	1.45	29	33	47	24	10
LP17	studied	3.50	1.78	19	19	27	14	6
LP21	studied	3.88	1.46	27	33	42	25	10
LP29	studied	4.50	1.80	47	52	73	37	16
LP39	studied	3.60	1.60	28	30	40	22	9
mean		3.87	2.03	26.1	29	39	22	8.9
standard error		0.09	0.18	2.16	2.5	3.4	1.8	0.7
Equated Impossible								
LI02	non-studied	4.38	5.75	15	17	19	14	4
LI03	non-studied	4.18	4.92	12	15	20	11	5
LI08	non-studied	4.15	4.60	16	17	25	12	6
LI11	non-studied	4.00	4.48	15	18	24	13	6
LI31	non-studied	3.89	4.82	16	20	29	14	7
LI33	non-studied	3.63	3.41	16	21	28	15	7
LI05	studied	4.15	5.28	12	14	18	11	4
LI07	studied	3.63	4.10	19	22	29	16	7
LI10	studied	4.43	5.35	24	32	48	21	12
LI14	studied	3.93	5.15	17	19	27	14	6
LI25	studied	4.08	5.21	14	16	20	12	5
LI26	studied	4.26	5.48	17	23	32	16	8
mean		4.06	4.88	16.1	20	27	14	6.4
standard error		0.07	0.18	0.89	1.4	2.2	0.8	0.6
Extreme	*Possible*							
LP07	non-studied	2.58	1.48	18	24	31	17	8
LP16	non-studied	2.50	1.60	17	19	28	13	7
LP23	non-studied	2.78	1.48	22	27	37	19	9
LP28	non-studied	2.73	1.44	23	25	33	18	8
LP31	non-studied	2.33	1.28	20	21	27	16	6
LP33	non-studied	2.03	1.08	29	31	40	23	9
LP01	studied	2.73	1.38	19	20	26	15	6
LP08	studied	2.43	1.25	28	32	39	24	9
LP25	studied	2.53	1.18	24	26	31	20	7
LP27	studied	2.23	1.30	16	17	24	12	6
LP35	studied	2.60	1.18	23	23	31	17	7
LP43	studied	2.85	1.50	29	30	41	22	9
mean		2.52	1.34	22.3	25	32	18	7.6
standard error		0.07	0.04	1.33	1.4	1.6	1.1	0.3
Extreme Impossible								
LI15	non-studied	5.15	5.90	18	21	32	14	8
LI16	non-studied	5.65	5.80	22	33	46	23	11
LI17	non-studied	4.98	5.55	17	19	23	15	5
LI19	non-studied	5.33	5.53	24	31	46	21	11
LI23	non-studied	5.15	5.18	29	33	50	23	11
LI32	non-studied	5.61	5.46	40	51	68	36	17
LI04	studied	4.95	5.23	21	27	41	18	10
LI21	studied	5.40	4.41	32	34	42	26	9
LI24	studied	6.00	5.00	33	40	54	29	13
LI27	studied	5.10	5.40	13	19	27	13	7
LI29	studied	5.28	5.70	19	27	38	18	10
LI35	studied	5.28	5.75	16	26	34	18	9
mean		5.32	5.41	23.7	30	42	21	10
standard error		0.08	0.12	2.36	2.7	3.6	1.9	0.9

Table 5
Pearson Correlation Matrix.

All figures (n=48)

	Complexity	**Impossibility**	**Lines**	**Angles**	**Elements**	**Points**
Complexity	1.00					
Impossibility	0.81***	1.00				
Lines	0.13	-0.30*	1.00			
Angles	0.37**	-0.04	0.90***	1.00		
Elements	0.41**	0.05	0.81***	0.98***	1.00	
Points	0.28*	-0.15	0.96***	0.94***	0.88***	1.00

Equated condition (n=24)

	Complexity	**Impossibility**	**Lines**	**Angles**	**Elements**	**Points**
Complexity	1.00					
Impossibility	0.45*	1.00				
Lines	0.08	-0.70***	1.00			
Angles	0.21	-0.56**	0.94***	1.00		
Elements	0.24	-0.50**	0.87***	0.98***	1.00	
Points	0.10	-0.67***	0.98***	0.94***	0.87***	1.00

Extreme condition (n=24)

	Complexity	**Impossibility**	**Lines**	**Angles**	**Elements**	**Points**
Complexity	1.00					
Impossibility	0.97***	1.00				
Lines	0.19	0.03	1.00			
Angles	0.53**	0.42*	0.84***	1.00		
Elements	0.57**	0.48*	0.74***	0.98***	1.00	
Points	0.40*	0.26	0.93***	0.94***	0.89***	1.00

*=.05
**=.01
***=.001

General Discussion

This research demonstrated several important points. First, object decision priming in the form of greater classification accuracy for studied than nonstudied objects was demonstrated for possible objects following stimulus exposure durations at study of 900 ms to 30 s. Second, the magnitude of the object decision priming observed for possible objects was not influenced by the duration of study time over the range of durations employed. Third, except following the longest exposure duration, impossible objects demonstrated an opposite pattern of results as nonstudied objects were classified more accurately than studied objects. Fourth, when the object decision test results for the impossible objects were reanalyzed in terms of subjective complexity ratings, gathered by Carrasco and Seamon (1996), the more complex objects continued to show greater classification accuracy for nonstudied than studied objects. However, the less complex impossible objects showed no difference in classification accuracy, except following the longest duration where studied objects were classified more accurately than nonstudied objects.

