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Memory-conjunction errors: Miscombination of stored stimulus features can produce illusions of memory

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We demonstrate that subjects will often claim to have previously seen a new stimulus if they have previously seen stimuli containing its component features. Memory for studied stimuli was measured using a "yes"/"no" recognition test. There were three types of test stimuli: *target stimuli*, which had been presented during study, *conjunction stimuli*, constructed by combining the features of separate study stimuli, and *feature stimuli*, in which studied stimulus features were combined with new, unstudied, features. For both nonsense words and faces, the subjects made many more false alarms for conjunction than for feature stimuli. Additional experiments demonstrated that the results were not due to physical similarity between study and test stimuli and that conjunction errors were much more common than feature errors in recall. The results demonstrate that features of stored stimuli maintain some independence in memory and can be incorrectly combined to produce recognition errors.

In attempting to call her husband at work, Betsy T. dialed the first three digits of her home number but the last four digits of her office number. Elsewhere, after being introduced to several new colleagues, including a Mr. Gillcrest and a Mr. Rosemond, Paul R. incorrectly referred to one of them as "Mr. Rosecrest." These characters each erroneously combined portions of two separate memory traces, thereby remembering an item that did not correspond to any single stimulus that had been experienced. We refer to such errors as *memory-conjunction errors*. The first purpose of this study was to empirically demonstrate that memory-conjunction errors occur frequently in both recognition and recall. The second purpose was to investigate whether such errors are restricted to a particular class of stored information (e.g., verbal information) or whether they constitute a general phenomenon of memory.

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Memory-conjunction errors are of interest for two reasons. First, most current models of explicit memory are *distributed models*, which propose that memory traces for previously experienced stimuli are represented as a set of units that roughly correspond to stimulus features. Such models can be contrasted with what McClelland and Nystrom (1988) call *single-trace models*, which propose that memories for previously experienced stimuli are stored as single units. Distributed models predict that memory-conjunction errors should commonly occur; single-trace models do not make such a prediction. One purpose of the current research is to test between these two classes of models.

The second reason that memory-conjunction errors are of interest is that if such errors commonly occur, they could constitute a significant source of error across a wide variety of real-world situations. For instance, a cognitive psychology student who has recently read about Elizabeth Loftus and John Morton might choose the distractor "Lofton" on a multiple-choice test. More seriously, a witness to a crime might claim to have seen an individual's face when the witness had in fact seen several faces that, when taken together, contained most of the facial features of the accused individual.

Empirical and Theoretical Precedents

A long and venerable line of research has provided evidence that memories for items and events are constructed from smaller units in memory. Candidates for such units include entries in schemas (Bartlett, 1932; Rumelhart & Norman, 1985; Thorndyke & Hayes-Roth, 1979), scripts (Schank & Abelson, 1977), or frames (Minsky, 1975). Bartlett (1932) demonstrated that people's recollections of events often included information that was not present in the actual event, and he argued that recollection of a complex event involved a reconstructive process in which items stored in memory were combined during retrieval. Subsequent research has supported the notion that memories are sometimes reconstructed at the time of retrieval (e.g., Anderson & Pichert, 1978; Barclay, 1988; Loftus & Palmer, 1974). In addition, research has clearly demonstrated that subjects mistake their inferences for material that they had actually experienced (Bower, Black, & Turner, 1979; Bransford, Barclay, & Franks, 1972; Loftus & Palmer, 1974).

For memories to be reconstructed at the time of retrieval, it is logically necessary that some sort of basic units exist from which recollections are built. The notion that memories for previously experienced stimuli are represented as sets of simple units is fairly old. For instance, Underwood (1969) proposed that memory for an event consisted in a collection of quasi-independent attributes such as spatial relations between stimulus items, stimulus frequency, and so on. A version of this proposal constitutes an underlying assumption of current distributed-memory models: These models assume that a memory trace for a particular stimulus is represented as a collection of quasi-independent perceptual features of the stimulus (see, e.g., McClelland & Rumelhart, 1985, 1986; Metcalfe, 1990). We additionally assume that some features of a stored stimulus can be retrieved while others are not. There is substantial empirical support for this assumption. For instance, a person may fail to retrieve a word and still correctly report its first letter and the number of syllables it contains (Brown & McNeill, 1966). Individuals may also remember both the location at which information appeared on a page, without remembering the information itself (Zechmeister & McKillip, 1972), and semantic associates of a word that cannot be retrieved (Eysenck, 1979). These findings demonstrate that in many situations, subjects can retrieve some stimulus features in the absence of others.

Previous Demonstrations of Memory-Conjunction Errors

Schooler and Tanaka (1991) distinguish between composite recollections, in which a single recollection contains items arising from multiple sources, and compromise recollections, in which previously experienced items are combined to produce a recollection that represents a perceptual or semantic averaging of the items. Memory-conjunction errors represent a specific type of composite recollection, since they involve the miscombination of parts of previously experienced stimuli. In this sense, memory-conjunction errors can be contrasted with prototypes (e.g., Posner & Keele, 1968) or memory blends (e.g., Loftus, 1977; Metcalfe, 1990), which represent compromises between several similar or related items.

