When Unfamiliarity Matters: Changing Environmental Context Between Study and Test Affects Recognition Memory for Unfamiliar Stimuli

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Performance in recognition memory has been shown to be relatively insensitive to the effect of environmental context changes between study and test. Recent evidence (P. Dalton, 1993) showed that environmental context changes between study and test affected recognition memory discrimination for unfamiliar stimuli (faces). The present study presented 2 experiments that replicated this finding, refined the experimental methodology, and extended the findings to unfamiliar verbal material (nonwords). Finally, a 3rd experiment showed that contextual changes did not affect recognition memory discrimination for familiar verbal material (words). Overall, the present study provides evidence in favor of context-dependent recognition when the material to be remembered is unfamiliar.

It has often been reported that changing the environmental context between study and test impairs memory performance when free recall is used as the memory task (e.g., Godden & Baddeley, 1975; S. M. Smith, 1979; though see Fernandez & Glenberg, 1985). By contrast, any effects of changing the environmental context between study and test have been extremely difficult to detect using dependent variables intended to measure participants' ability to discriminate target items from distractors in recognition memory tasks (e.g., Eich, 1985; Fernandez & Glenberg, 1985; Godden & Baddeley, 1980; Murnane & Phelps, 1993, 1994, 1995; but see S. M. Smith 1985, 1986).[1] For example, in two separate studies, Godden and Baddeley (1975, 1980) required participants to study lists of words both on land and underwater for a subsequent memory test. When memory performance was assessed by free recall (Godden & Baddeley, 1975), participants recalled more words when the study and test contexts were the same compared with when the context was changed between study and test. However, when memory performance was assessed by a recognition memory test (Godden & Baddeley, 1980), participants recognized no more words when the study and test contexts were the same compared with when the contexts were different.

Interestingly, a similar dissociation between free recall and recognition has been reported when changes in internal state are manipulated between study and test. As reviewed by Eich (1980), changes in the state induced by psychoactive drugs (e.g., alcohol) affected memory only when participants were tested using free recall, perhaps suggesting a commonality in the processes underlying state-dependent learning and context-dependent learning.

The presence of context-dependent learning in free recall and its absence in recognition memory discrimination is consistent with a number of different theoretical accounts. Perhaps the simplest and most intuitive account is the outshining hypothesis (S. M. Smith, 1988, 1994). The outshining hypothesis is so-named because it draws on the metaphor of observing a heavenly body, such as a star, under different levels of background brightness: in a dark night sky, a night sky containing a full moon, or a bright sunny day. Although the brightness of the star remains constant in the sky, the relative contribution of the star to the brightness of the sky decreases dramatically with an increase in the brightness of the alternative light sources. The star makes a valuable contribution and thus can be seen in the dark night sky, but adds relatively little light and thus is outshone in the brighter conditions of the full moon and the sun. According to the outshining hypothesis, context effects will be present under conditions in which associations (set up at study between the target items and the environmental context) contribute sufficiently to the other available cues (generated by the participant or provided to the participant at test by the experimenter) to enhance memory performance. Context effects are predicted to be present using the free recall task

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[1] The present study only addressed the issue of the effect of changes in environmental context between study and test on the ability to discriminate targets from distractors in yes–no recognition memory. For a discussion on same-direction changes in hit rate and false-alarm rate due to environmental context changes between study and test, see, for example, Murnane and Phelps (1995).

because there are relatively few experimental cues available to the participant, and thus the contextual cues can provide a relatively strong contribution to memory retrieval. By contrast, context effects are predicted to be reduced or absent when a recognition test is used to assess memory performance. This is because there are very strong experimental cues available to the participant (the copy cues of the items themselves) and so contextual cues can provide only a very weak relative contribution to memory performance. The outshining hypothesis further predicts that manipulations that decrease the strength of the item memory cue (i.e., manipulations that decrease the brightness of the competing light sources, using the outshining metaphor) will increase the relative contribution of the contextual cues. Early evidence appeared to be consistent with this prediction. For example, S. M. Smith (1986) demonstrated context-dependent effects in recognition when the items were encoded using a shallow incidental learning task, but not when items were encoded using a deep orienting task. This pattern of results can be explained if one considers that the contribution of the relatively weak contextual cues were only detected when the relative strengths of the item cues were reduced (such as by using a shallow learning task). However, more recent studies have failed to show a decrease in context effects with an increase in item strength, when context effects were measured by an increase in memory performance (e.g., Murnane & Phelps, 1995; S. M. Smith, Vela, & Williamson, 1988) or when context effects were measured by an increase in context-related clustering (e.g., Cousins & Hanley, 1996).

The basic idea that context-dependent recognition discrimination depends on the relative cue strength between contextual cues and other available cues has also been posited by authors who have not used the outshining metaphor explicitly (e.g., Dalton, 1993). Dalton (1993) considered that the effect of changing environmental context on recognition memory may be mediated by specific characteristics of the target material, like its familiarity. Anecdotal observations suggested that it is sometimes more difficult to recognize unfamiliar people compared with familiar people, especially when they are seen in a different environment from the one in which they were originally encountered. To test this hypothesis, Dalton assessed the effect of changes in environmental context on recognition memory for familiar and unfamiliar faces using a completely within-subject design. Familiarization of faces occurred by presenting half of a set of new faces to the participants a week before the main part of the experiment. On the test day, participants saw a series of faces (half familiar, presented a week earlier, and half unfamiliar) in two different university rooms. Each face was accompanied by a label that was the title of an occupation. The participants' task was to rate how likely the face matched the job title. After an unfilled interval, participants were tested in both study rooms. In each test, participants saw faces that were originally studied in both rooms, in addition to new, previously unseen faces, accompanied by old and new labels. The main results were that (a) changes in the environmental context between study and test (in this case, different university rooms) affected recognition memory

for unfamiliar, but not for familiar faces, and (b) changes in the local context (i.e., the labels attached to the faces) affected recognition for both kinds of stimuli.

