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UNIVERSITY OF CALIFORNIA  
RIVERSIDE

Interference in a Modified Recognition Task: An Evaluation of the Changed-trace  
and Multiple-trace Hypotheses

A Dissertation submitted in partial satisfaction  
of the requirements for the degree of

Doctor of Philosophy

in

Psychology

by

Anne Katherine Cybenko

December 2011

Dissertation Committee:

Dr. Steven Clark, Chairperson

Dr. Robert Rosenthal

Dr. Larry Rosenblum

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2011

The Dissertation of Anne Katherine Cybenko is approved:

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Committee Chairperson

University of California, Riverside

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## ABSTRACT OF THE DISSERTATION

Interference in a Modified Recognition Task: An Evaluation of the Changed-trace  
and Multiple-trace Hypotheses

by

Anne Katherine Cybenko

Doctor of Philosophy, Graduate Program in Psychology  
University of California, Riverside, December 2011  
Dr. Steven E. Clark, Chairperson

The changed-trace and multiple-trace theories of interference were tested in a series of six experiments. The changed-trace hypothesis attributes interference to a rewriting of an initial memory trace. The multiple-trace hypothesis attributes interference to a competition between separate memory traces. Experiments 1 and 2 replicated the modified recognition test used by Chandler (1989, 1991) and provide support for the changed-trace hypothesis due to the strong evidence of retroactive interference, but lack of evidence for proactive interference. The rest

of the experiments modify the basic paradigm by changing the type of stimuli (Experiments 3 and 4 introduce words as stimuli instead of images) and the number of presentations of stimuli (Experiments 5 and 6 increase the number of times the interfering stimuli are shown). These changes resulted in evidence for both proactive and retroactive interference. Proactive interference was found in the experiments that used a modified version of Chandler's methodology, supporting the multiple trace hypothesis. If a memory trace is changed, proactive interference will not occur. The lack of evidence for proactive interference rules out a purely changed-trace interpretation of interference effects.



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## **Introduction**

Forgetting is an everyday occurrence that can be inconsequential, (not remembering what was for dinner a few nights ago), a minor annoyance (not remembering where you parked your car that morning), embarrassing (not remembering a new coworker's name), or life changing (a misidentification from a lineup that leads to the imprisonment of an innocent person). It happens to everyone, yet it is not understood when, why, or how forgetting occurs. This dissertation is focused on how information that is learned before or after the learning of target information affects the forgetting of that target information.

The term, forgetting, in the context of memory and psychological research refers to the inability to recall something that was previously stored in short-term or long-term memory. Ebbinghaus (translated 1913) was the first scientist to document experimental research on forgetting by publishing the results of studies that he performed on himself. His experiments used very basic stimuli: nonsense strings of three letters (consonant – vowel – consonant) which he would learn and try to recall under a number of different conditions. His variables included: length of the series, number of repetitions, time between learning and recall, and repeated learning. The forgetting curve, a curve that displays how information is lost from memory over time, is one of the first findings in the broad research field of forgetting, and initiated a large body of research directed to the question: Why do we forget?

While there are many theories that have been developed and tested to answer the question of why we forget (many of which will be discussed later on), the current dissertation is focused on one theory of forgetting – the interference theory. The foundation of the interference theory is that we forget things due to the interference from other memories. People forget someone's name because they met 10 other people and those names interfered with the memory of the first person they met. Interference theory is a popular and well studied theory of forgetting and supporters of this theory are divided into two camps. One camp supports the changed-trace hypothesis - that is a memory trace is altered by subsequent information resulting in a forgetting of the initial stimulus. The second camp supports the multiple-trace hypothesis, in which a memory trace is created for each stimulus, but having multiple similar stimuli interferes with the retrieval of the correct stimulus. Although considerable progress has been made in developing theories of forgetting, a fundamental question has not been fully resolved: Is memory interference due to the addition of new memories or to changes in existing memories?

This question, first raised in the late 19<sup>th</sup> century, received renewed interest in the 1970's due to a series of experiments conducted by Elizabeth Loftus (for example, Loftus, Miller, & Burns, 1978) that had important implications regarding the reliability of eyewitness testimony in legal cases. Loftus's experiments showed that misleading, false misinformation, presented to an eyewitness after a witnessed event, could interfere with the witness's memory of

that event. In this context, the question of whether the original memory was still accessible or altered and forever lost, took on new importance. Loftus and her colleagues argued that the original memory was changed by the misinformation, whereas others, notably McCloskey and Zaragoza (1985) argued that the original information and the misinformation co-existed in separate memory traces, implying that the original memory was not altered due to a witness's exposure to misinformation. McCloskey and Zaragoza developed a new experimental paradigm, used later by Chandler (1989, 1991), to test between the two theories of interference. As will be shown, Chandler's results were complicated, and they did not resolve the controversy, or point clearly to one theory over another. This dissertation uses the experimental paradigm developed by McCloskey, Zaragoza, and Chandler, to reopen the investigation into the mechanisms of memory interference.

The introduction reviews the literature on theories of forgetting, with an emphasis on interference theories, and traces that literature to the work of Loftus, McCloskey and Zaragoza, and Chandler. Six new experiments are presented that establish the reliability of Chandler's results and extends her experimental paradigm in further investigation of multiple-trace and changed-trace theories of interference.

## **Theories of Forgetting**

### *Decay Theory*

The main idea driving the decay theory of forgetting is that memory fades over time due only to the passage of time. Thorndike (1914) coined the term decay theory following the work of Ebbinghaus, who showed that his memory for nonsense words decreased over time.

Baldwin and Shaw (1895) followed Ebbinghaus's work. They presented a classroom full of students with a drawing of a square on a blackboard. Students were tested on their memory for the square after a 10, 20, or 40 minute retention interval during which the students took notes on material for class. For each trial, memory was tested in one of two ways: recognition or identification. For the recognition test, participants were presented with a set of different squares, one of which was the target, and participants had to identify the target square. For the identification test, participants were presented with a test square, which was the same as the target and asked if the square they saw at the beginning of class was larger, smaller, or equal in size to the square that was being presented. They found that the percentage correct decreased as the retention interval increased for both types of testing. They concluded that their results supported the decay theory.



Hanawalt (1937) replicated Baldwin and Shaw's methodology using a between subjects design and found the same forgetting function using retention intervals that ranged from mere seconds to eight weeks.

Decay theory lost a lot of support in the early 1900's when researchers such as Jenkins and Dallenbach (1924) found that time alone doesn't account for forgetting.

### *Consolidation Theory*

The consolidation theory, proposed by Muller and Pilzecker, 1900, suggests that the learning of a stimulus continues after the stimulus is removed, and therefore memory is susceptible to disruption for a span of time. Memory for newly learned nonsense syllables was greatly impaired if new syllables were presented right after the original syllables. Participants were presented with a list of nonsense syllables. Emphasis was put on every other syllable which put the nonsense syllables into pairs. For testing, participants were given the first syllable from each pair and asked to recall the second syllables. However, if there was time between the presentation of the sets of syllables, memory was not as impaired. The new material interfered with the continued learning of the older stimulus. This theory was immediately favored by those studying amnesia as the consolidation theory does provide a possible explanation for retrograde amnesia, which is a loss of access to memory of the past due to a physical problem with the brain due to injury or illness (Burnham, 1903).

A number of studies were conducted starting in the 1950's to try to figure out how long it takes for a memory to consolidate. However, consistent results were never found as the estimated time varied from seconds to days depending on the conditions of each individual experiment (McGaugh & Herz, 1972; McGaugh. 2000). This view is still held by neuroscientists who have found evidence for it at the neural level (Lechner, Squire, & Byrne, 1999), but is currently largely ignored in psychology literature (Wixted, 2004).

### *Cue-Dependent Forgetting*

Cue-dependent forgetting is the inability to retrieve a memory because a stimulus or cue that was present at the time of the encoding of the stimulus is not utilized when the memory needs to be retrieved. The memory trace is intact and available but is temporarily forgotten simply because it cannot be retrieved. The first and most well-cited experiment on cue-dependent forgetting is Tulving and Pearlstone's 1966 word memory study. In this study, participants were presented with a list of 12, 24, or 48 words. These word lists contained 1, 2, or 4 words per category. Participants were given a free recall test after the list presentation. Participants were either given the category names as retrieval cues for some categories or no retrieval cues for other categories. Accuracy was higher when category label retrieval cues were given. This result indicates that words that are unable to be retrieved at the time of test without the category cue

are still stored in memory as intact memory traces. The problem is that they were only available for retrieval when the category labels were available as cues.

### *Interference Theory*

The interference theory forgetting is the final theory of forgetting that will be discussed in this dissertation as it is also the theory that this paper focuses on. The interference theory of forgetting states that the memory for an event can be affected by the learning of other related or unrelated events. The first study, conducted by Jenkins and Dallenbach (1924) provided evidence that time alone does not reduce memory of target items; instead, according to Jenkins and Dallenbach, it is the activities that the mind performs during the span of time that cause forgetting. Jenkins and Dallenbach, in their 1924 study, presented lists of nonsense syllables to two participants at various times of the night and day and with various retention intervals, then tested their memory for those nonsense syllables. Participants lived and slept in the lab, but during the day carried out their normal roles as students. In the no interference condition, the participants were awakened at night and presented the lists, and then awakened later to recall the lists. The interference condition examined the effect of the interference of daily activities and the lists of nonsense syllables were presented during the day. They examined recall after a 1, 2, 4, or 8 hour retention interval. They found a significant difference in rate of forgetting during sleep and waking. Participants across the retention intervals recalled twice as many syllables during the

sleeping condition than the awake condition. Their resulting argument was that if time alone caused forgetting, as was the idea behind the decay theory of forgetting, then there would be no difference between the sleeping and awake conditions. Results supported their hypothesis that there is more to forgetting than purely decay.

There are two types of interference: proactive interference and retroactive interference. Proactive interference is said to have occurred when an event or stimulus that precedes the target interferes with the memory for the target. Retroactive interference is said to have occurred when an event or stimulus that follows the target interferes with the memory of the target. Research on both types of interference will be discussed in detail in the next sections.

In addition to two types of interference, there are two schools of thought on why interference exists. Some support the changed-trace hypothesis and others support the multiple-trace hypothesis. The idea behind the changed-trace hypothesis is that interference occurs because information that follows an event can change the memory trace of that event. The multiple-trace hypothesis, on the other hand, states that each individual event creates its own memory trace and interference is not due to a change in the memory trace, but rather due to a retrieval problem. Again, evidence for both of these theories will be discussed in further detail below.

## **History of Interference Theory**

### *Retroactive Interference*

Muller and Pilzecker (1900) were the first to describe retroactive interference and the basic methodology for studying it. They presented participants with a list of word pairs to be recalled later. Half of the participants then received a second list of word pairs 34 seconds later and the other half received no second list. A few minutes later, both groups were tested on a cued recall task. Participants were presented with a word and were asked to recall its paired word. They found that the group with the extra list had 23% accuracy and the group with no intervening list had an accuracy of 48%.