Several examples of composite recollections have been reported. For instance, Bransford and Franks (1971) showed that subjects will incorrectly claim to have previously viewed a sentence containing a set of propositions if all of the propositions contained in the sentence were previously presented in study sentences. This sort of recognition error differs from memory-conjunction errors in two ways: subjects combined semantic, rather than perceptual, features of previously viewed stimuli, and the stimuli in the Bransford and Franks study were highly semantically interrelated, whereas the examples of memory-conjunction errors described at the start of this article do not involve semantically interrelated stimuli. Nonetheless, the Bransford and Franks study clearly demonstrates that previously viewed stimuli can be combined to produce a recollection that does not correspond to any single previously experienced stimulus.

The misinformation effect demonstrated by Loftus and her colleagues (Loftus, Miller, & Burns, 1978; Schooler, Gerhard, & Loftus, 1986) represents another example of composite recollection. In these studies, information provided verbally following an event is combined with information experienced during the event, resulting in poor memory performance for the original event. Again, although these errors differ from memory-conjunction errors in several ways (e.g., misleading postevent information is intentionally introduced in misinformation studies), they provide evidence that information acquired across independent experiences can be miscombined to produce memory errors.

Finally, possible examples of memory-conjunction errors have been demonstrated by Underwood and his colleagues (Underwood, Kapelak, & Malmi, 1976; Underwood & Zimmerman, 1973). In these studies, subjects first viewed words on a memory drum and then participated in a recognition test. In the Underwood and Zimmerman (1973) study, subjects were more likely to make false alarms to test words that shared syllables with study words than they were to make false alarms to words that did not share syllables with study words. In the Underwood et al. (1976) study, subjects were more likely to make false alarms to compound words when the component words had been present during study than when they had not been present. These findings provide support for the notion that words are represented in memory by smaller units that represent word components and, furthermore, that these components can be miscombined during a recognition test.

A Paradigm for Studying Memory-Conjunction Errors

The paradigm that we used to investigate memory-conjunction errors is an adaptation of a procedure developed by Treisman and Schmidt (1982) for studying perceptual miscombinations of visual features (illusory conjunctions). In most of our experiments, the subjects studied a set of stimuli until they had memorized them. Memory for the stimuli was later measured in a "yes"/"no" recognition test, in which there were three types of test stimuli. *Target stimuli* were identical to previously studied stimuli. *Conjunction stimuli* were new items constructed by combining the features of separately studied stimuli and were therefore composed of previously memorized components. Finally, *feature stimuli* were constructed by combining half of a study item's features with remaining features that were not present during study. Memory-conjunction errors were possible for conjunction stimuli but not for feature stimuli, since only for the former were all of the stimulus components contained in memory. Thus, a high false-alarm rate for conjunction stimuli compared with feature stimuli would imply that subjects are making memory-conjunction errors.

The purpose of Experiment 1 was to demonstrate that memory-conjunction errors occur in recognition and to investigate the role of voluntary control of processing in moderating error rate. The stimuli were two-syllable nonsense words. Experiment 2 tested whether memory-conjunction errors occur in recall. Experiments 3-6 investigated memory-conjunction errors for more ecologically valid visual stimuli—specifically, faces.

EXPERIMENT 1

The purposes of Experiment 1 were to demonstrate the occurrence of memory-conjunction errors in recognition and to examine the effects of varying instructions on the pattern of errors. Specifically, we repeated the same simple experiment twice. In Experiment 1A, the subjects studied a list of two-syllable nonsense words and later participated in a recognition test containing target, feature, and conjunction stimuli. The test stimuli were presented on a sheet of paper, and the subjects were simply told to circle the stimuli that they had previously studied. Experiment 1B was identical to Experiment 1A, except that the subjects were warned at the start of the test phase that some of the test stimuli contained syllables taken from two separate study words and were specifically instructed to avoid choosing those stimuli, since those responses would be counted as errors. If memory-conjunction errors reflect processing over which subjects have voluntary control, then the change in test instructions should produce a qualitative change in the pattern of errors.

Method

Subjects. Forty-eight subjects participated in Experiment 1A, and 24 participated in Experiment 1B. All 72 subjects were undergraduate students at Southeastern Louisiana University who participated for introductory psychology course credit. The subjects were tested individually.

Stimuli. Fifty-four nonsense syllables of the form consonant-vowel-consonant were created with the following constraints: each of the six vowels in the alphabet (including y) was represented equally often, none of the syllables formed an English word, suffix, or prefix, and none of the syllables were homophones of English words, suffixes, or prefixes. All of the stimuli in both the study and test phases of the experiment were two-syllable nonsense words constructed by randomly combining pairs of these syllables. Different random-syllable combinations were used to generate the stimuli for each subject; thus, each subject was presented with a unique set of study and test stimuli.

Design and Procedure. There were three phases of the experiment. In Phase 1, the subjects studied a list of nonsense words. In Phase 2, they performed a filler task in which they had to identify letters presented briefly on a computer screen. Finally, in Phase 3, the test phase, the subjects received a recognition test for nonsense words that they had initially studied.

