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Influences of Temporal Factors on Memory Conjunction Errors

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SUMMARY

Subjects viewed a series of faces presented two at a time for 16 seconds. Following either a 15-minute (Experiment 1) or 24-hour (Experiment 2) retention interval they received a recognition test that included old faces as well as faces constructed by recombining features from simultaneously presented study faces (simultaneous-conjunction condition), faces from successive pairs (near-conjunction condition), and faces that were two pairs apart (far-conjunction condition). In Experiment 1, false alarm rates decreased as the temporal distance between the relevant study faces increased. In Experiment 2, the false alarm rate in the simultaneous-conjunction condition was equal to the hit rate for old faces, and the false alarm rates for the other conditions was much lower. There was no effect of serial position during the study phase on the likelihood that parts of a face would later be miscombined to produce a recognition error in either experiment. The results suggest that witnesses to a crime are more likely to miscombine features of a to-be-remembered stimulus with those of another stimulus that was simultaneously present at the crime scene than with those of a stimulus encountered either earlier or later, especially when the test is delayed. Copyright © 2000 John Wiley & Sons, Ltd.

Many recent articles have reported that when people are asked to recollect prior events they sometimes make ‘memory conjunction errors’; that is, they sometimes miscombine parts of separate experiences, thereby remembering a composite that does not accurately correspond to any single, previously experienced event. As a simple example, subjects who are presented the words HANDSTAND and SHOTGUN during the study phase of a recognition experiment will often subsequently claim that the word HANDGUN has been presented (Reinitz and Demb, 1994; Reinitz *et al*., 1996). Similar miscombinations occur across syllables of non-words (Reinitz *et al*., 1992), across sentences (i.e. the subject of one sentence can be misremembered with the object of another sentence; Reinitz *et al*., 1992), and across faces, i.e. facial features that had occurred across different study faces may be later remembered as having occurred within a single face (Reinitz *et al*., 1992, 1994). Subjects will even sometimes remember landmarks in different cities as having occurred together when the recognition test includes electronically altered images that contain both landmarks (Albert *et al*., in press). Finally, memory conjunction errors are not restricted to a single type of memory test, but rather have been demonstrated in both recall and recognition (Reinitz *et al*., 1992).

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As the previous discussion illustrates, memory conjunction errors are easy to generate in the laboratory, occur across a very wide variety of stimulus types, and are frequently observed on both recall and recognition tests. It is therefore very probable that such miscombinations sometimes underlie real-world memory errors. From an applied perspective it is important to understand the conditions under which people are and are not likely to make these errors. This is particularly true since people tend to be highly confident that their false memories are accurate (Reinitz *et al*., 1992). However, most previous memory conjunction studies have not been concerned with issues that are specially relevant to real-world identification, and so it has been difficult to apply the findings to real-world situations.

The purpose of the current research was to test the influence of temporal factors that might influence the frequency of memory conjunction errors, and that are particularly relevant to issues pertaining to real-world identification. First, experiments that have investigated memory conjunction errors have tended to use very short retention intervals (i.e. 20 minutes or less between the study phase and the subsequent memory test). In real-world situations witnesses are often queried following much longer retention intervals. One goal of the paper was to test the ways in which patterns of memory conjunction errors change as the retention interval increases.

Second, there is controversy regarding whether the relative position of two items on a list influences the likelihood that their features will be miscombined during recollection; more specifically, it is unclear whether items that are close together on a study list are more likely to give rise to memory conjunction errors than are items that are farther apart on the study list. Studies of illusory conjunctions (perceptual miscombinations of features of simultaneously presented items) have generally failed to find an effect of spatial distance or number of intervening items on the likelihood of featural miscombinations (e.g. Treisman and Gelade, 1980; Treisman and Schmidt, 1982). Similar effects have rarely been directly tested in the domain of memory; however, there has been at least one report of a failure to find an effect of number of intervening, sequentially presented, items on miscombination errors (Cohen, 1997). Using a continuous recognition paradigm, Kroll *et al.* (1996) showed subjects a long sequence of two-syllable words (e.g. BARTER, VALLEY); the task was to indicate whenever a word had been previously presented. They found that patients with left-hemisphere damage showed a decrease in false alarms to conjunction words (e.g. BARLEY) when the previously viewed words were separated by five intervening items, rather than one. However, this finding pertained to moderately brain damaged subjects. Moreover, neither study tested for miscombinations of features from simultaneously presented items. The issue of whether study item proximity influences memory conjunction errors is important from an applied perspective, because it helps delineate the conditions under which false recognitions are most probable. The experiments that we report directly test the effects of between-item distance during study on subsequent false alarms to conjunction stimuli.