Muller and Pilzecker's (1900) work initiated a group of studies on retroactive interference. The type of stimuli varied from a chess layout (Skaggs, 1925) to a list of consonants (Robinson, 1927; Cheng, 1929). A few common patterns emerged from these early studies as to what factors determine the amount of retroactive interference. One of the most significant factors is how similar the interfering material is to the original to be remembered. Robinson (1920) initiated this line of research by having participants remember sets of numbers. Between presentation and recall of these numbers, he presented participants with more numbers, consonants, poetry, multiplication, or photos. Robinson found that participants who were given the second set of numbers recalled fewer of the original set of numbers than those in the other groups. The

conclusion was that the presence alone of intervening material doesn't cause interference, the type and quality of the material itself is what makes a difference.

Skaggs (1925) found similar results when participants had to reconstruct a chess board arrangement. Participants performed worse on the task when they were shown another similar chess board prior to recall than when they were shown a paper chess board with different chess men, multiplication problems, or post card images. As the intervening stimuli increased in similarity to the initial chessboard, he saw an increase in retroactive interference. Lund (1926), Robinson (1927), and Cheng (1929) found the same effect of similarity with nonsense words. McGeoch and McDonald (1931) and Johnson (1933) took a different approach and found that as the similarity of meaning of the words of the interfering list to the words on the to-be-remembered list increased, so did the amount of interference.

Another factor that affects the amount of retroactive interference is the amount of time between the original stimuli and the interpolated activity. However, results on this topic have been inconsistent. Robinson (1920) found no reliable differences or patterns when he tested a lapse of 5 minutes, 10 minutes or 15 minutes between reading the original list of numbers to be recalled and a second interfering list. This null effect could have been due to his intervals being too long as Spencer (1924) found that those who were given their interfering set of nonsense syllables 9 seconds after the original set had significantly more interference than those who were presented with the second set 20 minutes after

the original set. Skaggs (1925) also found that interference immediately following the initial presentation of stimuli has the most detrimental effect on recall.

Others (Spight, 1928; Van Ormer, 1932; Graves, 1936; Newman, 1939) have found evidence to support and/or expand the findings of Jenkins and Dallenbach. Newman (1939) found that if meaningful information was the information to be remembered instead of nonsense syllables, there was not a significant difference between the sleep and awake conditions. Participants in their study were told a story and later asked to recall it in as much detail as possible after a period of sleep or being awake. They recorded the number of details recalled by the participants and details were coded as either important to the focus of the story or insignificant. There was no difference between the sleeping and awake groups in terms of recall of significant details. This does go against the results of Jenkins and Dallenbach, but this could be due to a ceiling effect (86% in waking and 87% in sleeping) as there were only 12 significant items and both groups had a very high rate of accuracy. Those in the sleep (no interference) condition recalled a higher number (47%) of the insignificant details than those in the waking condition (36%), which is consistent with the results of Jenkins and Dallenbach.

McGeoch (1942) proposed a “transfer or competition response-theory” in which memory failure occurs because the wrong memories are retrieved. This is illustrated by a classic experimental paradigm, the A-B, A-D paradigm. In this paradigm, stimulus A is learned in association with stimulus B. Following this,

stimulus A is paired with stimulus D, so A is now paired with two different stimuli. Retroactive interference occurs if the second, A-D pairing interferes with the original A-B pair when participants are asked to recall B given A. The A-B and A-D memory traces compete with each other and the A-D pair dominates. This was all compared to a control condition, where the A-B list was followed with an unrelated D-E list.

Melton and Irwin (1940) thought interference was due to the interpolated information weakening the original memory traces. They presented participants with lists of 18 nonsense syllables. Participants were then presented with 5, 10, 20, or 40 trials of an interpolated list. Following the interpolated lists, all participants relearned the original list. Interference was measured by accuracy as compared to a control condition that did not receive any interpolated list. Performance decreased as the number of interpolated trials increased. Melton and Irwin also looked at the number of items from the interpolated list that became intrusions at the time of testing. The number of intrusions first increased and then decreased. Melton and Irwin attributed this strange combination of patterns of results to unlearning, or what they called, "Factor X". The original list information does not get reinforced or punished so instead it gets extinguished. The longer the intruding information is presented, the more of the original list gets extinguished.

Research using the AB-AC and AB-DE lists continued throughout the 1950's and 1960's. This technique has been modified a number of times, each



producing similar results and modifying the past ideas of interference theory. There have been far too many modifications to the interference theory to discuss here, but see Crowder (1976) and Postman (1961) for a more detailed discussion. The current versions of the interference theory, the changed-trace and multiple-trace hypotheses are the focus of this paper and will be discussed at length below.

### *Proactive Interference*

The study of proactive interference, the phenomena that material learned prior to learning a target stimulus will affect the memory of the target stimulus, got off to a later and less vigorous start than the study of retroactive interference. Whitely (1927) was the first to provide evidence for proactive interference. Whitely presented participants with a target list of words to be remembered, each of which was centered around a general theme. For example, all the words would be related to the Civil War. Participants were also given either a quiz on, or a summary of a topic that was either related or unrelated to the topic of their word list. This quiz or summary was presented to them right before the target word list, after the word list, or right before recall. He found that, compared to a control group, any interpolated information hindered later recall. The participants who were presented with material related to their lists showed the greatest hindrance as measured by percent correct and percent error in all temporal conditions. The extra information provided the most interference when immediately preceding

recall, followed by immediately preceding learning, and the participants who were presented with the extraneous information after learning showed the least amount of interference.

Similar to the studies on retroactive interference, the temporal interval between the potential interference and the target stimuli has an effect on the amount of interference. Maslow (1934) presented participants with 100 lists of 9 words each. Fifteen seconds after each list, they were asked to recall the list they just learned. Maslow varied the time between recall of one list (the proactive interference) and the presentation of the next list. The interval could be from 5 to 40 seconds in 5 second intervals. Maslow found an inverse relationship between intervening time and error rate.

Twenty years later, Underwood (1957) revisited the idea of proactive interference when he thought that the 75% loss in memory for nonsense words that were learned to perfection just 24 hours ago was too extreme to be purely retroactive inhibition. He proposed that the common practice of performing within subjects experiments, or giving participants practice lists was leading to proactive interference. Participants were being shown numerous lists within minutes, hours, or days of each other. He examined past studies that used participants for more than one condition. When plotting recall as a function of the number of lists the participant had previously learned, his predicted pattern emerged. He found that as the number of prior lists the participants had learned increased, their recall decreased substantially.

### *Retroactive and Proactive Interference Compared*

Whitley's (1927) article presented above was not only the first to really look at proactive interference, but also the first to compare the effects of proactive and retroactive interference. There were two levels of retroactive interference (interfering information could be given right after learning or just prior to recall), and one of proactive interference (interfering information presented just prior to learning). The strongest inhibition effect was retroactive presented just after learning, followed by the proactive interference and then the other retroactive condition. These results suggest that retroactive effects are stronger than proactive effects.

A plethora of studies have supported Whitley's finding that material presented to a participant after the target information is presented is more detrimental to their memory accuracy than material presented to a participant prior to the target information. Schmeidler (1939) found both proactive and retroactive interference on both a consonant learning and a visual line task. In all conditions, retroactive interference was stronger. The patterns of the amount of interference between conditions were parallel for both retroactive and proactive interference. McGeoch and Underwood (1943), Melton and Von Lacrum (1941), and Underwood (1945) all found the same pattern of superior interference for retroactive interference. Kalbaugh and Walls (1973) also show the effect for biographical and science materials. Underwood (1948) found a higher effect of

retroactive interference after a delay of 5 hours prior to recall, but no significant difference in retroactive and proactive inhibition after a delay of 48 hours.

Seidel (1959) presented participants with a combination of interfering lists both before and after the test list causing both proactive and retroactive interference for some participants. They found a stronger proactive interference effect when participants were presented with both interfering lists. Participants incorrectly recalled many more nonsense syllables from lists preceding the test list than those coming after it. For the participants presented with only one type of interfering list, participants who were presented with the interfering list before the target list made more mistakes than those receiving the interfering list after the target list..

### **Theories of Interference**

Researchers who support the interference theory of forgetting fall into two different camps regarding the mechanism that underlies interference. One group supports the changed-trace hypothesis, the other group supports the multiple-trace hypothesis. The main reason for conducting the experiments that will be presented is to add to the literature that tries to distinguish what is the mechanism of how interference occurs. The next section will describe both hypotheses behind the Interference theory in a mostly chronological order. It will become clear that the debate between supporters of the changed-trace and multiple trace hypotheses peaked and became heated in the 1980's.

Skaggs (1925) was the first proponent of the changed-trace hypothesis. His idea was that the presentation of new stimuli interferes with the consolidation of previous stimuli and will replace that memory trace.

McGeoch (1942) proposed another theory of forgetting to account for the interference seen in the laboratory. His response-competition theory (also referred to as multiple trace hypothesis) countered the consolidation theory and predicts that when there are two or more items that are potential responses to a memory query, the strength of the memory trace of each possible response determines which memory trace will be retrieved, in that the strongest trace will be retrieved. For example, if *cat* and *boat* are paired together followed by a later pairing of *cat* and *car*, *car* will be retrieved when a participant is given a prompt of *cat* because this pairing came later in the experiment and therefore the memory trace is stronger.

Probably the most well known studies presented in support of the changed-trace hypothesis were performed by Loftus (Loftus, Miller & Burns, 1978; Loftus & Loftus, 1980). Loftus, Miller, and Burns (1978) showed participants slides depicting a car driving on a street and getting involved in a car accident. The red car was on a side street and stopped at a stop sign (half of the participants) or a yield sign (the other half of the participants). The car turned and hit a pedestrian in a crosswalk. After the participants viewed the slides, participants responded to 20 questions. For participants in the misled condition, one of the questions contained misleading information that was inconsistent with

what they saw in the slides. Participants in the misled condition who had seen the yield sign in the slides were asked “Did another car pass the red Datsun when it was stopped at the stop sign?” (Loftus et al., 1978, p.20). Those in the control condition were asked “Did another car pass the red Datsun when it was stopped at the intersection?” (Loftus et al., 1978, p. 20). Participants were later given a forced-choice recognition test. Participants were asked to identify which slide they had seen previously from a pair of slides. One of the slides showed the car stopped at a stop sign and the other slide showed the car stopped at a yield sign. The question they were interested in was whether people in the misled condition would identify the original sign that they really saw, or if they would identify the sign that they were misled to think that they saw.

Participants in the misled condition chose the slide that contained the sign from the questionnaire and not the sign they had actually been presented with in the slides. The explanation for this result that was presented by the authors was that the new information (the yield sign) changed the memory of the original event (the stop sign).