For each subject, a unique study list of 24 two-syllable nonsense words was created by randomly conjoining 48 of the syllables. The remaining 6 syllables were used to construct feature stimuli in the test phase that followed. The 24 study items appeared in a column centered on a page of paper. The subjects were told that they would later receive a memory test for the words on the list. After studying the list for 5 min, each subject was instructed to read the word at the top of the list, look away, and spell the word from memory. After repeating this procedure for each of the 24 words, each subject briefly studied each word and then pronounced it without looking at the list. The purpose of these manipulations was to make sure that the subjects correctly perceived and encoded the nonsense words. The subjects repeated the entire study procedure twice, and the study phase lasted approximately 20 min.

A demanding task on a microcomputer intervened between the study phase and the test phase: The subjects searched for target stimuli (colored letters) in briefly presented arrays on a computer screen. This task lasted approximately 15 min.

Finally, the subjects were given a recognition test, which consisted of a list of 18 two-syllable nonsense words. Six words had been present on the study list (target stimuli). Six words were constructed by combining syllables from 2 different study words (conjunction stimuli). Syllables in conjunction stimuli always appeared in the same position within the word as they did during study; that is, if a syllable appeared as the first syllable in a study word, it was used as the first syllable in the conjunction stimulus, and so on. The final 6 words were constructed by combining one syllable from a word on the study list with one of the six syllables that had not been used during study (feature stimuli). Again, syllables in feature stimuli appeared in the same position within the words as they had during study; 3 feature stimuli contained first syllables of study words, and 3 feature stimuli contained second syllables of study words. Unless a study word appeared as a target, only one of its syllables was used during the test—that is, a single study word was never used to form 2 test words.

The syllables were not perfectly counterbalanced with respect to test condition, since this would have required running a very large number of subjects. However, for each subject, the construction of test stimuli and their order was random, given the constraints described above for the test stimuli. Thus, each syllable occurred across a number of test conditions, and across subjects, each syllable occurred sometimes as the first and sometimes as the second syllable of a study word. Across subjects, there was no systematic relation between study and test stimuli.

The 18 test words were printed in a column on a sheet of paper in a different random order for each subject. The subjects were asked to circle words that had been presented during the study phase. In Experiment 1B, the subjects were additionally warned about conjunction errors. That is, the subjects were told that

> some of the words are exactly the same as the ones you studied. Some are made up of some of the syllables you studied, but they may be combined in a different way. Only circle the exact words you studied. If you remember a syllable, but it is not in the exact word you studied, don't circle it.

The subjects in both experiments were given 2 min to complete the recognition test.

Results and Discussion

Two types of false alarms were possible: conjunction errors, which occurred when the subjects circled a conjunction stimulus, and feature errors, which occurred when the subjects circled a feature stimulus. If memory-conjunction errors occur, then subjects should make substantially more conjunction errors than feature errors.

Recognition performance for the various conditions in Experiments 1A and 1B is summarized in Table 1. Separate t tests for correlated groups showed that in both experiments, the difference in error rate between the conjunction and feature conditions was highly reliable [$t(47) = 7.74$, $p < .001$, for Experiment 1A, and $t(23) = 4.24$, $p < .01$, for Experiment 1B]. In both experiments, the subjects made slightly more than 3 times as many conjunction errors as feature errors. It is clear that warning the subjects about conjunction stimuli did not affect the pattern of results between the conditions; rather, the effect was simply to cause the subjects to adopt more conservative response criteria. In Experiment 1B, the subjects made fewer "old" responses in all conditions; this increased the error rate for target stimuli and decreased the error rates for feature and conjunction stimuli, compared with Experiment 1A. The results demonstrate that subjects frequently make memory-conjunction errors for two-syllable nonsense words and that the processes that produce these errors are not subject to voluntary control.

EXPERIMENT 2

Experiment 1 provides evidence that memory-conjunction errors occur for recognition of nonsense syllables. It is of interest to test whether these errors are specific to the recognition paradigm that we used or instead occur across a variety of standard explicit-memory tests. The purpose of Experiment 2 was to test whether memory-conjunction errors occur in recall. Piloting indicated that the nonsense-syllable stimuli used in Experiment 1 were very difficult to recall. For this reason, we used a different type of stimulus in Experiment 2—simple sentences.

Method

Subjects. Twenty-four Southeastern Louisiana University undergraduates participated for credit in their introductory psychology class. None of the subjects had participated in Experiment 1. Four subjects were run in each of six groups.

Table 1
Relative Frequency of "Old" Responses for Each Type of Test Stimulus in Experiments 1A and 1B

Stimulus Type	Experiment 1A	Experiment 1B
Target	.93	.84
Conjunction	.33	.19
Feature	.09	.06

Table 2
Mean Number of Responses and Standard Deviation for Each of the Five Response Types in Experiment 2

Response Type	*n*	*M*	*SD*
Correct	24	8.90	3.43
Conjunction error	13	.79	.83
Feature error	3	.13	.34
Reversal error	2	.13	.45
Incomplete	11	.54	.66

Note—n = number of subjects making each type of response.

Stimuli. Eighteen sentences of the form "The X saw the Y" were constructed by the experimenters. Both X and Y were the names of animals or people and were not proper nouns. A typical study sentence might be "The lawyer saw the bear." Half of the subjects received the sentences in their original form, and half received the sentences with the order of the nouns reversed. In addition, there were three different random study orders. The combination of three study orders with the two versions of each sentence resulted in six unique study lists. Each subject received his or her 18 study sentences centered on a piece of computer paper.