Finally, it is unclear whether serial position on the study list influences memory conjunction errors. Many studies have demonstrated that beginning and ending items are remembered more often than items occurring in the middle of a list (e.g. Deese and Kaufman, 1957). However, it is unclear whether similar patterns occur with regard to false recognition. The experiments that we report therefore test for serial-position effects. This is interesting from an applied perspective, because it tests whether stimuli that appeared at the beginning or end of events are insulated from

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memory errors. It is also important from a purely practical perspective, because it bears on the importance of including primacy and recency buffer items in memory conjunction experiments.

Our interest in studying the effects of these temporal factors is not purely applied. The effects of retention interval and study-item proximity are relevant to understanding the underlying cognitive mechanisms that give rise to memory conjunction errors. As we describe below, understanding the effects of these factors can help to constrain theoretical explanations for memory conjunction errors. By understanding the mechanisms that give rise to these errors, it will be possible to predict when such errors are likely to occur, and it may be possible to understand how they can be prevented.

What are the mechanisms that give rise to memory conjunction errors? Reinitz and his colleagues have proposed a theory in which recollective experience results from the construction of a transient short-term memory representation for a previously experienced event. Retrieval is proposed to centrally involve a conjunction process in which representations of previously experienced stimulus features are combined on the basis of stored relational information that specifies the way in which the features had been interrelated. Feature representations are proposed to be easier to encode, and more resistant to forgetting, than relational information. Memory conjunction errors are proposed to occur when relational information is poorly encoded, or forgotten, so that features are miscombined during the retrieval process. If this theoretical explanation is correct, then the hit rate ('old' responses to old stimuli) should decrease, and the false alarm rate to conjunction stimuli should increase, with an increasing retention interval, because responding will be increasingly driven by memory for stimulus features in the absence of memory for how those features had been interrelated. The explanation proposed by Reinitz *et al.* does not predict that the distance between study items should influence the likelihood of memory conjunction errors. The reason is that according to the theory, the 'glue' that binds features from a previously studied stimulus together takes the form of relational information. Once that information has been forgotten, features from a single stimulus are no longer bound together, and so are free to miscombine with features of other stimuli regardless of the distance between the studied items that contained those features.

Recently, Chandler and Gargano (1998) provided evidence that a discrimination mechanism plays an important role in memory interference for pictures. They showed that there is more interference between pictorially presented items when they are both presented during the study phase of an experiment than when one of the items is presented during the study phase, and the other is presented during the test phase. They proposed that when a retrieval cue activates more than one memory trace then a discrimination mechanism must be employed by the rememberer in order to properly segregate features from the two memory traces. If the events occurred close to one another in time, then it would be more difficult to discriminate between features, and so there should be a resulting increase in memory errors due to failure of this discrimination mechanism. Conjunction stimuli contain parts of separately experienced stimuli, and so should activate memory traces for multiple stimuli. The framework proposed by Chandler and Gargano therefore predicts that memory conjunction errors should become more likely as the proximity between study items decreases. Chandler and Gargano would also predict increasing conjunction errors as the retention interval increases, because items will lose their temporal discriminabilty

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over time (see also Underwood, 1969). The experiments that we report tested these predictions.

In the experiments reported here, subjects viewed a series of face pairs. Faces were presented one above the other for 16 seconds, and there was a 10-second blank interval before the next face pair was presented. Either 15 minutes (Experiment 1) or 24 hours (Experiment 2) later, subjects received a recognition test that included some old and some recombined (distractor) faces. Distractors were constructed of parts of faces that had occurred within the same pair (simultaneous-conjunction condition), faces that had occurred in successive pairs (near-conjunction condition), or faces that had been separated by an intervening pair (far-conjunction condition). Tests for serial position effects involved determining whether between-face miscombinations were differently likely when the relevant faces occurred at the beginning (or end) of the list relative to when those same faces occurred in the middle of the list. The test of relative position involved a comparison of the three distractor types; if relative position is an important determinant of memory conjunction errors then there should be the most false recognitions in the simultaneous conjunction condition, and the fewest false recognitions in the far conjunction condition.