Dalton's (1993) study suggests that the prior history of the stimulus material is an important variable in determining whether context effects will occur in recognition. The aim of this study was to investigate the generality of this position, by examining whether context effects in recognition can be found with other types of unfamiliar stimuli, such as nonwords. Many studies have demonstrated context effects with unfamiliar verbal material (nonwords) using recall-based memory tasks (Dulsky, 1935; Jensen, Harris, & Anderson, 1971; S. Smith & Guthrie, 1921; Weiss & Margolius, 1954), but to our knowledge no published studies have investigated context effects with unfamiliar verbal material using recognition memory tasks (see S. M. Smith, 1988, for a review).

The testing of the generality of Dalton's (1993) claim takes on added theoretical significance when one realizes that the context-dependent recognition of unfamiliar material can be predicted by only certain classes of global memory models. Although it was not our original intention to discriminate between different global memory models, we provide, in our discussion, an indication of which types of global memory models can and cannot account for this effect.

In the present experiments, changes in environmental contexts were manipulated by arranging two different rooms such that stimulation of visual and olfactory senses differed. Before attempting to extend Dalton's (1993) results from unfamiliar faces to unfamiliar verbal material, we decided to try to replicate the finding of contextual effects on recognition memory discrimination for unfamiliar faces. Context effects on recognition memory discrimination are reportedly difficult to detect, and therefore a replication of Dalton's finding would further support the view that the previous history of the target material is a relevant factor in obtaining reliable contextual effects on recognition discrimination.

Experiment 1

In Experiment 1, we aimed to replicate the effect of changes of environmental contexts between study and test on recognition memory discrimination for unfamiliar faces. We used a similar procedure to that used by Dalton (1993). Because our aim was to assess environmental context effects on recognition memory discrimination, Experiment 1 differed from Dalton's study in that we did not manipulate the effect of changes in local context on recognition memory for unfamiliar stimuli. Moreover, to have a more precise measurement of the effect of context manipulation than Dalton had, we used 32 target items in the same study–test context and 32 target items in the different study–test context condition, compared with the 12 target items used by Dalton in each study–test condition. Finally, as in Dalton's study, we presented each stimulus with an attached label. Dalton used at test some of the local labels presented at study. However, there is a problem with this arrangement because the repeated labels occurred only for the same context

conditions but not for the different context conditions. We removed this potential confound by pairing all the faces at test with new labels, thereby allowing a clear assessment of the effect of environmental context changes on recognition memory for unfamiliar faces.

Method

Participants. Twenty-four students and staff members of the University of Essex took part in the experiment.

Materials. Ninety-six unfamiliar male faces were created using Mac-a-Mug (1986). These were randomly assigned into six sets (1, 2, 3, 4, 5, and 6) of 16 faces each to have items studied and tested in the same environment, in a different environment, or being used as foils. The random assignment differed for each tested participant. A list of occupations was created so that each face was presented with an occupational label both at study and test. The labels were displayed just below each face. Figure 1 illustrates an example of the stimuli used.

Two different distinctive study–test environments were used. Room A was a large office (2.8 m × 5.4 m) with three desks, various chairs, a cupboard, shelves with books, colorful posters, and a large window situated in the laboratory of the Department of Psychology on the third floor. On one desk, there was a Macintosh Color Classic computer used to present the stimuli, various pictures, some colorful paper, a bottle, and a telephone. The screen background used for stimuli presentation in Room A was bright. During the presentation of the stimuli both at study and at test the room was brightly lit and scented with a distinctive smell of potpourri air freshener. Participants sat comfortably while performing the task. Room B was a small cubicle (2.4 m × 2.8 m) with two desks and two chairs, situated in the laboratory of the Department of Psychology on the ground floor. On one desk there was a Macintosh Color Classic computer used to present the stimuli. The screen background used for stimuli presentation in Room B was dark. During the presentation of the stimuli both at study and at test the room was dimly lit and scented with a pine fragrance. Participants sat comfortably while performing the task. All the faces at test were re-paired with a new, previously unseen occupational label.

Procedure. At study, participants were told that the experiment was concerned with the effect of environmental factors on the rating of male faces and that each face would be presented for 5 s with an occupational label. Participants were asked to judge how well the person seemed to "match" the occupation using a 5-point scale (1 = *poor match* to 5 = *good match*). Participants were told to state their rating out loud during the items' presentation. This cover story was used to induce incidental learning of the study material. No attempt was made to record the participants' ratings. Participants were asked to perform the ratings in one room, and then they were taken to the other room to perform the ratings on the second set of stimuli. The experimenters were different in each room. Participants rated 32 unfamiliar faces in Room A and 32 unfamiliar faces in Room B. The faces seen in Room A were from Sets 1 and 4 presented in a random order, whereas in Room B the faces were from Sets 2 and 5 presented in a random order.

Between study and test there was an interval of 10 min. During this interval participants were taken to a waiting room where newspapers and magazines were available, and they were told that the experimenter had to prepare some new material for some different unspecified tasks. At the end of the retention interval, participants were taken to one of the two rooms for the first part of an unexpected recognition memory test on only half of the target items presented at study. At the end of this testing, participants were taken to the remaining room where recognition memory was

Figure 1. A typical face with an occupational label used in Experiments 1 and 2.

assessed for the remaining items not tested in the previous room. There were four study–test room orders to completely counterbalance contexts between study and test (i.e., ABAB, BABA, ABBA, BAAB), and 6 participants were assigned to each of the four combinations. In the recognition test, participants were presented in each room with 16 targets that were studied in the same room, 16 targets that were studied in the different room, and 16 new items that were previously unstudied. These last faces were taken from Sets 3 and 6.

In the recognition memory test, each face was presented individually with an attached occupational label. Participants had to click on the "old" button on the screen if they had seen the face at study in either of the two rooms or the "new" button if they thought that they had not seen the face earlier in the experiment. Instructions specified that the labels accompanying the faces could be different from the original presentation and that recognition decisions had to be made on the basis of the face alone. Test lists were randomly arranged for every participant. No time constraints were imposed on this task. Each participant was tested individually and was debriefed about the real purpose of the study. The overall session lasted about 30 min.