Christiaansen and Ochalek (1983) conducted a pair of studies that suggest that the original memory trace is still available at the time of test. They presented participants with a series of 24 color slides depicting a shoplifting scene. Following the slide show, participants were presented with a narrative which was a detailed account of the scene that was just depicted in the slides. Participants in the experimental conditions were given some pieces of

information in the narrative that contradicted what had happened in the slides. Participants were given a test for their memory of the event 48 hours later. There were four different conditions in the experiment, a control condition and three experimental conditions. There was a control condition where the participants read the narrative that did not include any misleading information. Participants in the three experimental conditions read a narrative that included misleading information about what they had seen in the slides. Participants in two of the three experimental groups received a warning either right after reading the narrative (about 47 hours before testing) or right before testing (about 47 hours after reading the narrative). This warning stated that they had received some inaccurate information in the previous narrative and they should be wary of believing what they read. The final experimental group did not receive any warning and therefore was led to believe that the narrative was accurate.

The comparison that provided evidence for the multiple trace hypothesis was between the control condition and the biased condition and the control condition and the informed conditions. Those in the experimental condition who did not receive a warning performed significantly worse on the memory test (they responded with the inaccurate details from the narrative rather than the details from the original slide show). The participants who were warned of the misinformation right before testing had accuracy scores that were equal to those in the control condition. Participants who were warned right after the narrative that some of it was false had accuracy scores that were between the control and

without warning condition. The fact that the participants in the delayed/informed condition performed at the same rate as those who never received misleading information supports the idea that the original memory trace remained unchanged even with misleading information. If the original memory trace had been eliminated or modified with the misleading information, it would not be available even after participants were informed to not trust the narrative.

McCloskey and Zaragoza (1985) argued that the results of the Loftus studies on misleading post-event information do not discount the multiple trace hypothesis. They gave two plausible reasons for the results that were obtained in Loftus et al. (1978). The first was that participants did not encode the original stimulus (e.g. the stop sign in the slides), they did, however, encode the “misleading information” (e.g. the yield sign). The second explanation that McCloskey and Zaragoza presented that could explain the results of Loftus et al. was that participants did think they saw a stop sign in the slides, but trusted the experimenters when the yield sign came up in the questionnaire. McCloskey and Zaragoza’s study modified the basic misinformation methodology that was in the Loftus studies. Participants saw slides of a burglary. Participants saw 79 slides that showed a maintenance man enter an office, repair a chair, steal \$20 and a calculator and then leave the office. Within the slides were four embedded critical items. The items were a tool (hammer, wrench, or screwdriver), a soda can (Coke, 7-up, or Sunkist), a coffee jar (Folgers, Maxwell House, or Nescafe), and a magazine (Glamour, Vogue, or Mademoiselle).



The misinformation was presented to the participants in the form of a written account of what they were just presented in the slides (as opposed to in a questionnaire as in the Loftus studies). Each participant received two pieces of misinformation in the transcript and two pieces of correct information. Half of the participants were tested in the same way that the participants in the Loftus studies were tested – a forced-choice test where the options were the original stimuli versus the misleading stimuli. For example, if the participant saw a Coke in the slides and read about a 7-up in the synopsis, they were presented with a choice between the Coke and the 7-up in the standard recognition test. The other half of the participants were given a *modified recognition test*. The two options at test for the participants in the modified recognition test condition were the original stimulus and a novel stimulus-one that was not in the slides nor in the synopsis of the slides. For example, if the participant saw a Coke in the slides, and read about a 7-up in the synopsis, they were presented with a choice between a Coke and a Sunkist in the modified recognition test. The distinction between the recognition test used by Loftus et al. (1978) and that used by McCloskey and Zaragoza was the test used by Loftus et al. presented participants with a choice between the original information and the misinformation, whereas the modified McCloskey-Zaragoza test presented participants with a choice between the original information and a new choice option.

Participants who were tested using the recognition test used by Loftus et al. (1978) chose the misleading information (the 7-up) at test. However, participants who were tested using the modified recognition test were able to correctly identify the original item (Coke) indicating that the original memory trace was still intact. McCloskey and Zaragoza suggest that the Loftus results could have been a product of participants remembering both the original target and the interfering distracter and thinking that the experimenter wants them to pick the misleading information. A comparison of this methodology to others can be seen in Table 1.

Table 1

Summary of Misinformation Experiment Methodologies

Paper	Study	Misinformation	Testing	Type
Loftus et al.	Coke	7-up	Coke/7up	FCR
McCloskey & Zaragoza	Coke	7-up	Coke/Sunkist	FCR
Belli	Coke	7-up	Coke/Sunkist	y/n
Tversky & Tuchin	Coke	7-up	Coke/7-up/Sunkist	y/n

FCR = Forced Choice Recognition Test

y/n = Yes/No response for each testing option

Loftus, Schooler, and Wagenaar (1985) responded to McCloskey and Zaragoza's (1985) paper with some criticism of the reasoning behind the conclusions they made based on their methodology and results. They suggest

that the modified testing procedure is “not sufficiently sensitive to detect small impairments in memory” (Loftus et al, 1985, p. 376). They suggested that their testing procedure does not account for the possibility of memory blends, specifically that the interfering information does not replace the original memory trace, but rather features from both stimuli are blended together. Loftus (1977) provided evidence for this in terms of the memory of colors. Participants saw a series of slides that included an image of a green car. Later, participants were presented with incorrect interfering information that stated the car was blue. The test came later when participants were shown a series of color strips (including various shades of blue, shades of green, and some shades that were a green/blue mix) and were asked to identify the color of the car. Most participants rejected the green (the actual color of the car) and selected a pure blue or a blue/green blend. The rejection of the green response option suggested that the original memory trace had been eliminated or distorted. The selection of the blue/green color indicates that participants had integrated the new, interfering information into the old, original memory trace. Other studies have produced similar results. Weinberg, Wadsworth, and Baron (1983) found that participants who were presented with an initial image of a yellow yield sign, then received misleading information about a red stop sign, later identified a blend of the two – a red yield sign during the testing phase.

Loftus, Schooler, and Wagenaar proposed that participants in McCloskey and Zaragoza’s experiments may have had a memory that combined the two

objects (a Coke can and a 7-up can) so their memory did not match either of the choices they were asked to pick from at testing.

McCloskey and Zaragoza (1985b), in response to the criticism of Loftus et al (1985) and the suggestion of memory blends, state that the objection does not have significant merit. There is evidence that participants blend the original color with the misinformation color in their response, but that does not mean that their memories are blended together. There is not enough evidence for memory blends to use it as a plausible argument. Why does a yellow yield sign blended with a red stop sign produce a memory of a yellow stop sign as opposed to a red yield sign? There is no suggestion for how the process works nor is there much evidence that the process does occur, so McCloskey and Zaragoza (1985b) do not see it as a valid argument.

Loftus et al. recommended using a "betting form" recognition test where participants assign probability values to all possible responses. In the betting form test, if a participant is guessing between two responses, they would assign a 50 to both possible answers. Benzing (1985) (as cited in Loftus, Schooler, & Wagenaar, 1985) replicated McCloskey and Zaragoza's studies using a betting form test and found that participants who did not receive misinformation performed better than those who did receive misinformation.

In response to the betting form argument given by Loftus et al (1985), McCloskey and Zaragoza suggest that the betting form is more of a confidence in their memory test instead of an actual memory test. Someone can have the

correct memory, but for whatever reason may not be confident in it, or may not want to be totally wrong. They also point out that Benzinger's 1985 study did not use a correct counterbalancing methodology, and that the stimuli may have led to a systematic bias in results.

Zaragoza, McCloskey, and Jamis (1987) did a pair of follow up studies to McCloskey and Zaragoza's 1985 studies that used the same stimuli as the 1985 studies. Participants were shown a set of slides depicting a robbery and then were presented with a description of the slides. In the 1987 experiments, the summary contained correct information for the most part. There were two critical parts of the summary. For one of the critical pieces of information (soda, magazine, etc), the participants were presented with misinformation in the summary (told it was 7-up when there was really a Coke in the slides), whereas for another piece of critical information, they were given neutral information in the summary (there was a soda can on the desk when they had seen a Coke can). Comparisons were all done within subjects. Participants were tested using a prompted recall test. Questions were in the format of "The key to the desk was next to a \_\_\_\_ can?" (Zaragoza et al, 1987). They found that participants performed equally well on the recall test for items that had misinformation presented in the summary as those items that had neutral information presented in the summary. If the misinformation really changed the memory trace, participants should have performed considerably worse on the recall test for the misinformation items.

Belli (1989) and Tversky and Tuchin (1989) modified the test technique once again and used yes/no judgments at testing. Both papers presented results that were based on the same stimulus materials and presentation methodology (a slide showing a Vogue magazine, followed by a narrative that said it was a Mademoiselle magazine) that were used in McCloskey and Zaragoza (1985). At testing, participants were asked either two questions (Belli, 1989) or 3 questions (Tversky & Tuchin, 1989) for each critical item. Both studies asked a yes/no question about the critical item. For example, "Below the magazine rack there was a copy of Vogue magazine." (Tversky & Tuchin, 1989, p.87). Both studies also asked a yes/no question about a novel item. For example, "On the table was a copy of Glamour magazine." (Tversky & Tuchin, 1989, p.87) Tversky and Tuchin asked a third question about each critical item that Belli did not. They asked about the misinformation. For example, "There was a copy of Mademoiselle magazine on the table." (Tversky & Tuchin, 1989, p.87)

Belli (1989) and Tversky and Tuchin (1989) had some similar and some different findings. In both studies, misleading post-event information reduced the "Yes" responses to the question about the original item. Belli found that misled subjects were better than control subjects at rejecting the novel item. Tversky and Tuchin found that misled subjects were as good as the control subjects at rejecting the novel item. Their conclusions were that the misleading information did change the memory trace for the original information, which contradicts the results of McCloskey and Zaragoza (1985).

McCloskey and Zaragoza (1989) explained the results of both Belli (1989) and Tversky and Tuchin's (1989) by suggesting that their results were a product of response bias, source misattribution, and/or deliberation and the results do not provide evidence that misinformation impairs the original memory.

Bowman and Zaragoza (1989) studied the effect of modality on retroactive interference. Much of the earlier work on basic retroactive interference was conducted using a methodology where the target stimuli and the interfering stimuli were presented in the same modality (all words, all pictures, etc). However, much of the work on misleading post event information conducted in the late 1970's and early 1980's used images as the target stimuli and words as the misleading information. Bowman and Zaragoza had two conditions, one in which the target and interfering stimuli were a series of images depicting a maintenance man entering an office, fixing a chair, and stealing money and a calculator, and one in which the target and interfering stimuli were both a narrative describing the same maintenance man event that was depicted in the image conditions. They did not find significant interference when all items were presented visually ( 68% for control items and 75% for items with interference). They also did not find evidence of retroactive interference when all items were contained within a narrative ( 91% for control, 90% for items with interference). In this experiment, they used a modified recognition test. This modified recognition test has become a standard in the experiments that have continued to investigate the changed-trace and multiple-trace hypotheses. The modified

recognition test is where the test pairs were composed of the target stimulus and a novel, related stimulus as opposed to the more traditional recognition test where the choice is between the target and interfering stimuli. The interfering information was not present at test. The fact that they did not find any evidence of interference in this modified recognition test is an indication that the original memory trace was still available and had not been altered or erased by any misleading information.