EXPERIMENT 1

Method

Subjects

Ninety-six Boston University undergraduates participated for credit in their introductory psychology classes. They were tested in 32 groups, each consisting of three subjects.

Stimulus and apparatus

The study and test stimuli were line drawings of faces constructed using a simple identikit. Two types of feature sets were produced, eye–nose and hair–mouth. To form eye–nose feature sets eight pairs of eyes were randomly paired with eight noses. To form hair–mouth feature sets eight hairstyles were randomly paired with eight mouths. The eye–nose feature sets were then completely crossed with the hair–mouth feature sets to produce 64 faces. The ears and shape of the face were held constant for all of the faces. Additional details regarding the stimulus set are provided by Reinitz *et al.* (1992, pp. 5–6). All the faces were presented using Kodak slide projects equipped with Gerbrands tachistoscopic shutters. The faces subtended about 5° of visual angle vertically and about 2.5° horizontally. The projectors and shutters were controlled by an IBM-AT compatible computer and timing was controlled by a clock card in the computer.

Design and procedure

In the study phase of the experiment there were four trials, with each trial consisting of the simultaneous presentation of two faces. The face pairs were presented such that one face appeared directly above the other. A 1° gap separated the top and bottom faces. All face pairs were presented for 16 seconds and were separated by a 10-second inter-stimulus interval. All faces were presented equally often in the top and bottom locations. Subjects were instructed to simply study each and every face shown as best

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they could. In addition, they were informed of the stimulus duration of the face-pairs and were advised to divide their attention evenly between the faces. Subjects were not told that they would receive a face recognition test later in the experiment.

After a 15-minute retention interval in which a filler vocabulary test was administered, subjects received a surprise old/new recognition test that consisted of eight individual faces presented in succession. The stimulus duration for each test face was 10 seconds with a fixed interstimulus interval of 5 seconds. Two of the test faces were old (i.e. they had been presented during the study phase). The remaining six test faces were conjunction faces; that is, they were new faces constructed by recombining feature sets from faces previously studied. Two of these were simultaneous-conjunction faces, which were composites of two faces that were presented together as a pair at study; two were near-conjunction faces, which were composites of two faces that occurred in adjacent pairs at study; and two were far-conjunction faces, which were composites of faces that belonged to study pairs that had been separated by an intervening face-pair. One of these was constructed by recombining features from faces in the first and third pairs and the other was constructed by recombining features from faces in the second and fourth pairs. Old faces were drawn equally often from all four serial positions in the study phase, and simultaneous-conjunction faces were constructed equally often from all four study pair serial positions. Near-conjunction faces were constructed equally often by combining features from serial positions 1 and 2, 2 and 3, and 3 and 4 from the study phase. Different randomly chosen study and test faces were used for different subject groups, with the constraint that for each group that received specific old test faces in the first and fourth serial positions, and simultaneous-conjunction faces from the middle positions, there was a second group that received the identical test faces in the identical test order, but who had the study order shuffled so that the old faces appeared in the middle serial positions, and the simultaneous-conjunction items appeared at the end positions. Over all test trials, the feature sets used in each test condition occurred equally often in all four of the study phase serial positions. Subjects responded to each face by circling 'old' on their response sheet if they had viewed it during the study phase and 'new' if they had not. They were told to respond that a face was old only if they were sure that the face was exactly the same as a face that they had seen during the study phase.

The test condition order and the assignment of feature sets to test conditions were completely random for each group, with the constraint that each test stimulus appeared in every test condition equally often. Across groups, any given feature set occurred in a variety of test conditions, and there was no systematic relation between study and test stimuli.