These results show that possible objects can demonstrate priming in the object decision test, an observation that has been made many times in previous research (e.g., Cooper et al., 1992; Schacter & Cooper, 1993; Schacter et al. 1990; 1991). In addition, object decision priming for possible objects was not influenced by variations in study time, as Schacter et al. (1991) observed. However, the present results are also consistent with Carrasco and Seamon's (1996) finding of object decision priming for impossible objects, when object complexity is controlled, as both studies have demonstrated priming for moderately complex impossible objects. As Carrasco and Seamon noted, the observation of priming for both possible and impossible objects suggests that subjects can compute global structural descriptions for possible and impossible objects, providing the objects are not too complex.

Carrasco and Seamon (1996) also hypothesized that encoding complex impossible objects may require greater encoding resources than less complex possible or impossible objects to demonstrate priming in the object decision test. This hypothesis was examined in the present experiment in terms of our manipulation of study time. We found that increasing object study time was not sufficient to demonstrate priming for complex impossible objects. The failure to find priming for complex objects suggests that structural description representations cannot be readily generated for these stimuli. This view, noted previously by Carrasco and Seamon, required a modification of Schacter and Cooper's position that the structural description system cannot represent impossible objects (Cooper et al., 1992; Schacter & Cooper, 1993; Schacter et al. 1990; 1991). Moderately complex impossible objects can be structurally represented; highly complex impossible objects may not be structurally represented.

Could highly complex impossible objects yet demonstrate priming and suggest structural representation given greater encoding resources than those employed in the present research? Encoding resources in the form of stimulus exposure duration at study of up to 20 s per object (Schacter et al., 1991) or 30 s per object (the present experiment) have failed to provide that demonstration. It is possible that stimulus exposure durations greater than 30 s might show priming for complex impossible objects, but this research would be difficult to conduct. With very long and/or frequent exposures to the same set of objects, subjects can experience difficulty in maintaining their attention. In the present experiment, the subjects were carefully monitored during study, and verbal reminders were given to maintain focus on the stimuli. These reminders were necessary only during the longest exposure duration of 30 s, as subjects indicated in the experimental debriefing that this study condition was visually tiresome. Thus, additional study time per se might not produce priming for complex impossible objects. Perhaps a different encoding strategy that could be mentally engaging for a period of time that was longer than that needed for making left/right orientation judgments might reveal priming for complex objects. One possible encoding task that would require time and mental concentration would be to require the subjects to draw each studied object accurately from memory. Greater time and concentration would be required for more complex than less complex stimuli, but, given accurate representations of the stimuli, priming may be demonstrated for possible and impossible objects. However, this drawing from memory study condition would change the study conditions from incidental to intentional learning and, more important, might lead to explicit memory contamination of the object priming results.

Finally, the general observation of greater classification accuracy for nonstudied than studied impossible objects shown in Tables 1-3, and especially for the more complex impossible objects shown in Table 3, indicates a negative effect of study for these stimuli. The tendency to misclassify studied impossible objects as possible suggests the presence of a response bias. According to Ratcliff and McKoon (1995), subjects may be biased by stimulus familiarity to classify all previously studied objects as possible. In the present context, when subjects are faced with the difficult perceptual discrimination of determining whether complex objects are possible or impossible, they may unknowingly let familiarity due to prior exposure influence their object decision. Impossible objects that are both complex and unfamiliar may appear more subjectively «impossible» than comparable objects that are familiar. For impossible objects that are only moderately complex, a familiarity bias could still be present, but it might be mitigated by longer exposure durations that permit accurate structural representations for these stimuli to be generated. Thus, performance in the object decision test could be driven by either familiarity judgments, structural description representations, or both.

We suggest that when object stimuli differ in complexity, with impossible objects more complex than possible objects, object decision performance will vary with both object and study conditions. Possible objects will benefit from prior exposure because less complex objects can be represented structurally and there is a possible object response bias. Impossible objects will generally not benefit from prior exposure because highly complex objects are difficult to represent structurally. Moreover, the presence of a possible object response bias could lead to a negative effect of prior exposure. Impossible objects of moderate complexity are different. The demonstration of object decision priming for these objects suggests that accurate representations can be generated. With sufficient study time, a strong positive effect of generating an accurate structural representation can offset a weak negative effect of a response bias and yield object decision priming for these stimuli.

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