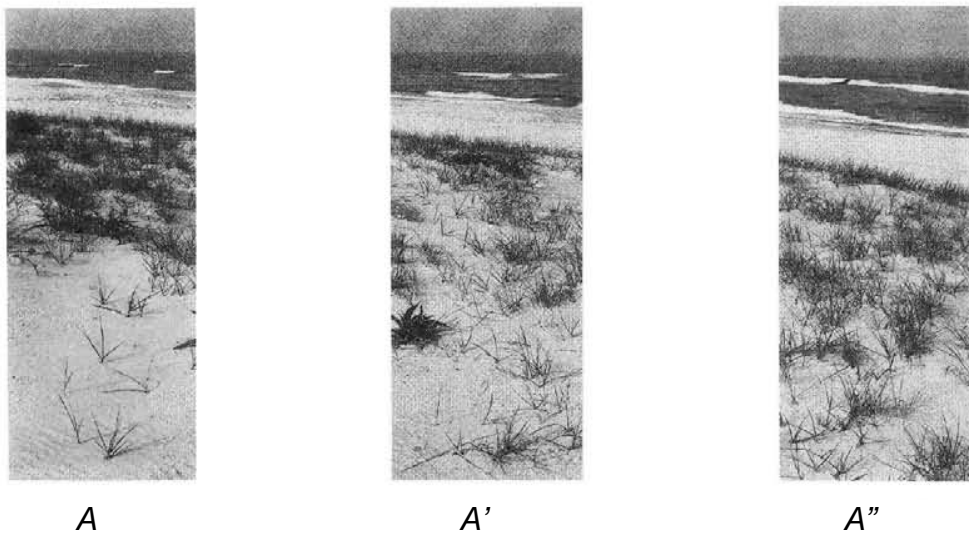
By 1989, after dozens of experiments, there was still no resolution, and no clear answer about the mechanisms of interference. There was strong evidence consistent with the changed-trace theory and strong evidence consistent with the multiple-trace theory. It seemed that the only things that were agreed upon were that 1. In the absence of an original memory, people adopt misinformation as the original memory, and 2. Misinformation can also impair the retrieval of the original memory or the memory itself. The underlying mechanisms, however, remained elusive.

### **Chandler's Experiments**

Chandler (1989, 1991) conducted a number of experiments using a technique similar to the one used by McCloskey and Zaragoza (1985) to study the changed trace/multiple trace debate. Chandler hypothesized that the results obtained by McCloskey and Zaragoza could have been a product of their stimuli



having too many unique discernable features such that even if the trace was altered, some of those features would remain unchanged. Thus, Chandler wanted to use stimuli that were very similar, without many unique discernable features. Chandler took nature photographs and cut them vertically to make three pictures, A, A', A'' (See Figure 1).



*Figure 1.* Example of a stimulus used in Chandler (1989, 1991)

The photographs all depicted scenes like a forest, flowers, a lake, rocks, a beach, etc. There were no stand-out features in any of the photographs – for example, if it was a beach scene, there were no people on the beach, no boats that would stand out, etc. A, A', and A'' were not very distinct from each other, reducing the number of unique features between them. It would not be enough for participants to remember seeing a pond and trees, as A, A', and A'' all contain those basic features. In her experiments, the A part of each photograph was the

target stimulus. *A* would always appear at test. Participants were presented with a series of these photographs that included *A* from each picture. Chandler's methodology was designed to look for evidence of both proactive and retroactive interference (between studies). In the studies looking for evidence of proactive interference, a second list was presented to participants before the *A* list. This prior list was composed of *A'* from half of the pictures. At test, participants were presented with a forced choice recognition task with *A* as the target and *A''* as the distracter. In the studies looking for evidence of retroactive interference, a second list was presented to participants after the *A* list. This subsequent list was composed of *A'* from half of the pictures. At test, participants were presented with a forced choice recognition task with *A* as the target and *A''* as the distracter.

In her 1989 and 1991 papers, Chandler conducted ten experiments. These experiments all used the same basic methodology as described above, each varied on one or more variables. The variables that Chandler used were: type of interference (retroactive or proactive), number of items, presentation time (amount of time the participant is allowed to view each picture from the target list), and delay between the presentation of the final stimuli and presentation of the first test item (with the exception of the 48 hour delay, the delay period was filled with unrelated conversation). The results of all of Chandler's experiments are presented in Table 2.

Table 2

Summary of Percent Correct Across Chandler's Experiments

Exp #	Year	Type	Items	Time	Delay	Condition	
						Control	Experimental
1	1989	Retro	48	10 sec	3 min	80	73*
2	1989	Retro	48	7.5 sec	10 min	79	72*
3	1989	Retro	48	4 sec	3 min	65	64
4	1989	Retro	140	8 sec	10 min	68	70
1	1991	Retro	48	10 sec	15 min	81	74*
2	1991	Retro	48	10 sec	48 hours	80	81
4	1991	Retro	54	10 sec	15min	80	73*
3	1991	Pro	48	6 sec	15 min	84	82
3	1991	Pro	48	10 sec	15 min	84	84
4	1991	Pro	54	10 sec	15 min	85	83

\* = Accuracy in the control condition is significantly better than accuracy in the experimental condition,  $p < .05$ .

Chandler found that recognition for the images where  $A'$  had been presented after  $A$  was worse than the control. There was no difference in performance between the control and the experimental conditions when  $A'$  had been presented before  $A$ . She found no proactive interference, but only retroactive interference. This finding supports the changed trace hypothesis because the multiple trace hypothesis would predict both proactive and

retroactive interference. However, when there was a significant delay (48 hours) between the presentation of the lists and the recognition task, no interference was found. According to the changed-trace hypothesis, the interference should remain constant over time because the original memory has been presumably changed. Chandler found no interference after 48 hours indicating that the original memory trace for *A* still remained unchanged.

### **Discussion of Chandler's Results**

The results of Chandler's 1989 and 1991 studies are somewhat anomalous, as they are inconsistent with the results of dozens of experiments showing proactive interference (Underwood, 1957) and inconsistent with modern theories of memory. More specifically, the fact that Chandler found no evidence of proactive interference in any of her studies stands out. Proactive interference is not known to be a phenomenon that occurs rarely. Evidence of proactive interference has been found in many studies since the beginning of research on interference (e.g. Underwood, 1957; Whitely, 1927; Maslow, 1935). Chandler's results necessitate follow-up studies that examine the absence of proactive interference. Is there something unique about Chandler's methodology and stimuli that might be illuminating as to the mechanisms behind proactive interference? Chandler used photographs as her stimuli, which is a change from the traditional proactive interference studies that mainly use words and syllables. The methodology used at testing in Chandler's experiments was also different

from the more traditional methodology. Chandler utilized a forced-choice recognition test, whereas most proactive interference studies use a recall or different recognition task.

Chandler's result of no evidence of proactive interference cannot be explained by most modern memory models, including a group of models generally characterizes as global matching models (see Clark & Gronlund, 1996). MINERVA 2 (Hintzman, 1988) is an example of such a model. MINERVA 2 assumes that events are stored in memory as separate, individual traces, even if an item is repeated. The presentation of a retrieval cue triggers all memory traces in parallel and traces are activated based on the similarity to the retrieval cue. SAM (Search of Associative Memory) is another global matching model (Raaijmakers & Shiffrin, 1981). In the SAM model, items are stored as separate memory traces. In addition to items being stored, the association strength between items is stored. When a cue is presented, the strength of the association between the cue and items in memory is what determines what memory traces are retrieved. Time is not a factor in SAM or MINERVA 2. An item that is similar to the target item has the same chance of interfering with the retrieval of the target item regardless of whether it was presented before or after the target item. Neither the SAM model nor MINERVA 2 (both of which have been well studied) can account for the Chandler's combination of results showing retroactive interference but no proactive interference. One of the goals of this dissertation is to try to understand the differences between Chandler's results

and the results from many previous memory experiments and well studied memory models.

The research on pure interference theory died down quite a bit after the late 1980's. However, there have been a few recent studies on the topic that have received much less publicity than those conducted in the 1980's. Payne, Togalia, and Anastasi (1994) found, in a meta-analysis of 44 experiments that utilized the modified procedure, that when combined, 30 of 40 cases showed a misinformation effect.

Windschitl (1996) conducted an experiment that used faces as stimuli. Windshitl used the modified recognition test and examined the effect of retention interval (10 minutes to 2 weeks) on interference. Participants were shown a series of faces, all of which had labels (such as "bride"). Then, they were shown a second list of faces that contained faces that were similar to, and had the same label as half of the faces from the target list. The test was a forced choice recognition test between the original face and a novel, similar face (the modified recognition test). He found that interference effects were evident after a retention interval of 10 minutes and 45 minutes, but not after a retention interval of 48 hours or 1 week. His results are extremely similar to the results found by Chandler, and provide evidence against the changed-trace hypothesis. Interference effects should not decrease over time if the interfering information changes the memory trace of the original information.

Chandler and Gargano (1998) found that if the potentially interfering part of the nature image was presented in the study phase, it was more likely to interfere than if it was presented after the study phase. This was also true when they used word pairs, indicating that the temporal aspect of interfering information is important.

While the research on pure interference theory has trailed off, it has not stopped. Fields such as eyewitness memory research have taken what has been learned about interference and applied it to a real world setting, which makes research on interference theory very much still relevant and interesting.

### **The Present Experiments**

There are two main questions that are related to each other that still remain unanswered. 1) Does a stimulus change the memory trace of a similar, preceding stimulus (changed-trace hypothesis) or do they coexist (multiple-trace hypothesis)? 2) Why is proactive interference found in some situations, but not in others? The most effective way to answer question number 1 may well be to look at question number 2. This dissertation will use and expand on Chandler's basic methodology to explore these two questions.

Since Chandler's methodology will be used as the base for this paper, the first step is to replicate Chandler's results. While she performed many variations of the basic task, just the basic experiment described above using both proactive and retroactive interference designs will be replicated. Chandler's results

should be replicated to determine the reliability of the basic results showing retroactive interference and no proactive interference.