Results and discussion

The mean frequencies of 'old' responses in the various test conditions are shown in Figure 1. The error bars in the figure show the 95% within-subject confidence intervals around the means (Loftus and Masson, 1994). These confidence intervals have two useful properties: first, they are related by a constant factor to the standard error of the difference between two means, and therefore provide a clear picture of the underlying pattern of population means that are being sampled in the experiment; and second, they provide a direct indication of the statistical power of the experiment, because the size of the confidence intervals decreases as power increases. As a result of

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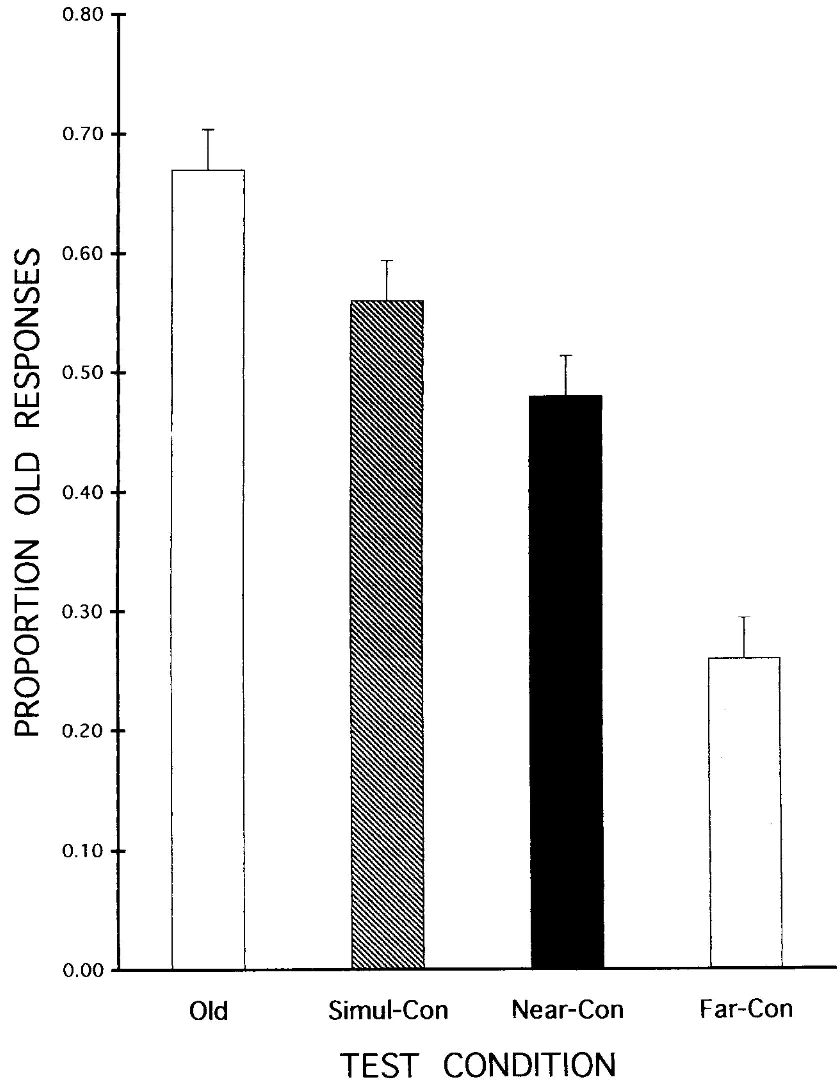

Figure 1. Experiment 1 results: Proportion of 'old' responses for each of the four test conditions following a 15-minute delay. The error bars show the 95% within-subjects confidence intervals (Loftus and Masson, 1994). Simul-Con, Near-Con, and Far-Con refer to the simultaneous-conjunction, near-conjunction, and far-conjunction conditions, respectively

the first property, it is possible to tell whether two means differ significantly (with alpha = 0.05) simply by examining whether the confidence intervals overlap. As a result of the second property it is possible to assess whether a failure to find significant differences is interesting by assessing the power of the experiment to detect such differences. The use of this statistical approach is based in our strong feeling that the most important aspect of experimental data such as ours is the underlying pattern of means across our experimental conditions. The use of confidence intervals illustrates this pattern in a much more direct and accessible way than does the more traditional

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Table 1. Mean proportion of 'old' responses in Experiments 1 and 2 for the test stimuli in each of the two stimulus orders