Design and Procedure. There were three phases of the experiment. First, the subjects studied the 18 sentences. They then performed a filler task in which they had to make orientation judgments about pictures of scenes. Finally, they were given a recall test for the sentences they had studied.

At the start of the study phase, the 4 subjects in each group received identical study sheets and were told that they would later be asked to remember the sentences. After they had studied the sentences for 5 min, they were told to cover all but the first sentence with a blank sheet of paper that had been provided, to study that sentence for a few seconds, and then to look away and repeat the sentence silently to themselves. The subjects were then instructed to uncover the next sentence and repeat the procedure. After the subjects had repeated all 18 sentences to themselves, they were given an additional 5 min to study the sentences, after which they again repeated each sentence silently to themselves.

The Guilford-Zimmerman spatial-orientation test was used as the filler task. This test required the subjects to make simple orientation judgments and took 15 min to complete.

Following the filler task, the subjects were given 5 min to write down as many of the sentences as they could on a blank sheet of paper that had been provided.

Results and Discussion

The subjects made four types of recall errors. Conjunction errors occurred when subjects incorrectly combined nouns from two separate sentences. Feature errors occurred when subjects incorrectly combined a noun from a study sentence with a noun that had not been presented during study. Reversal errors occurred when subjects correctly recalled the two nouns from a sentence, but in reverse order. Finally, incomplete responses occurred when subjects reported only a single noun from a sentence.

The mean frequencies with which subjects made each type of response are presented in Table 2. Conjunction errors were quite common and were made by 13 of the 24 subjects. On the other hand, feature errors were extremely rare—only three were made in the entire experiment. As in Experiment 1, the subjects made significantly more conjunction than feature errors [$t(23) = 3.76$, $p < .001$]. Thus, memory-conjunction errors occur in recall, as well as in recognition. This finding helps us reject the hypothesis that the memory-conjunction errors demonstrated in Experiment 1 are caused solely by familiarity differences between the distractors in the feature and conjunction conditions. The reason is that it is difficult to generate a familiarity-based explanation for recall errors. It seems to us unlikely that the identical patterns of effects that we observed in Experiments 1 and 2 would be produced by completely different underlying mechanisms in the two cases. For this reason, we prefer an explanation for memory-conjunction errors that is based on explicit recollection to one that attributes the errors to differential familiarity.

It is of interest to note that incomplete responses were relatively common. These responses are of course completely consistent with our basic premise. As we discussed earlier, an assumption of our approach is that it is possible to retrieve some parts of a stimulus without retrieving others. Incomplete responses demonstrate that this happens often for the sentence stimuli we used in Experiment 2.

In the first two experiments, we used a research paradigm borrowed from the perception literature to demonstrate that features of nonsense words and simple sentences maintain some independence in memory. If the stimuli were stored holistically as single, indivisible traces, the pattern of results obtained in these experiments could not have occurred. It is perhaps not surprising that syllables of nonsense words should retain some independence—after all, the stimuli have no meaning and are obviously artificial. The situation is hardly better for the sentence stimuli used in Experiment 2; although the sentences might be said to have meaning in some limited sense, the noun pairings that we used were obviously arbitrary. The very nature of the stimuli might induce subjects to encode them as syllable or noun pairs rather than as single units in memory. It is therefore of interest to extend our findings to other types of stimuli that are more ecologically valid and that are more likely to be stored holistically rather than as a set of features.

EXPERIMENT 3

Experiment 3 tested whether memory-conjunction errors occur for pictures of faces. Faces are of interest for three reasons. First, we wanted to extend our result to an ecologically valid type of stimulus. Faces certainly satisfy this criterion. Second, faces have an inherently cohesive property that our previous stimuli lacked. Several studies have demonstrated the holistic nature of processing in face perception (see, e.g., Carey & Diamond, 1977; Diamond & Carey, 1986). For this reason, faces provide a more rigorous test of the memory-conjunction hypothesis than do our previous stimuli. Finally, we were interested in faces because of the obvious real-world significance of the research. On the day of a crime, an eyewitness is likely to have seen many faces besides that of the perpetrator. It is of interest to know whether features from these faces may be conjoined, resulting in the false-positive recognition of an innocent person.

Several variables have been shown to decrease face-recognition accuracy. For instance, verbally describing a face may reduce accuracy in a subsequent recognition test (Schooler & Engstler-Schooler, 1990). More relevant to the current research, several studies have shown that previous exposure to faces can impair recognition accuracy for a target face. For instance, a witness may sometimes falsely identify an individual as the criminal if, on the day of the crime, the witness had seen that individual somewhere other than at the crime scene (Brown, Deffenbacher, & Sturgill, 1977; Houts, 1956).

Another example of how previous exposure to faces can lead to false recognitions is provided by Solso and McCarthy (1981). Subjects viewed 10 exemplar faces constructed from a single prototype face that contained four facial features (eyes, nose, mouth, and hair). Three of the exemplars contained three of the four prototype features, 4 of the exemplars contained two of the four prototype features, and 3 of the exemplars contained one of the four prototype features. After viewing the exemplars, subjects participated in an old-new recognition task in which the prototype was presented as one of the distractors. Thirty-five of the 36 subjects responded that the prototype had been presented during study; moreover, subjects were more confident in their responses to the prototype than they were in their responses to the old exemplars. Solso and McCarthy (1981) concluded that subjects blended the individual exemplars in memory to produce a prototype that represented the average values for the various facial features. However, since each individual feature of the prototype was presented on numerous occasions, it is alternatively possible that subjects were making memory-conjunction errors. This possibility provided additional impetus for Experiment 3.