Results and Discussion

Table 1 shows the percentage of hits, false alarms, d' and A' discrimination scores (see Donaldson, 1992) for unfamiliar faces in Experiment 1. Statistical analyses were carried out using d' scores, calculated according to the prescriptions set out by Snodgrass and Corwin (1988), and A' scores. The results of the analyses based on d' and A' scores were comparable in all of the experiments described in this study. Therefore, in this and in the following exper-

Table 1

Experiment 1: Percentages of Hits, False Alarms (FAs) Relative to Each Test Context, and d' and A' Scores According to Study and Test Contexts

Context	Test context	
	Room A	Room B
	Hits	
Study		
Room A	.62 (.05)	.52 (.04)
Room B	.54 (.04)	.58 (.04)
	FA	
Test		
Room A	.16 (.03)	
Room B	.15 (.02)	
	d'	
Study		
Room A	1.33 (.12)	1.10 (.09)
Room B	1.08 (.11)	1.25 (.12)
	A'	
Study		
Room A	.821 (.018)	.791 (.015)
Room B	.780 (.019)	.806 (.021)

Note. Standard errors are in parentheses.

iments, we only report the analyses based on *A'* scores. An *A'* score of 1 indicates perfect discrimination of targets from distractors; a score of .50 indicates that participants could not distinguish targets from distractors.

A 2 (study room) × 2 (test room) within-subjects analysis of variance (ANOVA) on *A'* scores showed neither a significant main effect of study room, nor a significant main effect of test room (*Fs* < 1), suggesting that study and text contexts did not independently contribute to recognition memory performance. The critical interaction between study and test contexts was significant, *F*(1, 23) = 7.10, *MSE* = .003, *p* < .02, suggesting that recognition discrimination was affected by the mismatching of study–test contexts. Overall, the performance in matched study–test contexts (mean *A'* = 0.814) was significantly greater than the mismatched study–test contexts (mean *A'* = 0.786).

In Experiment 1, we replicated the environmental context effect in the recognition memory discrimination for unfamiliar faces obtained by Dalton (1993). The effect size induced by environmental context changes in the present experiment (*d* = .54) was slightly less than that obtained in Dalton's Experiment 1 (i.e., *d* = .73). It thus appears that, given the results of Experiment 1 and those obtained by Dalton, changes in environmental context between study and test impair recognition memory discrimination for unfamiliar faces.

The aim of the second experiment was to extend this finding to unfamiliar verbal materials (i.e., to nonwords).

Experiment 2

Experiment 2 used the same methodology as in the previous experiment. The target items were nonwords

instead of unfamiliar faces. Each nonword was presented with an occupational label. At test, participants were required to perform a recognition memory task based solely on the nonwords. All the labels at test were new.

Method

Participants. Twenty-four students and staff members of the University of Essex took part in the experiment. None had taken part in the previous experiment.

Material, procedure, and design. Experiment 2 used the same procedure, design, and environments as Experiment 1. The target material was 96 English monosyllabic nonwords, ranging from four to six letters in length, which were selected from the material created by McCann and Besner (1987). Each nonword was presented at study with an occupational label. At test, all items were paired with new labels not previously experienced at study. At study, participants were told that a series of invented names with an occupational label would be presented at a rate of 5 s per item. Their task was to judge how well each invented name seemed to match the occupation using a 5-point scale (1 = *poor match* to 5 = *good match*). Participants were asked to state their rating judgment out loud during the presentation of the invented name.

At test, it was specified that the labels accompanying the invented names could be different from those used in the original presentation and that recognition decisions should be made on the basis of the invented names alone.

Results and Discussion

Table 2 shows the percentage of hits, false alarms, *d'* and *A'* discrimination scores for the nonwords in the different conditions of Experiment 2. A 2 (study room) × 2 (test room) within-subjects ANOVA on *A'* scores showed neither a significant main effect of study room, nor a significant

Table 2

Experiment 2: Percentages of Hits, False Alarms (FAs) Relative to Each Test Context, and d' and A' Scores According to Study and Test Contexts

Context	Test context	
	Room A	Room B
	Hits	
Study		
Room A	.60 (.03)	.54 (.03)
Room B	.52 (.03)	.60 (.03)
	FA	
Test		
Room A	.25 (.03)	
Room B	.22 (.03)	
	d'	
Study		
Room A	.93 (.10)	.86 (.10)
Room B	.78 (.14)	1.06 (.10)
	A'	
Study		
Room A	.757 (.019)	.741 (.021)
Room B	.709 (.031)	.780 (.017)

Note. Standard errors are in parentheses.

main effect of test room ($Fs < 1.03$), suggesting that study and text contexts did not independently contribute to recognition memory performance. The critical interaction between study and test contexts was significant, $F(1, 23) = 8.15$, $MSE = .006$, $p < .01$, suggesting that recognition discrimination was affected by the mismatch of study–test contexts. Overall, the performance in matched study–test contexts (mean $A' = .769$) was significantly greater than the mismatched study–test contexts (mean $A' = .725$).

The results of Experiment 2 replicated and extended the results of Experiment 1 with unfamiliar verbal material. Overall, the effect size due to environmental context manipulation at study–test was $d = .59$ in the present experiment. This is comparable to $d = .54$ obtained in Experiment 1. It thus seems that changes in environmental context between study and test affect recognition memory for unfamiliar stimuli.

Experiment 3

Both Experiments 1 and 2 showed a significant effect of changes in environmental context between study and test on recognition memory discrimination for unfamiliar stimuli. However, it is uncertain whether these results were due to the unfamiliarity of the target material or to the nature of the learning procedure. In the learning phase, participants had to rate the matching of a face or a name (i.e., a nonword) to an occupation. This incidental learning task may have promoted more extensive processing of the environmental context than is usually induced in standard verbal memory tasks. As a consequence, it could be argued that changes in context between study and test may also affect recognition discrimination for familiar stimuli when the occupational rating task is used. Some empirical findings suggest that this may not be the case, at least in the case of familiarized faces. In fact, Dalton (1993) showed that rating the matching between familiarized faces and occupational label did not produce a significant effect of environmental context on recognition discrimination.