	Test stimulus type			
	Old	Simul-Con	Near-Con	Far-Con
Experiment 1				
Order 1	0.69	0.58	0.50	0.26
Order 2	0.65	0.53	0.46	0.25
Experiment 2				
Order 1	0.69	0.73	0.44	0.38
Order 2	0.73	0.71	0.46	0.46

Note: In Order 1, Old stimuli were drawn from the first and last study positions, and simultaneous-conjunction stimuli were drawn from the middle positions. In Order 2, old stimuli were drawn from the middle positions, and simultaneous-conjunction stimuli were drawn from the end positions. Simul-Con = simultaneous-conjunction condition; Near-Con = near-conjunction condition, and Far-Con = far-conjunction condition.

hypothesis-testing approach and its accompanying plethora of difficult-to-interpret t-values and F-values.

It is clear from the figure that miscombination errors between faces decreased as the distance (in study trials) between faces increased. Our data analysis indicated that this distance effect is independent of the serial position that the stimuli occupied during the study phase of the experiment. For half of the subjects (i.e. 'order 1 subjects'), old faces were drawn from the first and fourth (last) serial positions. For the remaining subjects ('order 2 subjects') the identical old faces were drawn from the second and third (i.e. the middle) serial positions. For order 1 subjects, simultaneous-conjunction faces were drawn from the middle positions, and for order 2 subjects, the identical simultaneous-conjunction faces were drawn from the first and last positions. The means for these two orders are presented in the top two rows of Table 1. The patterns of performance for the two orders are obviously quite similar. To test the effects of order we performed an ANOVA with test condition as a within-subjects factor and stimulus order as a between-subjects factors. There was not a significant main effect of order ($F(1,92) = 1.37$, $MSe = 0.11$), nor did order interact with test condition ($F(3,276) = 0.11$, $MSe = 0.09$).

In short, the likelihood of miscombination errors was directly related to the relative distance between study items, with simultaneously presented items being most susceptible to miscombination. Additionally, the serial positions of the stimuli did not influence the frequency of memory conjunction errors. The relative positions of the items are crucial, but their absolute positions are unimportant.

EXPERIMENT 2

In Experiment 2 the interval between the study phase and the recognition test was 24 hours, rather than 15 minutes. There are two important reasons to test the effect of increasing the retention interval on the pattern of memory conjunction errors. First, witnesses to crimes are rarely asked to make an identification from a photo lineup immediately after the crime occurs – more typically, there is a delay of several hours or

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even several days between the event and the subsequent memory test. It is therefore important to see whether the pattern of results obtained in Experiment 1 is observed following a much longer delay. This is particularly true because the effects of some manipulations that initially interfere with eyewitness identification decline as the retention interval increases; for instance, the 'overshadowing' effects produced when witnesses provide verbal descriptions of faces become less pronounced over time (Pezdek and Finger, 1997).

From a theoretical perspective the effects of increasing the retention interval are potentially interesting because the resulting change in the pattern of means can provide insight into the relative forgetting rates for various sources of information. For instance, if people rapidly forget facial features then the rate of 'old' responses should decrease for conjunction stimuli, because subjects will be less likely to remember the old features. Alternatively, if subjects tend to remember features, but rapidly forget how features had been interrelated during the study phase, then false alarm rates should remain high for conjunction stimuli, and should approach the hit rate for old stimuli.

Method

Subjects

The subjects were 48 Boston University undergraduates who participated for credit in their introductory psychology classes. They were tested in sixteen three-subject groups.

Stimulus and apparatus

The same stimuli and apparatus used in Experiment 1 were again used here.

Design and procedure

The design and procedure were the same as in Experiment 1, except that subjects left the laboratory after the study phase and returned at the same time on the following day for the recognition test. The identical stimuli, study orders, and test orders used in Experiment 1 were again used here.