Method

Subjects. Twenty-four Southeastern Louisiana University undergraduates participated for class credit. Each subject was tested individually.

Stimuli. Line drawings of human faces on white backgrounds were constructed by using a simple identikit produced by the experimenters with instructions from Speirs (1984). First, 4 male and 4 female faces were constructed. Each face contained a completely unique set of features except for the ears and the shape of the face, which were held constant for all faces. The features of each face were divided into two feature sets: one consisted of hair and mouth, and the other of eyes and nose. The hair/mouth feature sets were completely crossed with the eyes/nose feature sets to create 64 faces.

Design and Procedure. The recognition procedure that was used in Experiment 1 was used again here. Each subject was presented with six randomly selected study faces, one at a time, for 30 sec each. The subjects were instructed to study the faces for a later recognition test. Each subject received a unique random set of study stimuli.

After the study phase, the subjects participated in a filler task that required discriminating which of two different target stimuli was briefly presented on a computer screen. This took about 45 min.

Following the filler task, the subjects were presented six stimuli in a recognition test. Two test faces had been previously studied

Figure 1. Examples of stimuli used in Experiments 3–6. The left and middle panels show potential study stimuli, and the right panel shows a conjunction stimulus constructed from them.

(target stimuli). In addition, two test faces were conjunction stimuli. Each of these was constructed by combining the hair/mouth feature set from one study face with the eyes/nose feature set from another. Finally, two test faces were feature stimuli. One of these was constructed by combining the hair/mouth feature set from a study stimulus with an eyes/nose feature set that had not been presented during study. The other was constructed by combining the eyes/nose feature set from a study stimulus with a hair/mouth feature set that had not been presented during study. As in Experiment 1, the test-condition order and the assignment of feature sets to test conditions was random for each subject, with the constraint that two exemplars of each of the three study conditions were constructed. Thus, across subjects, any given feature set occurred in various test conditions, and there was no systematic relation between study and test stimuli.

Examples of the stimuli are presented in Figure 1. The left and middle panels show potential study faces; the right panel shows a conjunction stimulus constructed from them.

The six test faces were presented individually, in random order. The subjects responded "yes" or "no" to the question, "Was this one of the faces you studied?" The subjects were warned that some of the test faces might be very similar to, but not exactly the same as, study faces, and were told to respond "yes" only if the test face was exactly the same as a study face.

At the end of the test phase, the subjects were asked to rate their confidence in their responses on a scale of 1 to 5. The subjects were instructed to use the scale values as follows: 1 = guessing, 2 = not very confident, 3 = fairly confident, 4 = very confident, 5 = absolutely sure. We decided to use the somewhat nonstandard procedure of having the subjects make confidence ratings after the test interval, rather than immediately following each response, for the following reasons. First, we wanted the test interval to be of equal duration for all subjects. Second, the test interval was short enough that there was not a long delay between any response and the subsequent confidence rating.

Results and Discussion

Memory performance for the three test conditions is presented in Table 3. The results are quite similar to those obtained for nonsense words in Experiment 1. As in the other experiments, the difference between the feature and conjunction conditions was reliable [$t(23) = 2.20$, $p < .05$]. The subjects made a total of 11 feature errors; of these, 6 involved old eyes/nose feature sets and 5 involved old hair/mouth feature sets. The fact that feature errors occurred about equally often for both types of feature sets is important. It indicates that the subjects were not simply memorizing one type of feature and suggests that they were attending to the faces as wholes rather than simply to the most salient feature type.

The results show that memory-conjunction errors occur for faces, as well as for our previous stimuli. This implies that faces may be represented in memory as sets of features that can be miscombined during recognition. Furthermore, Experiment 3 demonstrates that under some conditions, memory-conjunction errors for faces can occur quite frequently; the subjects made false-positive recognitions for conjunction stimuli on 46% of the trials.

The confidence data are also presented in Table 3. We point out that since different numbers of subjects made the various types of responses, the confidence data suffer from subject-selection problems. For this reason, the data must be approached with caution, particularly for those types of responses that were made by relatively few subjects. The subjects were significantly more confident in their correct recognitions than they were in their conjunction errors [$t(16) = 2.851$, $p < .05$]. It is probably not surprising that memories for previously seen faces are somewhat more compelling than are memories for faces that have not been previously encountered. Perhaps more surprising is the degree of confidence that the subjects had in their incorrect responses. The mean confidence rating for conjunction errors was closer to "very confident" than it was to "fairly confident." Furthermore, on many occasions, the subjects gave ratings of 5 for their conjunction errors. On these occasions, the subjects were sure that they had seen a face that they had not, in fact, experienced previously.