Proactive interference, while not as strong as retroactive interference has still been found in many experiments, yet Chandler found no evidence of it. The second set of Experiments will examine whether Chandler's results are a product of her unique stimuli and different methodology or if proactive interference is a myth. I will use Chandler's experimental paradigm but the stimuli will be words instead of photographs. This will create a technique that is a hybrid of Chandler's experiments and Whitely's (1927) study. Whitely (1927) found proactive interference using related words as stimuli. Stimuli for Experiments 3 and 4 will be categories of words. There will be 6 words from each of 8 word categories as the target words. The interference will come either before or after the target list for each participant and will be a list of 6 different words from 4 of the original categories. This way half of the word categories have a list of interfering words and half do not. Instead of having each test item (*A*) have only one interfering item (*A'*), test items now have a number of interfering items. In this experiment, I would expect to find both proactive and retroactive interference due to the nature of the stimuli. All words that are presented are common, familiar words. There is not item-specific interference as there is in Chandler's experiments, instead it is a group of words that are interfering with another group of words.

Chandler's evidence against the multiple trace hypothesis is that there should have been proactive interference especially after 48 hours. This could be



a product of relative strength. If there are multiple memory traces, and competition between them only occurs when one is overwhelmingly strong and not when their strength is equal, Chandler's results are explained. Immediate retroactive interference occurs because the interfering information is much stronger because it was much more recent (relatively speaking). Proactive interference does not occur for the same reason – the information coming afterwards is stronger. No proactive or retroactive interference is found after 48 hours because the memory traces are not equal in strength. To test this modified multiple trace hypothesis, I will increase the strength of the interference. If *A'* is presented numerous times prior to the presentation of *A*, *A'* may suppress the target at testing and proactive interference will be seen. Multiple presentations of *A'* should not cause proactive interference according to the changed trace hypothesis as *A* will still change the memory trace and will be retrieved at test. Adjusting presentation time could also be a way to manipulate the strength of each memory trace. If all *A'* images are presented for a longer time than the *A* images, the trace of *A'* could be stronger and more likely to interfere.

## **Chapter 1**

### **Experiment 1**

Experiment 1 was conducted to gather evidence for item specific retroactive interference in a modified recognition test. Experiment 1 was a replication of Experiments 1 and 2 from Chandler (1989) and Experiment 1 from

Chandler (1991) in which the modified recognition test methodology was based on McCloskey and Zaragoza (1985). In this experiment, participants were presented with a sequence of target stimuli (nature photographs) one at a time. This was followed by another sequence of nature photographs that were very similar to half of the original target list. This second list was the potentially item specific interfering information. After a distracter task, participants were presented with pairs of images, one from the target list and a similar, novel one. If there is retroactive interference occurring, it will be evident by a higher accuracy for the target stimuli that had no similar interfering stimuli than those that did have similar interfering stimuli.

## **Method**

### **Participants**

Thirty-two undergraduate students from the University of California, Riverside participated in this study. Participants received course credit for an introductory psychology class for their participation. Recruitment took place through the psychology department online system.

### **Materials**

The materials for the study were created from 48 color photographs that were downloaded from a website dedicated to nature photography ([www.freenaturepictures.com](http://www.freenaturepictures.com)). Each photograph depicted a different nature scene (mountains, snow, trees, flowers, etc). Photographs were only used if the theme continued throughout the whole scene; if the photograph was of a lake,

the lake continued from left to right. Each photograph was divided vertically into three equal parts that will be referred to as A, A' and A". See Figure 2 for example stimuli. Stimuli remained digitized and were presented on powerpoint.





*Figure 2.* Examples of stimuli used in Experiments 1, 2, 4, & 5

### **Procedure**

Participants were tested in groups of one to eight. Testing took place in a conference room with participants seated around a table and the projection screen at the wall at the end of the table.

To keep timing consistent between Experiment 1 and later Experiments, participants began by doing 2 minutes and 24 seconds of math problems. These problems were given to them on a piece of paper and they were instructed to work on the problems as quickly as possible without sacrificing accuracy. The problems consisted of multiplication and division of one to three digit numbers. Participants were instructed not to use calculators but were allowed to show their work.

Once the time was up for the math problems, the study phase began. Participants were told that they were going to be presented with a group of photographs, one at a time. Participants were asked to pay close attention to each photograph. The lights were dimmed to allow better viewing of the photographs. One section (A) of each of the 48 stimuli photographs was presented sequentially for 10 seconds each for a total study time of 8 minutes. Sixteen of the study stimuli were the left side of the pictures, 16 were from the center of the pictures, and 16 were the right side of the pictures. These stimuli were presented in a random order.

After the study phase ended, participants were allowed to rest their eyes for a minute before the interfering phase began. Again, they were told that they would be presented with a set of photographs, presented sequentially, and they were to simply pay attention to each photograph. There were 24 photographs presented for 6 seconds each in the interfering phase for a total of two minutes and 24 seconds. These photographs were A' of 24 of the photographs from the study phase. Eight of these stimuli were another part of the photos where the left side was presented in the study phase, of these eight, four were the center part and four were the right part. The same rule applied to the photos where the right side and the center were presented in the study phase. These interfering stimuli were A' and the order was randomized between groups. The interfering stimuli were counterbalanced between participants in that the two parts of each photograph that were not used in the study phase were used as an interfering

stimulus. After the presentation of the final interfering stimulus, participants were instructed to return to their page of math problems for another five minutes. The math in this case was used solely as a distracter task to lengthen the time between the presentation of the study list and the memory test.

After the five minutes of math problems, participants were given their response sheet for the memory test. The response sheet was labeled from 1 – 48 and beside each of the numbers were the letters L and R. Participants were given the following instructions:

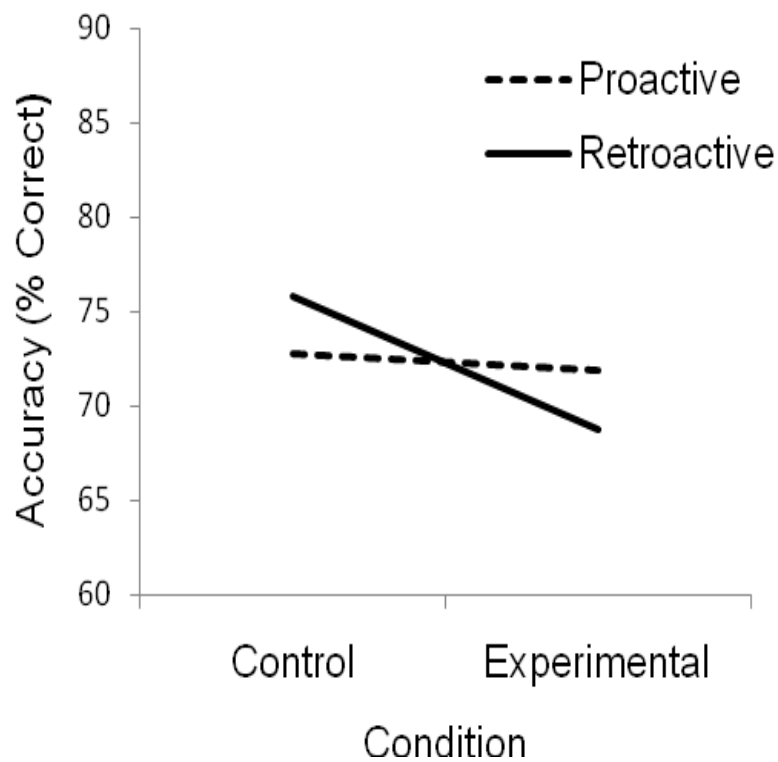
“You will be presented with two photographs at a time on the overhead. These photographs will be next to each other. One of these pictures was in one of the previous lists. Please circle L if the photo on the left is the one you have seen before. Please circle R if the photo on the right is the one you have seen before. Please don’t leave any blank, guess if you have to. Please do not circle both L and R for any one question. There are no trick questions. One and only one of the photographs is one that you’ve seen before in the study. Are there any questions?”

The test stimuli were presented for seven seconds each for a total test time of 5 minutes and 36 seconds, which was ample time for all participants to make their decisions. Each pair consisted of a photograph from the study list (A) and a novel part of that photograph (A’). The target, A, was presented on the left and the right an equal number of times. There were two types of stimuli at testing. The control stimuli (24 total) were those for which the target A was

presented in the study list, and no other part of that picture was presented in the interfering list. The Experimental stimuli (24 total) were those for which the target A was presented in the study list and A' was presented in the interfering list.

### Results

The results of Experiment 1 are all reported as the percent of correct responses at the time of testing (See Figure 3). Performance in the experimental condition (  $M = 68.7$ ,  $SD = 11.1$ ) was less accurate than that of the control condition (  $M = 75.8$ ,  $SD = 8.8$ ),  $t(31) = 4.682$ ,  $p < .001$ ,  $r = .644$ .



*Figure 3.* Results from Experiments 1 and 2

### **Discussion**

As predicted, the results of Experiment 1 provide evidence of retroactive interference in a modified recognition task using nature photographs. The retroactive interference is evident in the fact that accuracy in this within participant task was higher for the items that had no related interfering stimuli than those that did have interfering stimuli.

The results of this experiment support both the changed-trace and multiple-trace hypotheses but do not discriminate between the two. The changed-trace hypothesis predicts retroactive interference because the photograph that comes second (the interfering image) presumably changes or erases the memory trace of the first image. The multiple-trace hypothesis is also supported because the interfering list creates new memory traces that compete with, block, or cannot be discriminated from the original trace.

As was true for Chandler's experiments, this experiment was not conducted to discriminate between the changed trace and multiple trace hypotheses. This experiment was conducted to make sure that we could find evidence of retroactive interference in a modified recognition task using the stimuli that we created. The following five studies will help provide more insight into whether interfering information alters an original memory trace or creates a new one.



## **Experiment 2**

Like Experiment 1, Experiment 2 was conducted to replicate the results from Chandler (1991 Exp 3 & 4). Experiment 2 uses the same procedure as Experiment 1 with the exception of the placement of the interfering information. In Experiment 2, the interfering list was presented prior to the target list with the purpose of looking for evidence of proactive interference. The changed-trace hypothesis predicts no evidence of proactive interference because the second list (the target list) will still be accessible in memory. The multiple trace hypothesis on the other hand predicts that there will be evidence of proactive interference as that memory trace is still available and may interfere with the retrieval of the target memory trace.

### **Method**

#### **Participants**

Twenty-eight undergraduate students from the University of California, Riverside participated in this study. Participants received course credit for an introductory psychology class for their participation. Recruitment took place through the psychology department online system.

#### **Materials**

The materials used in Experiment 2 were the same materials used in Experiment 1.

#### **Procedure**

The procedure used in Experiment 2 was similar to the procedure used in Experiment 1 except for the order of the tasks. Participants were first presented with their interfering list of pictures, followed by the critical study list. To equate the amount of time between the study list and the test list for Experiments 1 and 2, participants in Experiment 2 worked on math problems for seven minutes and twenty-four seconds after the end of the study list. The study list, the test list, and the counterbalancing all remained the same between Experiment 1 and Experiment 2.