Results and discussion

As in Experiment 1 there was no evidence whatsoever for recency or primacy effects. The means in the various test conditions are shown in the bottom two rows of Table 1 separately for the two stimulus orders. We again ran an ANOVA treating test condition as a within-subjects factor and order as a between-subjects factor; neither the effect of order nor the order by test condition interaction approached significance (both p's > 0.3). The data are therefore collapsed across order in Figure 2, which shows the means for the test conditions along with their 95% within-subjects confidence intervals. The results are quite different from those of Experiment 1. Most notably, when the test was delayed subjects were unable to discriminate old stimuli from simultaneous-conjunction stimuli. The frequency of 'old' responses to both of these test-stimulus types was far higher than for faces in the near- and far-conjunction conditions. Finally, although there were more false alarms to near-conjunction faces

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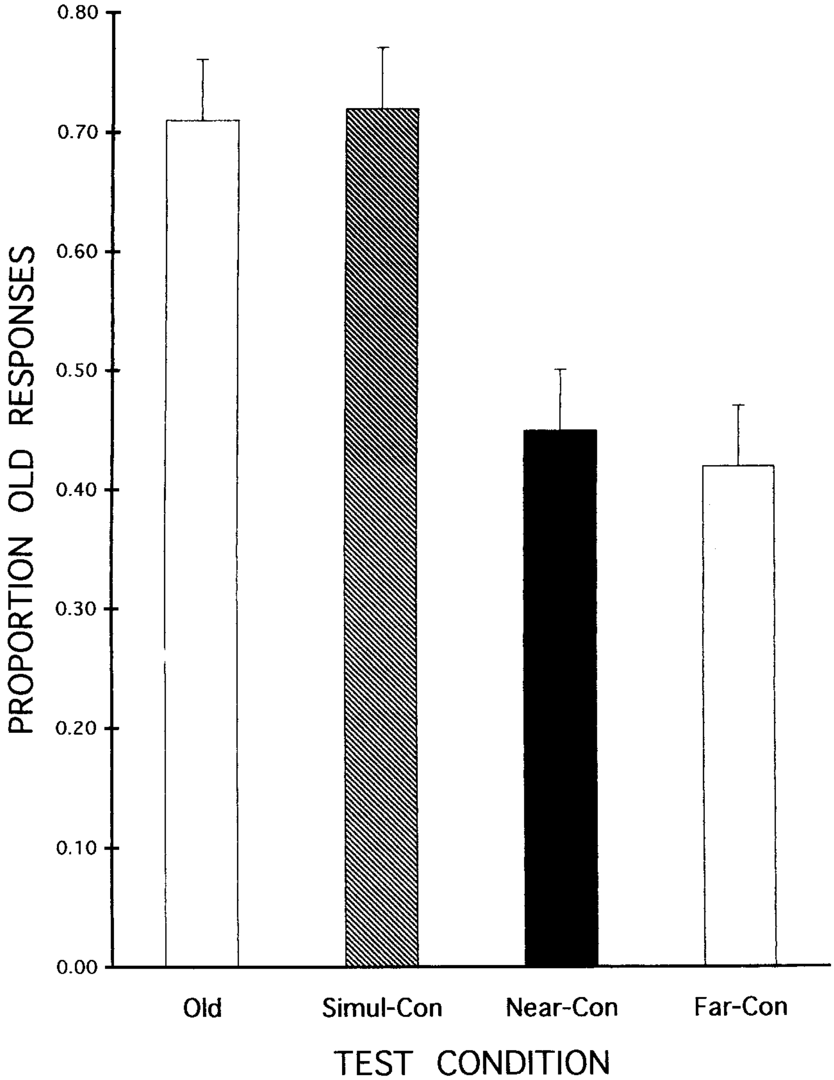

Figure 2. Experiment 2 results: Proportion of 'old' responses for each of the four test conditions following a 24-hour delay. The error bars show the 95% within-subjects confidence intervals (Loftus and Masson, 1994). Simul-Con, Near-Con, and Far-Con refer to the simultaneous-conjunction, near-conjunction, and far-conjunction conditions, respectively

than to far-conjunction faces in Experiment 1, this difference disappeared when the retention interval was lengthened.

In order to test whether the pattern of means differed significantly between the experiments we performed an ANOVA treating test condition as a within-subjects variable and experiment as a between-subjects variable. Consistent with our proposals, there was a significant experiment by test condition interaction, $F(3,426) = 2.69$, $MSe = 0.11$.