Table 3
Relative Frequency of "Old" Responses for Each Type of Test Stimulus and Confidence Ratings for "Old" and "New" Responses for Each Stimulus Type in Experiment 3

	"Old" Responses			"New" Responses	
Stimulus Type	*n*	Relative Frequency	Confidence Rating	*n*	Confidence Rating
Target	24	.87	4.31	6	3.17
Conjunction	17	.46	3.59	17	3.68
Feature	10	.23	4.05	21	3.95

Note—n = number of subjects making each type of response.

The similarity of the current results to those of Experiment 1 may indicate that similar memorial processes are involved in the recognition of quite different stimulus types. However, an alternative explanation for the results of Experiment 3 needs to be ruled out. It is possible that, on the average, the conjunction stimuli were more physically similar to the study faces from which they were constructed than were the feature stimuli. If this were true, the subjects may have made more errors in the conjunction than in the feature condition simply because the conjunction faces looked more like faces they had seen during study than did the feature faces. Experiment 4 tested this possible explanation for the results.

EXPERIMENT 4

In this experiment, we simply asked the subjects to rate the similarity of the test stimuli used in Experiment 3 to the study stimuli from which they were constructed.

Method

Subjects. Twenty-four Southeastern Louisiana University undergraduates participated for class credit. None of the subjects had participated in Experiment 3. The subjects were tested individually.

Stimuli. The stimuli were the same faces used in Experiment 3.

Procedure. The subjects rated pairs of faces for similarity on a scale of 1 to 10. The subjects were told that a response of "1" indicated that the stimuli were not in any way similar and that a response of "10" indicated that the stimuli were identical. Each subject rated the faces seen by the Experiment 3 subject who had been assigned the corresponding subject number—for instance, Subject 1 in Experiment 4 rated the faces seen by Subject 1 in Experiment 3.

The experimenter presented the faces in pairs consisting of one study face and one test face. Conjunction stimuli were paired with each of the two study faces that contained feature sets used to make the test face. Each feature stimulus was paired with the single study face with which it shared features. The order of presentation of the face pairs was random. No time limit was given for rating each pair of faces.

Results and Discussion

The mean ratings of the degree to which feature and conjunction stimuli were similar to study stimuli were 6.60 and 6.84, respectively. The difference between the two types of test stimuli did not approach significance [$t(23) = .548$]. Experiment 4 thus fails to provide evidence that the Experiment 3 test stimuli were differentially similar to study stimuli and strengthens the conclusion that the subjects made memory-conjunction errors for faces.

EXPERIMENT 5

In all of our recognition experiments, an equal number of feature and conjunction stimuli were presented at test. The net result was that the subjects saw twice as many old feature sets in the conjunction as in the feature condition, since each conjunction stimulus contained two previously studied feature sets and each feature stimulus contained only one previously studied feature set. This unequal distribution of old feature sets across test conditions could result in more "old" responses for conjunction compared with feature stimuli: If we assume that some feature sets are more memorable than others and that subjects respond that a test stimulus is old if they recognize a feature set, then we would expect more "old" responses for conjunction than for feature stimuli, simply because a conjunction stimulus is more likely than a feature stimulus to contain a highly memorable feature set.

To test this explanation, we presented two feature stimuli for each conjunction stimulus that was presented during the test. An equal number of old feature sets therefore appeared in the feature and conjunction conditions. If subjects base their responses on recognition of particularly memorable features, this manipulation should eliminate the difference that we previously observed between the feature and conjunction conditions.

Method

Subjects. Thirty Southeastern Louisiana University undergraduates participated for credit in their introductory psychology classes. The subjects were tested individually.

Stimuli. The stimuli were the same faces used in Experiments 3 and 4.

Design and Procedure. The procedure was similar to that of our other recognition experiments. The subjects studied six faces, one at a time, for 30 sec each. A filler task followed, which involved searching for a target letter among distractors. Finally, there was a "yes"/"no" recognition test, in which eight faces were presented. During the test, the subjects received two old stimuli, two conjunction stimuli, and four feature stimuli. As in the other experiments, the subjects were warned that "some of the faces may be very similar to, but not exactly the same as, faces that you saw earlier." The subjects were told to respond that a face was old only if the test face was exactly the same as a study face.

It was important that the same feature sets appeared in all of the test conditions equally often. To achieve this, 10 sets of six study stimuli were chosen randomly. Each random study set was presented to 3 separate subjects who then received different test stimuli. Across the 3 subjects, each of the 12 feature sets presented during study occurred once in each of the three test conditions.

Following the test, the subjects were asked to give confidence ratings for their responses on a scale of 1 to 5. Scale values were labeled as in Experiment 3.

Results and Discussion

The mean number of "old" responses and the absolute number of "old" responses for the three test conditions are presented in Table 4. The results are quite striking. The subjects made about 3 times as many conjunction errors as feature errors. The difference in false-alarm frequency between the feature and conjunction conditions was quite reliable [$t(29) = 4.98$, $p < .001$]. This provides a replication of Experiment 3 and demonstrates that subjects are likely to make false-positive recognition responses to faces that exclusively contain previously viewed features.