## **Results**

The results of Experiment 2 are reported as the percent of correct responses (See Figure 3). Performance in the interference condition (  $M = 71.88$ ,  $SD = 9.65$ ) was not significantly less accurate than performance in the control condition (  $M=72.77$ ,  $SD = 10.43$ ),  $t(27) = .486$ ,  $p = .631$ ,  $r = .093$

## **Discussion**

As with Experiment 1, the results of Experiment 2 showed the same pattern as those reported in Chandler (1991). No evidence for proactive interference was found using this modified recognition task. The lack of evidence for proactive interference supports the changed trace hypothesis but not the multiple trace hypothesis. If the changed trace hypothesis is correct, the original memory trace is changed by any subsequent presentation of that or a similar

stimulus, and the material from the target list will change the memory trace from the first interfering list rendering the interfering information unavailable and therefore no interference will be observed. As no proactive interference was detected, the changed trace hypothesis was supported by the results of Experiment 2.

The results of Experiment 2 do not support the multiple trace hypothesis. The multiple trace hypothesis predicted that proactive interference would be evident in Experiment 2. However, there was no evidence of proactive interference in this modified recognition test. So, the question that arises is why was there no proactive interference evident in Experiment 2 when proactive interference has been found in other studies?

The results of the present Experiment 1 (in addition to the results of the corresponding experiments in Chandler, 1989 and 1991) support both the changed trace and multiple trace hypotheses. The results of the present Experiment 2 (in addition to the results of the related experiments in Chandler, 1991) support the changed trace but not the multiple trace hypothesis. However, Chandler (1991, Exp 2) provided evidence in support of the multiple trace hypothesis that could not be explained by the changed trace hypothesis. In that study, Chandler increased the retention interval between presentation and test from a few minutes to 48 hours. According to the changed trace hypothesis, this should not change the amount of interference because the original item is no longer in its original form in memory as soon as the interfering information is

presented. Chandler found that when the retention interval was increased, evidence of retroactive interference disappeared. If the original memory trace was changed by the introduction of interfering information, there is no way for it to spontaneously regenerate to its original form resulting in the elimination of evidence for retroactive interference.

No proactive interference was found in Experiment 2; however, proactive interference has been found in a number of studies as described in the introduction. Why then, does proactive interference occur in some cases but not others? Experiments 3 and 4 were conducted with methodology very similar to Experiments 1 and 2 respectively, but a few significant changes were introduced to further examine the focus questions of why is there proactive interference sometimes and not others, and to support either the changed-trace or multiple-trace hypothesis.

## **Chapter 2**

### **Experiment 3**

Evidence for retroactive interference was found in Experiment 1 as well as in a number of Chandler's Experiments. However, as in Chandler's experiments, Experiment 2 produced no evidence of proactive interference. These results continue to challenge the well-established phenomenon of proactive interference. There are two main methodological differences between the present Experiment 2 (as well as Chandler's Experiments) and the typical experiment where proactive interference has been evident. 1. The current stimuli are pictures and the typical stimuli are words. 2. The current test methodology is a forced choice recognition test instead of the more typical cued recall test. Experiments 3 and 4 will address the first difference. The stimuli will be the typical words instead of images. As with Experiments 1 and 2, Experiments 3 and 4 are a pair of studies looking at the effect of interference with the former experiment looking for evidence of retroactive interference and the latter looking for evidence of proactive interference. The purpose of Experiment 3 was to test the common prediction of the changed-trace and multiple-trace hypotheses that retroactive interference will occur. In this experiment, the stimuli are groups of related words and the test is a modified recognition test.

## **Method**

### **Participants**

Twenty-nine undergraduate students from the University of California, Riverside participated in this study. Participants received course credit for an introductory psychology class for their participation. Recruitment took place through the psychology department online system.

### **Materials**

One hundred and forty-four words were used as stimuli in this study. Words were chosen from Van Overschelde, Rawson, and Dunlosky's (2004) category norms, which are an update of the Battig and Montague (1969) norms. The 18 most common words from eight of their categories were used. The categories were: animals, colors, body parts, fruits, sports, clothing, countries, and car models (See Table 3). These categories were used because the content of the lists were very different from each other and each list contained at least 20 words. The 18 words from each list were divided into 3 groups so that the words in each group had an average rank of 9.5 within the category. A target list was created by taking one of the groups from each category and randomizing the order. The remaining two groups were each used as the interfering words and the distracter words for half of the participants.

Table 3

Stimuli for Experiment 3 and Experiment 4

Animal	Color	Body Part	Vegetable	Sport	Car	Clothing	Country
Dog	Green	Arm	Carrot	Basketball	Toyota	Pants	America
Cat	Blue	Foot	Lettuce	Soccer	Ford	Sock	Canada
Horse	Red	Leg	Broccoli	Football	Honda	Shirt	France
Tiger	Purple	Finger	Peas	Baseball	Chevy	Underwear	Germany
Lion	Orange	Head	Tomato	Tennis	Mercedes	Shoe	Mexico
Bear	Yellow	Toe	Cucumber	Hockey	BMW	Hat	England
Elephant	Black	Nose	Potato	Volleyball	Jeep	Sweater	Italy
Deer	White	Eye	Celery	Swimming	Porsche	Shorts	China
Cow	Pink	Hand	Corn	Golf	Lexus	Jacket	Spain
Mouse	Indigo	Stomach	Onion	Rugby	VW	Skirt	Japan
Pig	Silver	Ear	Grn Beans	Lacrosse	Nissan	Jeans	Russia
Rat	Gold	Mouth	Spinach	Track	Dodge	Bra	Brazil
Rabbit	Gray	Knee	Cauliflower	Fld hockey	Audi	Coat	Iraq
Giraffe	Violet	Neck	Squash	Skiing	Mazda	Dress	Ireland
Squirrel	Brown	Heart	Beans	Softball	Ferrari	Gloves	Australia
Zebra	Magenta	Brain	Radish	Cheerleading	Volvo	Scarf	Argentina
Moose	Maroon	Hair	Asparagus	Running	Acura	Sweatshirt	Afghanistan
Goat	Turquoise	Elbow	Cabbage	Gymnastics	Mitsubishi	Boxers	India

**Procedure**

The procedure for Experiment 3 was based on the procedure used in Experiment 1. Participants were tested in groups of one to eight. Testing took place in a conference room with participants seated around a table and the

projection screen at the wall at the end of the table. Participants began by working on a page of math problems for 48 seconds. These problems were given to them on a piece of paper and they were instructed to work on the problems as quickly as possible without sacrificing accuracy. The problems consisted of multiplication and division of one to three digit numbers.

At the end of a minute, participants were asked to stop working on their math problems and to pay attention to the screen at the end of the room. They were told that they would be presented with a list of words and they were to pay attention to each word. The target list of 48 words was then presented one at a time for two seconds each. The presentation time for each stimulus in this experiment was shorter than in Experiments 1 and 2 due to the simplicity of the stimuli and the results of a pilot study that showed that longer presentation times produced a ceiling effect. Participants were then told that they would be presented with another list of words and told to again pay attention to each word. An interfering list of 24 words was then presented. This list was made up of six words from each of four of the categories. These were words that were not from the target list. Every word that was not on the target list was presented in this list one quarter of the time. Each word was again presented for 2 seconds.

After both the target list and the interfering list had been presented, participants were asked to continue working on their math problems for another five minutes prior to recognition testing. At the end of the five minutes, participants were given a response sheet with 48 word pairs on it. Each pair



consisted of a target word and a distracter word that was from the same category as the target word but was not yet presented in the experiment. Half of the pairs were from categories that had interfering words from that category presented to them. Participants were asked to circle the word from each pair that they had been presented with during the experiment. They were asked to not leave any blank and to only circle one word from each pair as there were no trick questions. Once the entire group had finished, participants were debriefed, thanked, and given credit for their participation.

### **Results**

The results of Experiment 3 are all reported as the percent of correct responses at the time of testing (See Figure 4) Performance in the interference condition was less accurate (  $M = 80.51$ ,  $SD = 11.30$  ) than that of the control condition (  $M = 85.62$ ,  $SD = 10.86$  ),  $t(28) = 2.139$ ,  $p = .013$ ,  $r = .375$ .

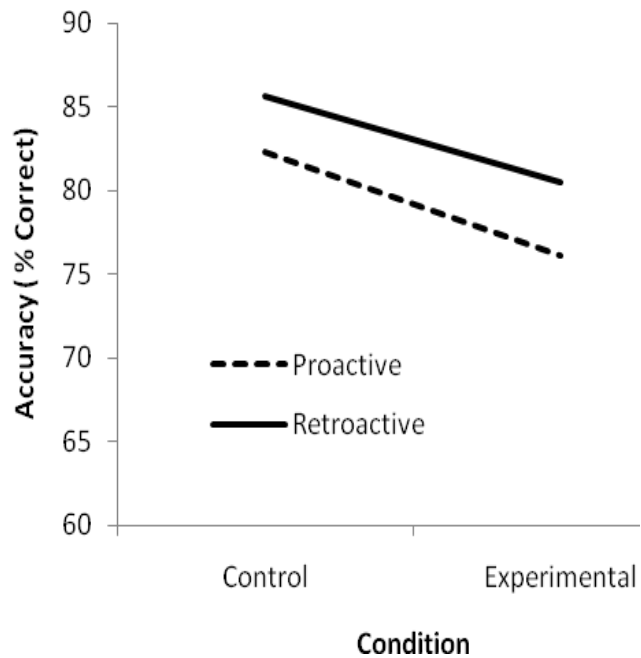


Figure 4. Results from Experiments 3 and 4

### Discussion

As predicted, the results of Experiment 3 provide support for both the changed-trace and multiple trace hypotheses by showing evidence of retroactive interference in the modified recognition test. Again, this experiment did not support one theory over the other, and was not meant to. The purpose of Experiment 3 was to test whether the word lists that were used as stimuli would produce retroactive interference, as predicted by both theories.

## **Experiment 4**

Experiments 1 and 3 provided evidence of retroactive interference, while Experiment 2 failed to find any evidence for proactive interference in the modified recognition task. The methodology for Experiment 4 is similar to that in Experiment 3 and used by Whitely (1927), who had participants study lists of words prior to studying a target list. In Whitely's 1927 experiment, words that were presented prior to the target list were either related to the target words or not related to the target words. Compared to a control condition, where only the target list was presented, participants who were presented with an interfering list prior to the target list showed poorer performance on the memory task. The participants who were presented with the related list prior to the target list had the most interference, followed by the participants who were presented with the unrelated list as their interfering information. Experiment 4 was conducted because the results will support either the changed-trace or multiple-trace hypothesis. If there is evidence of proactive interference, the results will support the multiple trace hypothesis and provide evidence against the changed-trace hypothesis. If there is no evidence of proactive interference, the results will support the changed-trace hypothesis and refute the multiple-trace hypothesis.