It is important to note that we did not obtain baseline measures of false alarms (i.e. false-alarm rates to partially or completely new stimuli) in either experiment. As a

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result, we do not know the extent to which differential response bias in the two experiments contributed to the absolute values of the means. For instance, the hit rate (i.e. 'old' responses to old stimuli) was the same in the two experiments. This may indicate that subjects in the two experiments were equally sensitive to old stimuli. However, it may instead be the case that subjects in Experiment 2 had a greater overall likelihood to respond that a stimulus was old, so that a relatively high hit rate resulted despite reduced sensitivity to whether a face was actually old. Thus comparisons of absolute values of means across the experiments are meaningless. In a similar vein, it is important to note that the absolute values of the means are influenced by the memorability of the specific faces that we used in our experiments. As a result, the absolute values of the means that we obtained are not likely to correspond to the absolute values obtained for real faces. The important findings of this paper pertain to the patterns of means, rather than to the absolute values of the means. For instance, subjects clearly make more conjunction errors in a simultaneous-conjunction condition than in the other conjunction conditions. Similarly, the finding of a significant experiment by test condition interaction demonstrates that the *pattern* of means across the test conditions was different in the two experiments.

The striking finding of Experiment 2 is that following a 24-hour retention interval, subjects misidentified faces constructed from parts of simultaneously occurring study faces as often as they correctly identified old faces. It is important to note that this effect was not simply the result of generally poor memory, since subjects were much less likely to endorse near- and far-conjunction stimuli. Instead, the specific information necessary for distinguishing old faces from faces constructed from parts of simultaneously occurring faces was forgotten (or not assessed) following a 24-hour delay.

GENERAL DISCUSSION

Summary of results

Both experiments showed that simultaneously occurring items are particularly vulnerable to memorial miscombinations of their features. In Experiment 1 the likelihood of such miscombinations decreased as between-item distance on the study list increased. In Experiment 2 the false alarm rates for near- and far-conjunction faces were equal, but were much lower than the false alarm rate for simultaneous-conjunction faces. Moreover, there was no effect of list position in either experiment: the likelihood of miscombining the features of simultaneously presented faces was equal regardless of where on the list those faces occurred, and the frequency of 'old' responses to near-conjunction faces was equal regardless of whether or not the conjunction face included features from a face that occurred in an end position during the study phase. Most importantly, Experiment 2 demonstrated that after a 24-hour period subjects were unable to discriminate truly old faces from new faces constructed of simultaneously occurring facial features.

Applied implications

The results have strong implications regarding the conditions under which people are likely to make memory conjunction errors outside the laboratory. In particular,

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people are most likely to miscombine parts of stimuli that were experienced simultaneously, and much less likely to miscombine parts of items that were experienced in separate episodes, particularly following a long retention interval. So, for instance, a witness to a crime may miscombine parts of the perpetrator's face (or parts of a licence plate number, etc.) with those from the face of another individual (or of another licence plate number) that was present at the crime, but is less likely to miscombine parts of the perpetrator's face with those from a face seen earlier or later in the day. However, it should be noted that, although less likely, memory conjunction errors involving temporally more distant items do sometimes occur.

In addition, there was no evidence for a serial position effect. This implies that items experienced at the start or at the end of an event are as likely as those in the middle to give rise to memory conjunction errors. From an applied perspective, this means that no special claims regarding increased memory accuracy are warranted simply on the basis of when during an event that a stimulus was experienced.

Finally, it is important to point out that the likelihood of misidentification was greatest under the experimental conditions that were most relevant to real-world identification. Specifically, over time subjects became less able to distinguish simultaneous-conjunction faces from truly old faces. Subjects did not simply forget facial features – if they had, then stimuli in all the conditions should have become less discriminable from one another because performance in all of the conditions should have moved towards chance. Instead, subjects appear to remember the set of facial features that had occurred simultaneously; however, they forget the specific faces that the features had occurred within. As a result, it would be helpful to have descriptions of not only the perpetrator of a crime, but also of the other individuals that were present during the crime. If a face in a lineup contains features that are similar to features that had occurred across the faces of several such individuals then the witness may inadvertently choose that face, particularly after a delay.