Nevertheless, we intended for Experiment 3 to assess the possibility that the rating methodology used in the previous experiment may have induced an environmental context effect on recognition discrimination for unfamiliar verbal material. To this aim, we used the same methodology used in Experiment 2, but the target items were words instead of nonwords. If the rating procedure was responsible for the context effect observed using target nonwords, then it should be possible to replicate the same effect using words. However, if the rating procedure was not instrumental in inducing a context effect on the recognition discrimination of nonwords, then a context effect should not be present when words are used as targets. In the final experiment, each word was associated with an occupational label. At test, participants were required to perform a recognition memory task based solely on the words. Again, all of the labels at test were new.

Method

Participants. Twenty-four students and staff members of the University of Essex took part in the experiment. None had taken part in the previous experiments.

Material, procedure, and design. Experiment 3 used the same procedure, design, and environments as Experiment 2. The target material was 96 English words, ranging from four to seven letters in length, and their frequency of occurrence ranged from 65 to 100 occurrences per million (Kučera & Francis, 1967).

Results and Discussion

Table 3 shows the percentage of hits, false alarms, d' and A' discrimination scores for the words in the different conditions of Experiment 3. A 2 (study room) $\times$ 2 (test room) within-subjects ANOVA on A' scores showed neither a significant main effect of study room, $F(1, 23) = 2.12$, $MSE = .001$, $p > .10$, nor a significant main effect of test room ($F < 1$), suggesting that study and text contexts did not independently contribute to recognition memory performance. The critical interaction between study and test contexts also was nonsignificant ($F < 1$), suggesting that recognition discrimination was not affected by the mismatch of study–test contexts. Overall, the performance in matched study–test contexts (mean $A' = .871$) was not significantly different from the mismatched study–test contexts (mean $A' = .866$).

The results of Experiment 3 showed that environmental context manipulations did not affect recognition memory discrimination for target words. Given an expected size of the effect of the environmental context manipulation of $d = .59$, as estimated from Experiment 2, the present experiment

Table 3

Experiment 3: Percentages of Hits, False Alarms (FAs) Relative to Each Test Context, and d' and A' Scores According to Study and Test Contexts

Context	Test context	
	Room A	Room B
	Hits	
Study		
Room A	.73 (.04)	.69 (.03)
Room B	.70 (.03)	.68 (.03)
	FA	
Test		
Room A	.12 (.02)	
Room B	.10 (.01)	
	d'	
Study		
Room A	1.81 (.12)	1.73 (.14)
Room B	1.71 (.13)	1.73 (.14)
	A'	
Study		
Room A	.879 (.016)	.869 (.016)
Room B	.863 (.021)	.864 (.017)

Note. Standard errors are in parentheses.

had a power of .82 to detect a significant effect of contextual changes on recognition discrimination. It thus seems that changes in environmental context between study and test do not affect recognition memory discrimination for words when an incidental matching learning task is used at study.

This conclusion is also supported by a comparison of the context effect scores obtained in the last two experiments. The effects of context, calculated in A' scores, were .044 ($SE = .015$) versus .005 ($SE = .008$) in Experiments 2 and 3, respectively. A t test on these scores indicated the presence of a larger context effect on recognition discrimination in Experiment 2, $t(46) = 2.28$, $p < .05$. This result further strengthens the view that the context effect obtained in Experiment 2, and by generalization in Experiment 1, was due to the nature of the stimuli (i.e., unfamiliar pictorial or verbal material) and not to the nature of the experimental methodology.

General Discussion

To summarize, the aim of the present study was to assess the effect of changes in the environmental context between study and test on recognition memory discrimination. Unfamiliar faces were used to replicate previous results using similar material (i.e., Dalton, 1993). Unfamiliar verbal stimuli were also used to extend these findings and test the general prediction that the prior history of the stimulus material is a relevant variable affecting the occurrence of context effects on recognition tasks. In Experiment 1, we replicated Dalton's original findings that context effects in recognition memory discrimination are detectable when unfamiliar faces are used as targets. In Experiment 2, we extended the effect of environmental context effects on recognition memory discrimination to unfamiliar verbal material (i.e., nonwords). Finally, Experiment 3 showed that when familiar verbal material was used as the target material, there were no significant effects of environmental context changes on recognition memory discrimination.

These results challenge the classical dichotomy whereby free recall seems affected by environmental changes between study and test, whereas recognition memory discrimination is mainly unaffected by this manipulation: This classic account is too simplistic. Accordingly, comprehensive theories of contextual effects in memory have to offer an explanation of the above finding.

In the present study, we did not intend to provide empirical tests of current theories of context effects in memory; therefore, our results cannot be taken as evidence in favor of a specific theoretical framework. Nevertheless, the outshining hypothesis may accommodate the present results if it is assumed that unfamiliar stimuli were not good copy-cues at test. According to this interpretation, the weak environmental contextual cues associated with the target stimuli at study were outshone at test by the very strong copy-cue for familiar items, but were not completely outshone at test by the less strong copy-cue for unfamiliar items. As a consequence, environmental context effects were detected when unfamiliar but not familiar stimuli were used as targets. This version of the outshining hypothesis is compatible with a two-process theory of recognition memory

(e.g., Jacoby, 1991; Mandler, 1980) if one assumes (a) that familiarity-based processes are less effective in supporting recognition of unfamiliar compared to familiar stimuli and (b) that retrieval processes may help recognition memory by using contextual elements as retrieval cues for targets.

A variant of the above suggestion was proposed by Dalton (1993). She suggested that the memory trace for unfamiliar items may contain contextual attributes but the memory trace for familiar items may not (or the contribution of the experimental context to the memory trace may be less strong). This may be because an unfamiliar item is associated with only a specific environmental context (the experimental context at study), whereas a familiar item is associated with multiple environmental contexts (only one of which is the experimental context at study). According to this view, the presence of the studied context with a target item at test provides a more specific cue for unfamiliar stimuli than for familiar stimuli, because the contextual attributes stored with a target item are more likely to be present in the same than in a different test context, and the effectiveness of a more specific cue is likely to be greater than the effectiveness of a less specific cue.