## **Method**

### **Participants**

Thirty one undergraduate students from the University of California, Riverside participated in this study. Participants received course credit for an introductory psychology class for their participation. Recruitment took place through the psychology department online system.

### **Materials**

The materials used in Experiment 4 were identical to the materials used in Experiment 3.

### **Procedure**

The procedure for Experiment 4 was very close to the procedure used for Experiment 3. The only difference came in the ordering of the interfering list of words. Participants in Experiment 3 were presented with the interfering list after the target list. Participants in Experiment 4 were presented with the interfering list of words prior to the target list. Participants began the experiment with the interfering list of 24 words, then were presented with the target list and ended with six minutes of math problems. The testing part of Experiments 3 and 4 were identical.

## **Results**

The results of Experiment 4 are all reported as the percent of correct responses at the time of testing (See Figure 4) Performance in the interference

condition was less accurate (  $M = 76.14$ ,  $SD = 12.49$  ) than that of the control condition (  $M = 82.33$ ,  $SD = 9.94$  ),  $t(30) = 2.66$ ,  $p = .013$ ,  $r = .437$ .

### **Discussion**

The results of Experiment 4 provided evidence of proactive interference using a modified recognition test when the stimuli were groups of related words. This is in contrast to the results of the current Experiment 2, and Chandler's experiments on proactive interference. This result is in line with the results of many interference studies that find evidence of proactive interference, and it supports the predictions of global matching models of memory. The important question is why was there evidence of proactive interference in Experiment 4, but not in Experiment 2?

The traditional multiple-trace hypothesis cannot account for the absence of proactive interference in Experiment 2 and in Chandler's (1991) experiments on retroactive interference. It is possible that the memory trace of the interfering information must be stronger in some way than the target information in order to have an interfering effect. If this is true, retroactive interference occurs because the interfering information has the benefit of being much more recent in the case where the retention interval is just a few minutes in length. The recency of the interfering memory trace makes it strong enough to interfere. This also explains why no retroactive interference was found in Chandler's (1991) experiment with the 48 hour retention interval. The recency of the interfering information is not

overwhelmingly stronger than the recency of the target list and therefore the interfering information no longer interferes.

It is possible that in Experiment 2, the memory trace for the prior interfering stimulus was not strong enough to really interfere. However, in Experiment 4, there were many related words that created enough competition for the target word that proactive interference was found. If this assumption is true, one should be able to find evidence for proactive interference using the methodology from Experiment 2 if the memory trace for the potentially interfering information is strong enough to actually interfere.

## **Chapter 3**

### **Experiment 5**

Experiments 5 and 6 were conducted to test the modified version of the multiple trace hypothesis as described above. Experiment 5 looked for evidence of retroactive interference when the memory trace was strengthened by increasing the number of presentations of the interfering list. The materials and procedure were nearly identical to that of Experiment 1, except that some of the images in the interfering list were shown multiple times. Both the changed-trace and multiple-trace hypothesis make the prediction that there will be evidence for retroactive interference in Experiment 5.

#### **Method**

##### **Participants**

Eighteen undergraduate students from the University of California, Riverside participated in this study. Participants received course credit for an introductory psychology class for their participation. Recruitment took place through the psychology department online system.

##### **Materials**

The materials for Experiment 5 were the same materials that were used in Experiments 1 and 2.

##### **Procedure**

Participants were tested in groups of one to eight. Testing took place in a conference room with participants seated around a table and the projection

screen at the wall at the end of the table.

Participants began by doing eight minutes of math problems. These problems were given to them on a piece of paper and they were instructed to work on the problems as quickly as possible without sacrificing accuracy. The problems consisted of multiplication and division of one to three digit numbers. Participants were instructed not to use calculators but were allowed to show their work. The purpose of the math problems was to keep the timing of the experiment consistent between Experiment 5 and Experiment 6.

Once the time was up for the math problems, the study phase began. Participants were told that they were going to be presented with a group of photographs, one at a time. Participants were asked to pay close attention to each photograph. The lights were dimmed to allow better viewing of the photographs. One section (A) of each of the 48 stimuli photographs was presented sequentially for 10 seconds each for a total study time of eight minutes. Sixteen of the study stimuli were the left side of the pictures, 16 were from the center of the pictures, and 16 were the right side of the pictures. These stimuli were presented in a random order that was the same for each participant.

After the study phase ended, participants were allowed to rest their eyes for a minute before the interfering phase began. Again, they were told that they would be presented with a set of photographs, presented sequentially, and they were to simply pay attention to each photograph. There were 32 photographs presented in this interfering phase. Sixteen of these photographs were



presented once for six seconds. Sixteen of these photographs were presented four times for six seconds each time. These photographs were a second part of 32 of the photographs from the study phase. These interfering stimuli were A' and the order was randomized. After the presentation of the final interfering stimulus, participants were instructed to return to their page of math problems for another five minutes. The math in this case was used solely as a distracter task to lengthen the time between the presentation of the study list and the memory test.

After the five minutes of math problems, participants were given their response sheet for the memory test. The response sheet was labeled from 1 – 48 and beside each of the numbers was the letters L and R. Participants were given the following instructions:

“You will be presented with two photographs at a time on the overhead. These photographs will be next to each other. One of these pictures was in one of the previous lists. Please circle L if the photo on the left is the one you have seen before. Please circle R if the photo on the right is the one you have seen before. Please don't leave any blank, guess if you have to. Please do not circle both L and R for any one question. There are no trick questions. One and only one of the photographs is one that you've seen before in the study. Are there any questions?”

The test stimuli were presented for seven seconds each for a total test time of 5 minutes and 36 seconds, which was ample time for all participants to

make their decisions. Each pair consisted of a photograph from the study list (*A*) and a novel part of that photograph (*A'*). The target, *A*, was presented on the left and the right an equal number of times. The two other parts of each photograph were used as *A'* and were counterbalanced between groups.

### Results

The results of Experiment 5 are all reported as the percent of correct responses (See Figure 5). Performance in multiple exposure Experimental condition (  $M = 67.78$ ,  $SD = 12.33$ ) was worse than performance in the single exposure Experimental condition (  $M = 72.25$ ,  $SD = 12.66$ ), which was worse than performance in the control condition (  $M = 76.79$ ,  $SD = 14.35$  ),  $F(2,34) = 8.534$ ,  $p = .001$ .

Tukey tests and paired samples t-tests revealed that the accuracy in the control condition was significantly higher than both the single exposure condition ( $t(17) = 2.423$ ,  $p = .027$ ,  $r = .507$ ) and the multiple exposure condition ( $t(17) = 3.423$ ,  $p = .0032$ ,  $r = .639$ ). The accuracy of the single exposure condition was also significantly higher than the multiple exposure condition ( $t(17) = 2.284$ ,  $p = .036$ ,  $r = .485$  ).

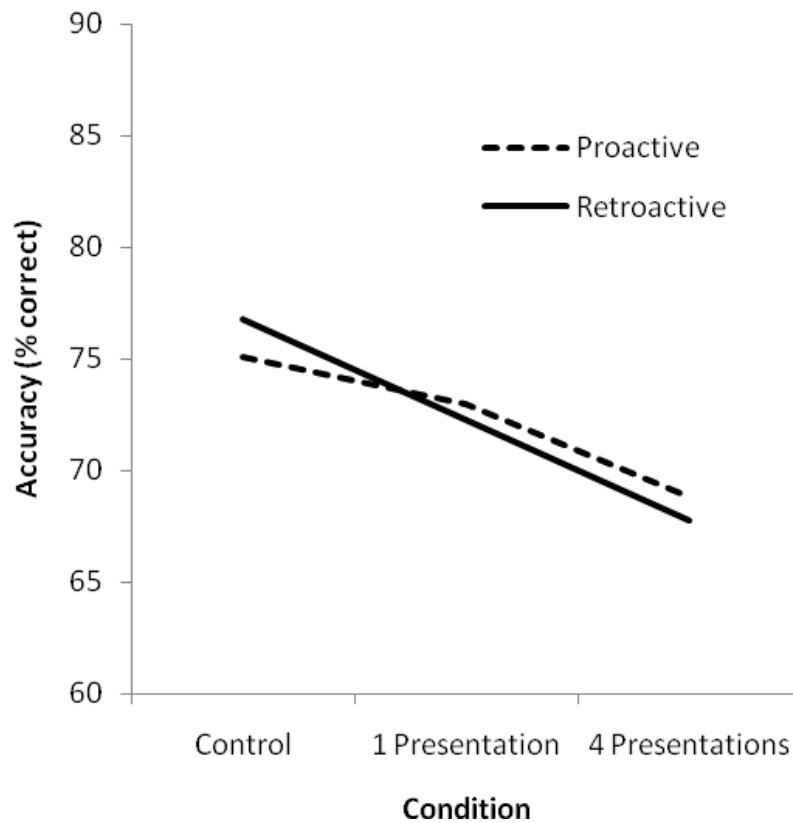


Figure 5. Results from Experiments 5 and 6

### Discussion

Evidence for retroactive interference was again found in Experiment 5. This was evidenced by the fact that the accuracy on the memory test was worse for the images that had similar, interfering images. An interesting finding was that the more times an interfering image was presented, the more likely that the

image interfered with the memory for the target image. This will be discussed more at length in the general discussion after Experiment 6.

## **Experiment 6**

Experiment 6 was conducted to test the threshold theory of interference prediction that the lack of evidence for interference in Experiment 2 is due to the interfering information not being strong enough competition to noticeably interfere. According to the changed-trace hypothesis, proactive interference should not occur. If evidence of proactive interference is found in Experiment 6, the changed-trace hypothesis would not be supported

### **Method**

#### **Participants**

Twenty one undergraduate students from the University of California, Riverside participated in this study. Participants received course credit for an introductory psychology class for their participation. Recruitment took place through the psychology department online system.

#### **Materials**

The materials that were used in Experiment 6 were identical to those used in Experiments 1, 2, and 5.

#### **Procedure**

The procedure used in Experiment 6 was very similar to the procedure used in Experiment 5 except for the order of the tasks. Participants were first

presented with their interfering list of pictures instead of the math problems. The interfering list was then followed by the study list. In order to keep the amount of time between the study list and the test list the same as in Experiment 5, participants in Experiment 6 worked on math problems for thirteen minutes after the end of the study list. The study list and testing procedure all remained the same between Experiment 5 and Experiment 6.

### **Results**

The results of Experiment 6 are all reported as the percent of correct responses (See Figure 5). Performance in the multiple exposure Experimental condition was (  $M = 68.79$ ,  $SD = 12.79$ ) lower than performance in the single exposure Experimental condition (  $M = 72.95$ ,  $SD = 10.70$  ), which was also lower than performance in the control condition (  $M = 75.05$ ,  $SD = 10.80$ ),  $F(2,40) = 5.629$ ,  $p = .007$ .