Theoretical implications

The results have important theoretical implications regarding the mechanisms that produce memory conjunction errors, and that produce memory interference. Most importantly, the results demonstrate that features of co-occurring items are more confusable than are the features of temporally distant items. Put differently, when stimuli occur at the same time, it is difficult to subsequently segregate their parts at the time of retrieval. This finding implies the involvement of a discrimination process during retrieval that is sensitive to the temporal characteristics of studied features. When stimuli do not differ with regard to their temporal characteristics (as is the case in the simultaneous conjunction condition) then their features are prone to miscombination. As stimuli become more temporally distant during study, their features become easier to discriminate. It is important to note that at short retention intervals factors other than temporal discriminability play a role in remembering stimuli. If temporal discriminability alone were responsible, then subjects would be unable to distinguish old stimuli from simultaneous-conjunction stimuli, since in both cases all of the features occurred at the same time during study. It appears that relational information of the sort proposed by Reinitz and his colleagues plays a role in remembering stimuli over relatively short retention intervals. At long retention intervals, temporal discriminability appears to play the dominant role in driving

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recognition performance. Subjects appear to remember whether features had occurred at the same time or at different times, but not whether features that had occurred at the same time had occurred within a single stimulus.

The results are therefore consistent with models that emphasize the importance of discriminabilty as a fundamental mechanism in interference (e.g. Chandler, 1991; Chandler and Gargano, 1998; Underwood, 1969), while at the same time supporting the proposal that relational information contributes to memory performance at short retention intervals, and not at long retention intervals. Moreover, the findings provide evidence against explanations for memory conjunction errors that do not include a discrimination process sensitive to temporal aspects of stimuli. For instance, Metcalfe (1990) showed that her CHARM model predicts that memory conjunction errors will sometimes occur when a single retrieval cue activates multiple, similar, traces; however, there is no mechanism within the model that discriminates between traces on the basis of temporal factors alone. There are various ways that CHARM could be modified to account for our results (for instance, time of presentation could be included as a feature in the stimulus representation). The point here is not to attack models such as CHARM, but rather to point out the need to incorporate a discrimination process sensitive to when stimuli occurred.

As mentioned previously, the theoretical explanation provided by Reinitz and colleagues does not include a temporal discrimination mechanism. The current findings indicate the need for a temporal discrimination process to be included within this theoretical framework. The results of Experiment 2 indicate that simultaneity of presentation makes stimulus features remarkably vulnerable to miscombination. It appears that when features are encoded into memory they are tagged with their time of presentation, and that features with identical temporal tags cannot be segregated into the separate stimuli in which they had occurred. This discussion implies that there are two independent types of information that aid in the proper conjunction of stimulus features during retrieval. One of these is information about how features were interrelated (which presumably accounts for the difference in 'old' responses between the old and simultaneous-conjunction conditions in Experiment 1). Experiment 2 indicates that this type of information is vulnerable to rapid forgetting; following a 24-hour retention interval subjects could no longer make this discrimination. Temporal tags associated with specific feature representations provide additional useful information for guiding retrieval. Temporal tags appear to be relatively long-lasting, and help ensure that simultaneously occurring features are conjoined into a single memory. However, they can lead to miscombinations of features when relational information is unavailable, and multiple stimuli of a particular type had been presented simultaneously.

Finally, the results are problematic for theories attributing memory conjunction errors to familiarity processes. All the features that had occurred during the study phase should be about equally familiar, so according to familiarity-based theories there is no reason why any proximity effects should be observed.

Final comments

It is important to point out that unfamiliar faces were used as stimuli in our experiment. We assume that any effects obtained using faces would be easier to obtain using other types of stimuli, because most stimuli are proposed to be recognized on the basis

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of their parts, whereas faces are proposed to be recognized on the basis of a more 'holistic', global, representation (e.g. Diamond and Carey, 1986; Tanaka and Sengco, 1997). Moreover, the same patterns of memory conjunction errors obtained for faces have generally been found for other stimulus types. However, differential patterns of memory interference have been reported for pictorial stimuli and for words. For instance, Chandler and Gargano (1998) provide evidence that a discrimination process plays a central role in producing interference for pictures, but not for words. It is therefore unclear whether the results reported here generalize to highly familiar, linguistic, stimuli. Comparisons of proximity effects for pictures and words can provide a useful avenue for both applied and theoretically based future research.

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