In addition to cue specificity, the contextual cues associated with unfamiliar material may act differently from the contextual cues associated with familiar material. According to this view, the environment may act more like an interactive context in facilitating recognition memory discrimination for unfamiliar items, but it may act more like an independent context for familiar items. The terms *interactive* and *independent contexts* are taken from the nomenclature adopted by Baddeley (1982). Interactive encoding occurs when the context changes the meaning of a stimulus. For example, the words *strawberry* and *traffic* might act as an interactive context when associated with the polysemous target word *jam*, because the associated word may affect the meaning attributed to the stimulus. A change in the interactive context from "strawberry jam" at study to "traffic jam" at test may reduce recognition memory discrimination considerably because the meaning elicited at test does not match the meaning elicited at encoding (Light & Carter-Sobell, 1970). A significant reduction in recognition memory discrimination can also occur following a more subtle change in meaning, from one semantic aspect of a stimulus to another (e.g., Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974; Tulving & Thomson, 1973). By contrast, examples of independent contexts are the physiological state, the internal mood state, or the environment in which a stimulus is experienced.

Changes in independent contexts have been thought not to change the meaning in which a stimulus is experienced and have traditionally not given rise to a significant reduction in recognition memory discrimination for familiar stimuli (e.g., Experiment 3; Dalton, 1993; Murnane & Phelps, 1994). It is assumed that the meanings of familiar stimuli are relatively stable with respect to changes in independent contexts, at least partly due to the prior history of association of the meaning of the stimulus within many different independent contexts. However, it is reasonable to assume that the meanings of unfamiliar stimuli are less stable, having been

experienced only twice: once at study and once at test. It follows that the meaning of unfamiliar stimuli may be more vulnerable to changes in context, and even changes in the physiological state, the internal mood state, or the environment may act as weak interactive contexts for unfamiliar stimuli. Therefore, it is plausible to suggest that the reinstatement of the original study context in which an unfamiliar item was first experienced cues the original meaning of the unfamiliar target, thus leading to the recognition of the target. This would result in significant changes in recognition memory discrimination for unfamiliar stimuli. However, no significant changes in recognition memory should occur for familiar items, because the environmental study context is unlikely to affect their meaning.

The distinction between interactive and independent cues can be illustrated by the following example. Consider that the meaning of the unfamiliar nonword *snocks* is unstable, giving rise to associations of both "snacks" and "socks." In the small dark cubicle, a participant may see the nonword, *snocks* and be reminded of a pair of "smelly socks." However, in the light, colorful room, a participant may see the same nonword, *snocks,* and be reminded of some "light snacks." In this example, a different meaning of *snocks* is associated with a particular environment. Therefore, if the environmental context is the same at study and test, then recognition will be facilitated because the meaning of the target item at test may more closely resemble the meaning induced at study. By contrast, the familiar word, *golf,* may maintain a stable meaning across both environments, providing no contextual cueing advantage based on the compatability of meaning induced between same and different study–test environments.

The importance of our results is heightened by a consideration of how well global memory models such as the theory of distributed associative memory (TODAM; Murdock, 1982), search of associative memory (SAM; Gillund & Shiffrin, 1984), or MINERVA 2 (Hintzman, 1988) can accommodate the combined effects of familiarity and environmental context changes on recognition memory tasks. Global memory models assume that recognition involves matching the information available in a test item with all the stored information in memory. The information stored in memory contains both to-be-remembered items and contextual information (including the environmental context associated with each item). Our results are salient because they differ from the predictions of Murnane and Phelps (1994), who scrutinized various global matching theories of memory and concluded that context effects in recognition memory discrimination would be absent or very small in the type of design used in the present study. In the final section of the General Discussion, we outline three ways in which global memory models may possibly account for our results.

Global memory models may account for our results by differentially modeling the associations between stimuli and context for familiar and unfamiliar stimuli. We outlined above how the contextual information associated with unfamiliar stimuli may be more complete, more specific, or

more interactive than the contextual information associated with familiar stimuli. Clark and Gronlund (1996) have shown that global memory models can account for the disruptive effect to recognition memory when studied pairs of verbal items are re-paired at test. In these experiments, pairs of items such as A–B, C–D, and E–F are typically studied. At test, the same pair (e.g., A–B) or repaired pairs (e.g., E–D) may be presented. Participants have to recognize if the second element of a pair had been presented previously. The usual finding, which is accounted for by global memory models (for details, see Clark & Gronlund, 1996), is that B items, in A–B test pairs, are better recognized than D items in E–D pairs. For our explanation, the change in environmental context between study and test is like re-pairing at test two items presented in different pairs at study. If the contextual information associated with unfamiliar stimuli was more complete, more specific, or more interactive than the contextual information associated with familiar stimuli, then any disruption caused by the repairing of the context and the target stimuli will be greater for unfamiliar stimuli compared with familiar stimuli.

Alternatively, the analysis of context effects on global memory models provided by Murnane and Phelps (1994) may be extended to account for our results. We present below two alternatives of this account. In line with Murnane and Phelps (1994), both alternatives require that there is a multiplicative relationship between the context strengths and the item strengths. One version accounts for our results by assuming that the increase in activation associated with the presentation of an item (the difference between the activation of target and distractor stimuli) is greater for unfamiliar stimuli than for familiar stimuli. This can be modeled with a single continuum of item strength for both familiar and unfamiliar stimuli either by assuming that the increase in item strength caused by the presentation at study of an unfamiliar stimulus is greater than the increase in item strength caused by the presentation of a familiar stimulus, or by assuming that the activation functions combining item and context strengths are negatively accelerating and diverging, or both. The second alternative accounts for our results by proposing that familiar and unfamiliar stimuli may be qualitatively different. This final account assumes that an additional parameter is required to account for our results.