Both a paired samples t-test (  $t(20) = 3.359$ ,  $p = .003$ ,  $r = .601$ ) and Tukey HSD (HSD = 4.67, HSD crit = 3.44) reveal a significant difference between the control condition and the multiple exposure experimental condition. Both tests also revealed no significant difference between the control condition and the single interfering stimulus condition,  $t(20) = 1.289$ ,  $p = .212$ ,  $r = .277$  HSD = 1.56.

The predicted pattern of results was tested using contrasts. Contrasts are a way to compare data to one or more hypothesized patterns (Rosenthal & Rosnow, 1991) Lambda weights for the no interfering stimuli condition and a

single interfering stimuli condition were both set at one. The weight for the four interfering stimuli condition was set at negative two. The results supported this predicted pattern that there was not a significant difference between the control and single interfering stimuli condition, but performance in both conditions was better than performance in the multiple exposure experimental condition  $t(20) = 3.164, p = .0047, r = .578$ .

### **Discussion**

The results of Experiment 6 are the probably the most significant and telling results from the current paper. Proactive interference was evident in Experiment 6 based on the fact that performance on the modified recognition test was worse for the stimuli that had multiple interfering photos than those that had single or no interfering images. This finding is in direct contrast to the prediction of the changed-trace hypothesis that proactive interference would not be evident. These results support a modified version of the multiple-trace hypothesis that interfering information will interfere if the memory trace is strong enough. By presenting the interfering information multiple times, the interfering memory traces were strong enough to interfere with the retrieval of the target stimuli. Implications of the results of Experiment 6 will be further discussed in the context of the results of Experiments 1-5 in the general discussion.

## **General Discussion**

### *Overview of Results*

This paper presented a series of six experiments that were conducted to empirically study the changed-trace and multiple-trace accounts of interference theories of forgetting. The basis of the changed-trace hypothesis is that interfering information changes an original memory trace. The basis of the multiple-trace hypothesis is that interfering information creates its own memory trace that is separate from the original, but can interfere with the original. Experiment 1 was conducted to determine whether significant interference would occur with the present methodology and stimuli. The methodology used was based on the methodology used by Chandler (1989, 1991). Evidence for retroactive interference was found, which is predicted by both interference hypotheses.

Experiment 2 was the first experiment that had the potential to differentiate the two hypotheses. The purpose of Experiment 2 was to find evidence that proactive interference exists using Chandler's (1989, 1991) methodology. According to the changed-trace hypothesis, proactive interference should not be evident in the modified recognition task because the target information came second and therefore changed the trace of the preceding similar information, so the intended interfering images will provide no interference. The multiple-trace hypothesis, on the other hand, does predict that proactive interference would be evident in Experiment 2 because the retrieval of

the target image from memory could be interfered with by the memory trace of the similar stimulus. No evidence of proactive interference was found in Experiment 2, which would support the changed-trace, but not the multiple trace theory of interference. However, there are a few pieces of evidence that do not support the changed-trace hypothesis. First, there are a number of studies, as described in the introduction, that have found proactive interference using a similar paradigm. Second, Chandler (1991) found that when the delay between presentation of the stimuli and test was increased to 48 hours, evidence of retroactive interference disappeared even though overall accuracy remained high. The only explanation of the results of that study is that the original memory trace is still in memory.

Experiments 3 and 4 were conducted to look for retroactive ( Exp 3) and proactive ( Exp 4) interference in a way that was similar to Experiments 1 and 2. The design of Experiments 3 and 4 was a combination of the modified recognition test used by Chandler (1989, 1991) and the present Experiments 1 and 2, and a word recognition test that is more typically used in traditional interference studies. No evidence of proactive interference was found in Experiment 2, but it has been found in previous word memory studies. Experiments 3 and 4 found evidence for retroactive and proactive interference respectively. The evidence for proactive interference in Experiment 4 but lack of evidence for proactive interference in Experiment 2 prompted a third pair of experiments to examine the plausibility of a modified version of the multiple-trace



hypothesis that takes into account the strength of any competing memory traces. One difference between Experiment 2 and Experiment 4 was that in Experiment 4 there were multiple related words that would interfere with any singular target word, but in Experiment 2 there was only one similar related image to interfere with any target image. Prior to test in Experiment 4, participants were exposed to twelve related words in the interfering condition, and six related words in the control condition. It is possible that the larger amount of potentially interfering information in Experiment 4 as compared to Experiment 2 produced the proactive interference. Perhaps the memory traces for the interpolated information in Experiment 2 were not strong enough to interfere with the recognition of the target stimuli, but the memory traces for the multiple interpolated words in Experiment 4 were strong enough to interfere with the recognition of the target stimuli. Experiments 5 and 6 were conducted to test this modified version of the multiple-trace hypothesis.

Experiment 5 and 6 modified the methodology used in Experiments 1 and 2 to include a multiple interfering stimuli condition. One-third of the target stimuli had related images presented four times either prior to ( Experiment 6 ) or following ( Experiment 5 ) the target list. The changed-trace hypothesis would again predict that Experiment 5 would show retroactive interference, and Experiment 6 would not show evidence of proactive interference. The multiple-trace hypothesis would again predict that Experiment 5 would show evidence of

retroactive interference and Experiment 6 would show evidence of proactive interference.

As predicted by both hypotheses, Experiment 5 showed evidence of retroactive interference. As predicted by the multiple-trace hypothesis but not by the changed-trace hypothesis, Experiment 6 provided evidence of retroactive interference. The results of Experiment 6 suggest that the changed trace hypothesis is not accurate. If subsequent stimuli change an original memory trace, there should not be evidence of proactive interference because the target stimulus would change the original stimulus that was presented in the interfering list.

#### *A modified multiple-trace hypothesis*

While the traditional multiple-trace hypothesis predicted proactive interference in Experiment 2, a modified version of the hypothesis (the threshold theory of interference) could possibly account for the lack of proactive interference in that experiment. It is reasonable that the competition between traces does not occur when the competitors are equal in strength to the target trace; instead interference only occurs when the competitors are overwhelmingly stronger than the target trace. It is unclear whether this is a stair-step or a more continuous process, and that should certainly be studied in the future. This theory is similar in some ways, and different in others to Bjork and Bjork's new theory of disuse (1988).

Bjork and Bjork (1988), in the new theory of disuse, suggest that the strength of competing information can affect the ability to retrieve target information. Their theory adds four assumptions to Thorndike's (1914) law of disuse. 1. There is a limit on how many items in memory can be retrieved at one point in time. 2. Every memory has both a storage (how well learned it is) and retrieval (how easy it is to access) strength. 3. Retrieving an item from memory makes it more retrievable in the future and makes other similar items less retrievable. 4. The storage strength and retrieval strength together determine whether an item is able to be retrieved at a given time. While this theory does not address the changed-trace and multiple-trace hypotheses, it is relevant to the current dissertation. In particular, the assumption that items in memory have different strengths. One way to increase the strength of a memory trace is to increase the number of presentations of that item. This in turn will decrease the retrieval strength of similar items. The results of the current set of studies can support those assumptions. As the memory trace is strengthened by multiple exposures in Experiments 5 and 6, the ability to retrieve similar items, even if they come afterwards is decreased.

The threshold theory of interference speaks more specifically to the multiple-trace/changed-trace debate than the new theory of disuse, and can account for the results of Chandler (1989, 1991) and the results of the current set of studies in a way that neither the traditional multiple-trace hypothesis nor the changed-trace hypothesis can. This modified hypothesis can account for the fact

that no proactive interference was found in Experiment 2, but proactive interference was found in Experiments 4 and 6. In Experiment 2, the memory traces for the interpolated information were not strong enough to compete with the memory trace for the target stimuli because the recency of the targets makes them stronger than the relatively older competitors. In this Experiment, each stimulus was only shown once, so the strength of all memory traces in terms of the frequency of presentations was the same. Experiment 6 increased the number of presentations of each of the stimuli in the interfering list. This increase in presentations of images from the interfering list increased the strength of the memory traces for these images and increased the competition between the target stimulus and the interfering stimulus at the time of test.

Evidence for this modified theory can also come from the results of Chandler (1991). She found that a delay of 48 hours between the presentation of stimuli and test, eliminated all evidence of both proactive and retroactive interference. Two days after the presentation of stimuli, the few minutes lapse between the presentation of the target stimuli and the interfering stimuli no longer crosses the threshold of being a large enough difference in memory trace strength to cause interference. Retroactive interference occurred in Chandler's experiments with a short retention interval because, relative to the time span of the experiment, the strength of the second, interfering stimuli was much stronger and the difference in strength crossed the threshold. This few minute difference was not enough to cross the threshold 48 hours later.

This modified theory has similarities to the source of activation confusion (SAC) model (Reder, et al, 2000). SAC is similar to ACT-R (Anderson, 1993), and is a computational memory model. Memory representations consist of semantic, perceptual, and episodic information, and nodes are activated by spreading activation and decay. SAC is specifically mentioned here because it takes into account the number of presentations, and the context of the presentations of a stimulus (episodic node) when accounting for the memory representation. The pattern of results that were produced by the current set of experiments would most likely be similar to the pattern of results that the SAC model would predict.

In addition to accounting for the results of the current Experiments, the Threshold Theory may be able to help explain the discrepancy in results from studies on the interference theory.

### *Future Directions*

Although the debate between supporters of the changed-trace hypothesis and the multiple-trace hypothesis has not been put to rest with this dissertation, the evidence against the pure changed-trace hypothesis is strong. The changed-trace hypothesis cannot account for the evidence for proactive interference found in Experiment 6. The threshold theory proposed here is supported by the current results, but needs further testing. If there are multiple traces that only compete

when they are of relatively equal strength, the question of what does “equal strength” mean is the logical next question.

Experiments 5 and 6 in the current dissertation only tested one way of increasing the strength of a memory trace for a stimulus. The number of presentations was the only manipulation in the current study. The next set of studies should examine what else can increase the memory strength of a stimulus so that similar stimuli that are experienced later do not interfere. Stimuli that occur later will always have the advantage of time; they are more recent. However, Chandler (1991) showed that the delay between presentation and test can become insignificant as evidence for retroactive interference disappeared with a 24 hour delay.

There are a number of experiments that could be conducted to determine the relative strength needed for one memory to interfere with another memory. For example, Experiment 6 could be replicated using more than 4 repetitions to see if the amount of interference decreases as the number of repetitions of the original stimuli is increased. Other variables that may decrease interference could be: size of the image (an image that is viewed larger may have a stronger memory trace than one that is viewed very small), presentation time, colored images vs. black and white, etc.

The goal of this dissertation was to present a set of 6 Experiments that supported a broad multiple-trace hypothesis of the interference theory. When taken as a group, the results of the Experiments provided evidence that the

changed-trace hypothesis, in its current form, is most likely inaccurate. The current studies provided evidence for a modified version of the multiple-trace hypothesis that should be studied in more detail in the future.

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