One of the goals of Experiment 5 was to demonstrate that the difference in conjunction and feature false-alarm rates that we have repeatedly obtained is not caused by the differential distribution of particularly memorable features across the stimuli in the two conditions. Since identical old features appeared equally often in the feature and

Table 4
Relative Frequency and Absolute Number of "Old" Responses for Each Type of Test Stimulus and Confidence Ratings for "Old" and "New" Responses for Each Stimulus Type in Experiment 5

	"Old" Responses				"New" Responses	
Stimulus Type	*n*	Relative Frequency	Absolute Number	Confidence Rating	n	Confidence Rating
Target	29	.82	49	4.48	10	3.15
Conjunction	27	.57	34	4.19	19	3.97
Feature	19	.20	24	3.59	29	4.15

Note—*n* = number of subjects making each type of response.

conjunction conditions, one test of this is to compare the absolute number of errors in the two conditions rather than the mean number of errors. This comparison is also of interest because it could provide additional evidence against a familiarity-based explanation for the results of our recognition experiments. Since the identical old feature sets occurred in the feature and conjunction conditions, the overall familiarity produced by these features should be the same when one compares the two conjunction stimuli in which a given set of features appeared with the four feature stimuli that contained the same old features. We point out that Experiment 2 provided strong a priori evidence against both a "memorable features" and a "differential familiarity" explanation of memory-conjunction errors, since neither would predict that the errors would occur in free recall. The current data provide additional evidence against these explanations: The subjects made a significantly greater absolute number of errors in the conjunction condition than they did in the feature condition [$t(29) = 1.80, p < .05$, by a one-tailed test]. We point out that this result adds additional support to the assertion that during study, subjects are not adopting the strategy of encoding single, memorable features, since this strategy would also lead to equal false-alarm rates for the feature and conjunction conditions. Rather, the results are consistent with the notion that holistic processing of the stimuli can nonetheless lead to an underlying representation in which basic units roughly correspond to stimulus features.

The confidence data are also presented in Table 4. The subjects were again quite confident that their false alarms in the conjunction condition constituted correct responses. The only significant comparisons were between the target and feature conditions, for both "old" responses [$t(17) = 3.634, p < .01$] and "new" responses [$t(9) = 2.645, p < .05$]. We again point out that these confidence differences necessarily reflect different samples of subjects and so should be regarded with caution.

EXPERIMENT 6

The previous recognition experiments lacked test stimuli that were completely constructed from unstudied features. Such a condition is of interest because it would provide a baseline measure of error rate, thereby making it possible to test the effect on recognition of the presence of some old features. This comparison bears on the issue of the role of familiarity in our recognition results. The presence of old features would obviously make feature stimuli more familiar than completely new stimuli, so according to a familiarity explanation, there should certainly be more false alarms to feature stimuli than to new stimuli, and error rate should increase in a regular manner as the number of old features increases. If it is instead the case that memory-conjunction errors crucially involve the miscombination of features contained in memory, then there should be little difference in error rate between the new and feature conditions, since in neither case are all of the stimulus features memorized.

Method

Subjects. Forty-eight undergraduates at the University of Central Arkansas participated for class credit.

Stimuli. The stimuli were the faces used in Experiments 3, 4, and 5.

Procedure. The procedure was identical to that of Experiment 3, with the exception that the subjects received eight test stimuli. As in Experiment 3, each subject received two target, two feature, and two conjunction stimuli. Additionally, the subjects received two "new" stimuli, which were completely constructed from features that had not been studied.

Results and Discussion

The relative frequencies of "old" responses for the target, conjunction, feature, and new conditions were .71, .52, .19, and .13, respectively. As can be seen, the difference in error rate between the feature and new conditions was small. A *t* test for correlated groups showed that this difference failed to approach significance [$t(47) = 1.359, p = .18$]. All other pairwise comparisons were significant, with $p < .01$. The results of Experiment 6 cast further doubt on a purely familiarity-based explanation for memory-conjunction errors and demonstrate that such errors occur only for stimuli composed completely of previously memorized features.

GENERAL DISCUSSION

Summary of Results

The experiments reported here demonstrate that memory-conjunction errors occur frequently for two types of memory tests (recognition and recall) and across a variety of stimulus types. Experiment 4 showed that the effect was not due to the similarity of the test items to the study items, Experiment 5 showed that the results were not due to the greater likelihood of particularly memorable stimulus features appearing in the conjunction condition compared with the feature condition, and Experiment 6 showed that subjects do not make many more errors for feature stimuli than they do for stimuli composed completely of new features.

Theoretical Implications of the Results

The results are consistent with the assertion that the act of remembering a previously experienced stimulus involves the conjunction of basic units in memory that roughly correspond to stimulus features. The results therefore provide strong evidence against any model that proposes that retrieval involves the activation of a single memory trace that represents a previously experienced stimulus. For example, in most versions of Anderson's (1983) ACT theory, retrieval of an episodic trace is depicted as the activation of a single node that represents the previously experienced stimulus. In such a system, there is no reason to expect that memory-conjunction errors would occur, since memories are not composed of smaller features.

In contrast, memory-conjunction errors would be predicted if memories for related stimuli were stored as overlapping representations in which stimulus features constituted the representational units, as distributed-memory models propose. Featural conjunction is a process posited by distributed models, although the exact mechanism by which such conjunction occurs varies across models; for instance, McClelland and Rumelhart (1985, 1986) propose that conjunction occurs by means of the spread of activation across processing units, whereas Metcalfe Eich (1982; Metcalfe, 1990) proposes that an autocorrelation procedure is responsible for featural conjunction. However, both of these notions of featural conjunction explicitly propose that the information required to choose the appropriate features to conjoin during recollection is independent of the stored stimulus features themselves. The current study indicates that this proposal is correct.