In line with the analysis by Murnane and Phelps (1994), let us assume that items stored in memory may vary in item strength (or level of activation), and also assume that the contexts stored in memory may vary in contextual specificity (or increased level of activation associated with the context). We can consider that successful discrimination of targets from distractors occurs when the overall activation induced by targets is larger than the activation induced by distractors. As Murnane and Phelps (1994) have shown, it is possible to examine the impact of changes in environmental context on recognition memory discrimination in various paradigms used to manipulate the effect of contextual changes, when context is considered as a part of a test cue. Predictions can be obtained assuming that item and context

activations can be high if the stimuli and contextual cues are the same at study and test, and low if the stimuli and contextual cues are different at study and test, and that the overall activation obtained with a tested cue is obtained as a function of both the levels of item and context activations. Because in the present experiments we used a completely within-subjects manipulation of contexts in which the same contexts were experienced by participants during learning and test, we concentrate on the so-called AB–A paradigm (see Murnane & Phelps, 1993, 1994, 1995, for a detailed discussion of the predictions on context-dependent recognition discrimination for this paradigm and for the description–derivation of the formulas used to calculate global activations in same and different study–test context conditions).

In line with Murnane and Phelps (1994), the components of the global memory match that provide the differential contributions of same and different study–test contexts on global activation of targets are given by the following: $A_{\text{same}} = f(I_{\text{H}}, C_{\text{H}}) + f(I_{\text{L}}, C_{\text{L}})$, for items studied and tested in the same environment, and $A_{\text{different}} = f(I_{\text{H}}, C_{\text{L}}) + f(I_{\text{L}}, C_{\text{H}})$, for items studied and tested in different environments, where f is either a linear or a nonlinear strictly increasing function relating item strength to context strength, I and C indicate item and context strength, and Subscripts H and L indicate high and low activation levels, respectively.

Context effects on recognition memory discrimination are present if $A_{\text{same}} > A_{\text{different}}$ or equivalently if $[f(I_{\text{H}}, C_{\text{H}}) + f(I_{\text{L}}, C_{\text{L}})] > [f(I_{\text{H}}, C_{\text{L}}) + f(I_{\text{L}}, C_{\text{H}})]$.[2] This situation can occur only if the strictly increasing function linking the item strength and the context strength parameters allows an interactive contribution of these parameters to global activation. This can be seen by examining Figure 2. Figure 2 considers how the overall activation of a particular item associated with a particular context (the y-axis) may change with changes in item strength (the x-axis) and context strength (the different curves or lines). Figure 2A shows the case where the activation function combining item and context strength parameters is additive. In this case, the high and low context strength curves for items of different item strengths are parallel. This means that the advantage of cuing in the same environmental context as that studied (i.e., the advantage of C_{H} over C_{L}) is independent of item strength and so will lead to an increase in the overall activation of a target item (I_{H}), which is exactly identical to the increase in the overall activation of a nontarget item (I_{L}). Parallel curves similar to these do not give rise to context effects in recognition memory discrimination because the difference between the activation induced by targets and the activation induced by nontargets remains constant in all contexts. In one version of TODAM, the activation function conforms to an additive combination of item and context strength parameters and therefore must predict that no context effects in recognition memory discrimination should occur (for a discussion, see Murnane & Phelps, 1994, 1995). The presence of a reliable context effect in recognition memory discrimination in the present study and in Dalton (1993) is at variance with this version of TODAM. However, this claim is only correct under the assumption that item and context information are represented as separate subcomponents of

the vector representation used in TODAM. It would be a straightforward extension of TODAM to represent association between item and context information using the same technique of convolving an item and context vector. In this extension, there would not be an additive contribution of item and context strength parameters, and therefore this extension of TODAM may successfully model a reliable context effect in recognition memory discrimination.

Figure 2B shows the case where the overall activation function combining item strength and context strength is multiplicative. In this case, the divergent curves show that high item strength and high context strength lead to exceptionally high overall levels of activation, and low item strength and low context strength lead to exceptionally low overall levels of activation. For divergent curves, the overall advantage of cuing in the same study–test environmental context (i.e., the advantage of C_{H} over C_{L}) is greater for items with high item strengths (targets) than for items with low item strengths (nontargets). Divergent curves similar to these are therefore required for context effects to occur.

One way in which context effects may be predicted for recognition of unfamiliar but not familiar material is if the item strength of a stimulus is considered to be a continuum of familiarity, ranging from unseen unfamiliar stimuli (least item strength), just seen unfamiliar stimuli, unseen familiar stimuli, and just seen familiar stimuli (greatest item strength). That is, we need to assume that unfamiliar distractors possess, in general, a relatively reduced item strength, and that familiar distractors possess, in general, a relatively increased level of item strength. Critically, we also need to assume that the increase in activation through a single presentation at study is greater for unfamiliar stimuli than for familiar stimuli. This situation is represented in Figure 3. There is some evidence in favor of this critical assumption. In Dalton's (1993) Experiment 1, participants were better at discriminating between unfamiliar target faces and unfamiliar distractors than discriminating between familiar target faces and familiar distractors. Dalton observed (Experiment 1) a hit rate for unfamiliar faces in the same study–test context of .62, and a false-alarm rate for unfamiliar faces of .26 (i.e., a difference of .36), whereas the hit rate for familiarized faces in the same study–test context was .93 and the false-alarm rate for familiarized faces was .71 (i.e., a difference of .22). The differential activation contribution of environmental changes between study and test on recog-