Although the current research provides support for this general class of model, our results do not favor a specific model over others. However, we point out that convolution/correlation models such as those proposed by Murdock (1982) and Metcalfe-Eich (1982) are far more likely to produce blend errors (in which what is retrieved is a perceptual compromise between two previously viewed stimuli) than they are to produce composite errors (such as memory-conjunction errors). Blend errors are notoriously difficult to produce experimentally (see Schooler and Tanaka, 1991), whereas composite errors are quite easy to produce. This general pattern constitutes evidence against convolution/correlation models.

The Role of Familiarity in Memory-Conjunction Errors

Jacoby and his colleagues (Jacoby, Kelley, and Dywan, 1989; Jacoby, Woloshyn, and Kelley, 1989) have demonstrated that previously encountered stimuli that cannot be consciously remembered can unconsciously affect judgments by producing a feeling of familiarity. These authors might argue that in the current experiments, the subjects were unable to explicitly remember all of the stimuli they had seen during study. Instead, the subjects based their recognition responses partly on the degree to which the stimuli seemed familiar. Since conjunction stimuli contained more old features than did feature stimuli, they produced greater overall familiarity and so were judged as old more often. This explanation shares with the distributed-memory explanation described previously the assumption that stimulus features are represented as basic units in memory, since the explanation requires the existence of some underlying units that are matched with stimulus features to produce familiarity. The notion of how features are conjoined to make recognition judgments is quite different, however. Here, conjunction is simply defined as the cumulative familiarity produced by the activation of independent units in memory.

Several comments are relevant with regard to this familiarity-based explanation for our results. First, it is important to point out that memory-conjunction errors were shown in Experiment 2 to occur during recall. As we have previously discussed, there is no familiarity-based explanation for memory-conjunction errors that predicts that these errors will be common in free recall. Second, Experiment 5 provided additional evidence against a familiarity-based explanation for memory-conjunction errors. In that experiment, the subjects made more conjunction errors than feature errors even though there were twice as many opportunities to make feature errors as there were to make conjunction errors. Finally, in Experiment 6, there was at best only a small difference in error rate between feature stimuli, for which half of the features had been previously studied, and stimuli completely composed of new features. Feature stimuli clearly should be more familiar than new stimuli; the failure to find an error-rate difference provides additional evidence against a simple familiarity-based explanation for our results. Thus, although we cannot completely rule out a familiarity-based explanation, such an explanation is not well supported by our results. Other popular models also attribute recognition performance to the overall familiarity generated by the test stimulus. For instance, the SAM model (Raaijmakers & Shiffrin, 1981) proposes that recognition is determined by the generalized familiarity rating that is assigned to a test stimulus on the basis of a comparison of the stimulus with traces stored during study. Our results do not support such an explanation.

Applications to Issues of Real-World Identifications

There are applied, as well as theoretical, implications of the results. In real-world situations, individuals may falsely recognize a stimulus if all of its features have been experienced across several stimuli. Experiments 3–6 indicate that this may be a problem in eyewitness identification of faces; however, it should be pointed out that witnesses are often asked to recognize stimuli other than faces (for instance, cars or license plate numbers). In this regard, it is relevant to note that we have demonstrated that memory-conjunction errors occur across a wide variety of stimuli. Finally, in our experiments, stimuli were viewed relatively briefly and were viewed only once. These viewing conditions caused the subjects to frequently make memory-conjunction errors, and these are exactly the conditions under which many witnesses view critical stimuli.

Nonetheless, the proposal that witnesses make memory-conjunction errors for faces must be considered speculative for several reasons. First, the drawings of faces used in our experiments were far less information-rich than real faces. Second, there is evidence that pictures of faces are processed differently from faces viewed in more real-world settings (see, e.g., Bruce & Valentine, 1988; Read, Vokey, & Hammersley, 1990). Finally, several studies have shown that subjects may encode a face either holistically or as a set of features, depending on the task (Bower & Karlin, 1974; Wells & Turtle, 1988). Recognition performance is typically better when faces are processed holistically (Wells & Hryciw, 1984). It is possible that some aspect of our stimuli or of our task led the subjects to encode the faces as sets of features. A study task that was likely to lead to holistic encoding, such as personality assessment, might greatly decrease the frequency of memory-conjunction errors.

Final Comments

In our experiments, we borrowed a procedure developed by Treisman and Schmidt (1982) to study the formation of percepts. In their studies, subjects were more likely to incorrectly respond that a target was present when all of its features were present in a brief visual display than when only some of the target features were present in the display. Their conclusion was that visual percepts are constructed from quasi-independent visual features. We also found more conjunction than feature errors; however, in our experiments, the subjects were accessing memories rather than perceiving stimuli. The analogous conclusion to be drawn is that memories for previously viewed stimuli are constructed from quasi-independent stored features. We believe that the general approach that we have described for investigating retrieval errors holds great promise, both for studying issues relevant to eyewitness accuracy and, more generally, for investigating the processes underlying memory retrieval.

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