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[2] Predictions on the activation of new items are not relevant to the prediction of context effects on memory discrimination in the AB–A paradigm. This is because new items are always tested in a context that was previously experienced at study, and so there is only a unique level of context activation to be applied to estimate memory activation for each distractor. Predictions on the activation of new items are, instead, relevant on the prediction of context effects on memory discrimination in the AB–X paradigm. In this paradigm participants are presented with old and new items in new and already experienced-at-learning contexts. This design was not implemented in the present study. For discussions on environmental context effects on recognition memory in this paradigm, see Murnane and Phelps (1993, 1994, 1995).
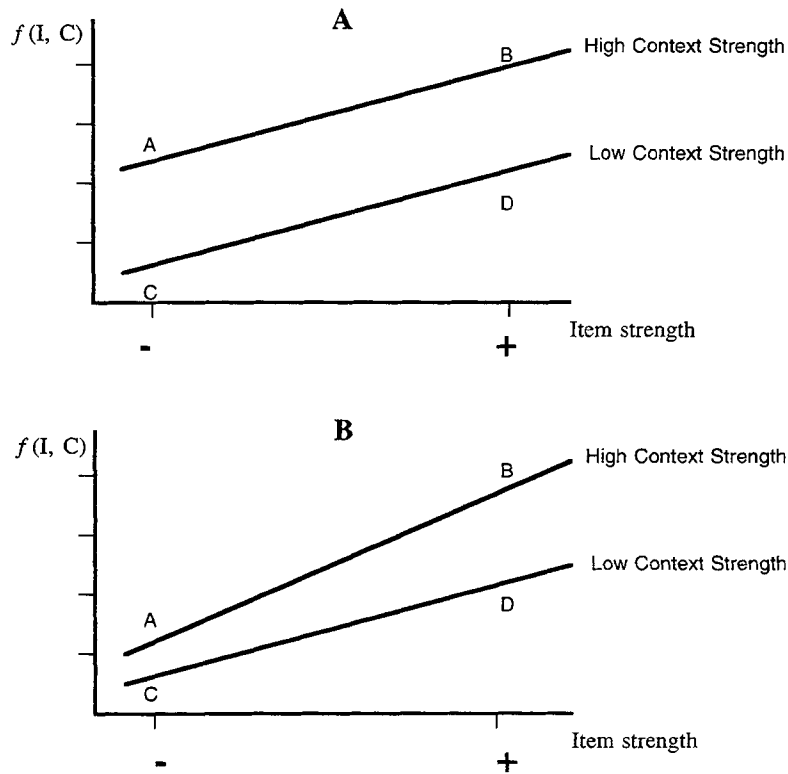
Figure 2. Activation of individual items as item strength increases. I = item, C = context. A: the overall activations using noninteractive, parallel activation functions. B: the activations using diverging activation functions that interactively combine item strength and context strength.

nition memory discrimination is given by the following: A_{same} − $A_{different}$ = $f(I_H, C_H)$ + $f(I_L, C_L)$ − $f(I_H, C_L)$ − $f(I_L, C_H)$.

We can determine that when target items are familiar, the differential contribution to activation due to context effects is given by (adding the relevant levels of activation corresponding to the letters in Figure 3) the following: A_{same} − $A_{different}$ = F + G − H − E.

If the difference between the high and low item strengths and the difference between the high and low context strengths are small, as illustrated, then the overall sum will be positive, but possibly not significantly greater than zero. In line with this prediction, small but nonsignificant advantages in recognition memory discrimination are observed for familiar stimuli when the same context is experienced at study and test in AB–A designs (e.g., Experiment 3; Dalton, 1993; Murnane & Phelps, 1994).

If target items are unfamiliar, then the differential contribution to activation due to context effects is given by (adding the relevant levels of activation corresponding to the letters in Figure 3) the following: A_{same} − $A_{different}$ = B + C − D − A.

The difference between the high and low item strengths and the difference between the high and low context strengths are greater for unfamiliar than for familiar items and so the overall sum will be positive and more likely to be significantly greater than zero. In line with this prediction,

significant context-dependent recognition discrimination effects in AB–A designs are observed for unfamiliar stimuli (see Experiments 1 and 2; Dalton, 1993). As Figure 3A illustrates, the data may be most easily modeled by proposing negatively accelerated activation functions that diverge (such as those used by SAM), because this type of function naturally produces a larger increase in activation following study presentation when the item strength is lower (unfamiliar items), and a smaller increase in activation following study presentation when the item strength is higher (familiar items). Models proposing linearly increasing (see Figure 3B) or positively accelerated (see Figure 3C) activation functions (such as MINERVA 2) can model these data only if the increase in item strength of an unfamiliar stimulus associated with its presentation was assumed to be very much greater than the increase in item strength of a familiar stimulus associated with its presentation.

Although Dalton's (1993) data may be accommodated by considering the item strength of a stimulus to be a continuum of familiarity, these models cannot be successfully applied to our data. Recall that the critical assumption required to model Dalton's data was that the increase in activation associated with the single presentation of an unfamiliar item was greater than the increase in activation associated with the single presentation of a familiar item. Contrary to this assumption, we observed that recognition memory discrimi-
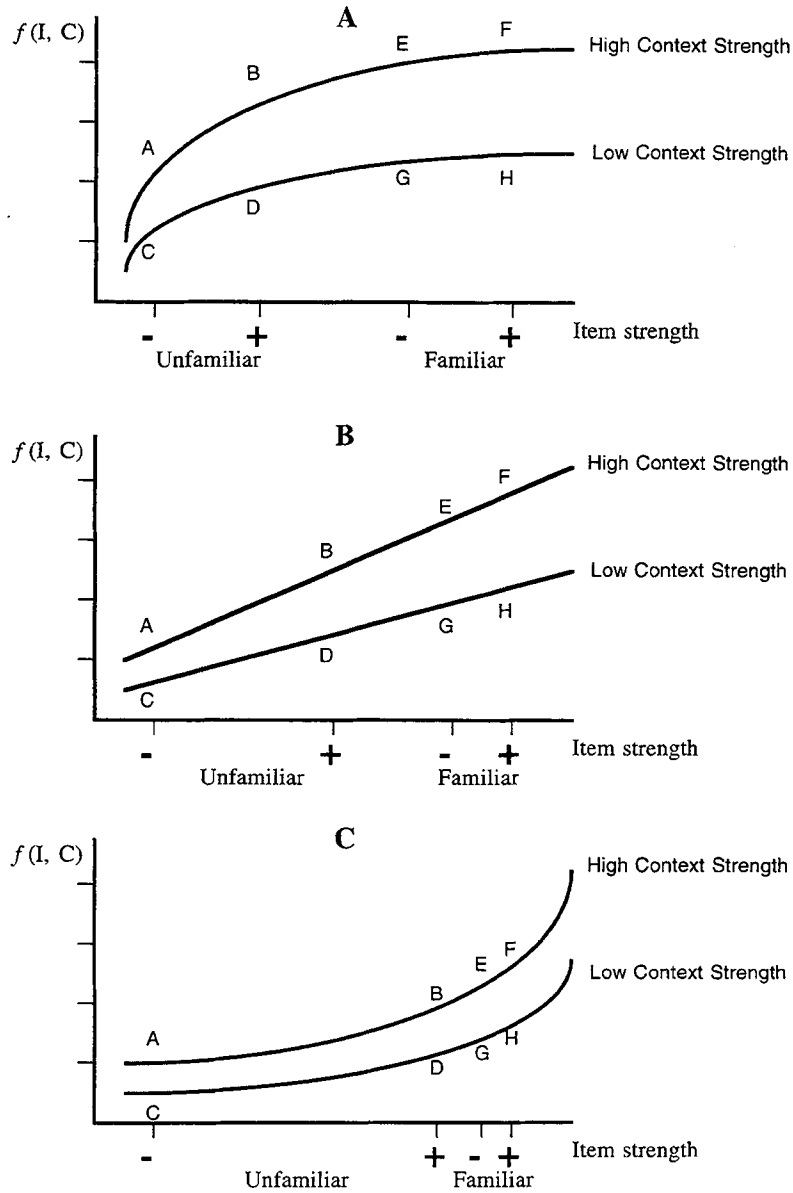
Figure 3. Activation of individual items as item strength increases. I = item, C = context. A: the overall activations using negatively accelerated, diverging activation functions. B: The overall activations using linear, diverging activation functions. C: the overall activations using positively accelerated, diverging activation functions.

nation of unfamiliar (nonword) targets from unfamiliar (nonword) distractors was poorer than recognition memory discrimination of familiar (word) targets from familiar (word) distractors. That is, the difference between hits and false alarms in our experiments was greater for familiar items than for unfamiliar items, because we observed a hit rate for words in the same study–test context of .60 and a false-alarm rate for nonwords of .24 (i.e., a difference of .36), whereas the hit rate for words in the same study–test context was .70 and the false-alarm rate for words was .11 (i.e., a difference of .59). Therefore, it would appear that this

purely familiarity-based explanation of context effects on recognition memory discrimination for unfamiliar items within global memory models may be inadequate.

One way in which our data may be modeled is to consider that unfamiliar and familiar stimuli are qualitatively different, and should be treated accordingly. Memory discrimination of familiar verbal items (words) may be supported by an additional factor, such as stable semantics, which is unavailable to help discriminate the unfamiliar verbal items (nonwords). Figure 4 illustrates how our data may be modeled, using linear or nonlinear strictly increasing activation func-
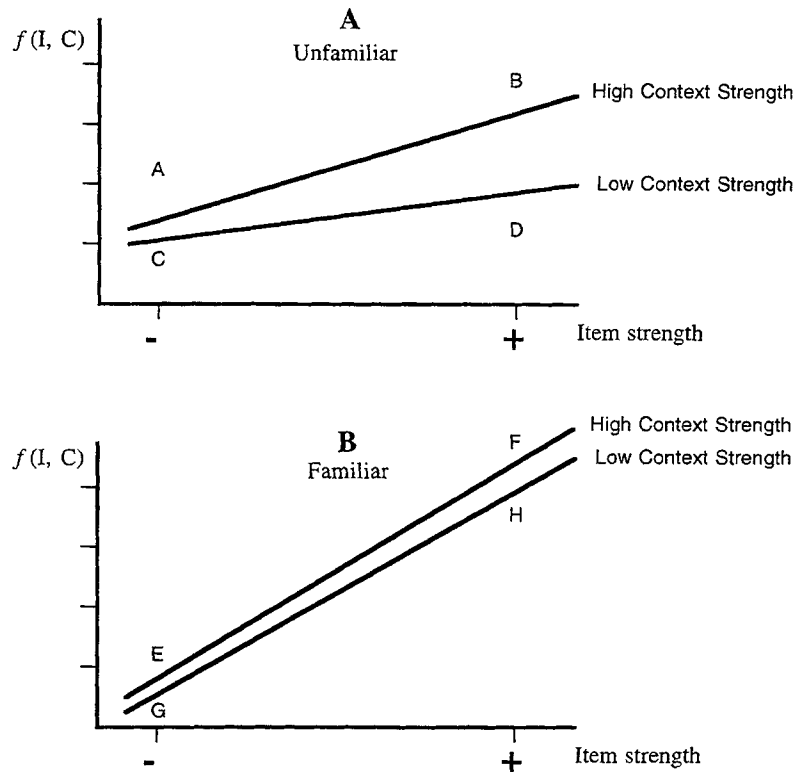
Figure 4. Activation of individual items as item strength increases. I = item, C = context. A: the overall activations for unfamiliar items. B: the overall activations for familiar items.

tions, by assuming that unfamiliar and familiar materials are qualitatively different. The additional parameter associated with the prior knowledge of the stimulus may have been overlooked by previous theorists interested in context effects in recognition memory discrimination (e.g., Murnane & Phelps, 1994). As can be seen, the context effect for unfamiliar stimuli (given by B + C − D − A) is greater than the context effect for familiar stimuli (F + G − H − E), and the increase in activation associated with a presentation of a familiar stimulus is greater than the increase in activation associated with a presentation of an unfamiliar stimulus. Although clearly posthoc, it seems reasonable to assume that the familiarization of faces from unfamiliar to familiar (as it occurred in Dalton, 1993, by repeated exposure of unfamiliar faces, 1 week previously) may be represented on a continuum of increasing item strength, whereas the item strengths of words and nonwords may differ by more than simply the repeated exposure to words compared with nonwords. That is, it seems reasonable that there may be a qualitative difference between words and nonwords (based on, say, stable semantics) that needs to be considered when modeling environmental context effects on recognition memory discrimination.

We have considered some but not all of the available methods for handling our data within global memory models. All of these suggestions are clearly post hoc, and they were given only as possible indications on how current

theories can give an account of the present data. Further evidence is required to discriminate between these theoretical alternatives. It is important, however, to stress that any alternative has to accommodate the empirical finding that environmental contextual effects on recognition memory discrimination seems affected by the characteristics of the stimulus items, such as the familiarity of the stimuli to the participants.

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