REDUCING RETROACTIVE INTERFERENCE THROUGH RECODING

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by

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Abstract

The purpose of the present study was to examine the effects of a recoding cue on retroactive interference experienced by grade 2 and grade 4 children. Children in the control condition learned one list of foods, while children in the experimental conditions learned two lists of foods. All children were asked to recall the first (or only) list learned 24 hours later in a free recall manner. Children in the retroactive interference/recoding conditions were informed of a perceptual recoding cue (that all the foods in the second list were green in colour) either after acquisition or just prior to the long-term retention test. The results indicated that 1) children in the recoding conditions experienced less retroactive interference than uninformed children, 2) both the younger and older children benefitted from the recoding cue regardless of time of instruction, and 3) the effects of the recoding cue were located primarily at storage. The perceptual recoding cue allowed the children to reorganize their memories and maintain them as two distinct sets of information.

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Reducing Retroactive Interference Through Recoding

An area of research that has important implications for children's long-term retention is the study of retroactive interference. Retroactive interference (RI) has been defined as the tendency for people to forget target information after learning additional information. This interference is usually increased when the two sets of information are similar and is decreased when the two sets are distinct (Bower, Thompson-Schill, & Tulving, 1994). Retroactive interference has been demonstrated through many different paradigms including matching recognition (Chandler, 1993), paired-associate learning lists (Bower et al., 1994), and free recall (Bower, Wagner, Newman, Randle, & Hodges, 1996).

A typical study of retroactive interference consists of a control group that learns only one list and at least one other, experimental group that learns two lists. The groups are then asked to recall the first (or only) list learned with the control group remembering more items than the experimental group. The experimental group exhibits retroactive interference when the second list learned interferes with recall of the first list (Howe, 1995).

The effects of retroactive interference on memories already in storage has direct application to concerns about suggestibility in legal cases, especially for child witnesses. More and more often young children are required to testify in court or give information in an investigation, particularly in cases of sexual abuse. This makes the question of how reliable children's memories are an important one to answer. Children involved in an investigation are often questioned many times, possibly by different individuals. They may be told different accounts of the incident which may affect their original memory of the event. Thus, a key part of determining the suggestibility of a child witness is to examine "the extent to which erroneous postevent information interferes with the original memory" (Ceci & Bruck, 1993, p. 412), as in retroactive interference research.

Distinctiveness and Retroactive Interference

Retroactive interference is greatest when the second set of information learned is highly similar to the first set of information learned, a phenomenon that can be explained in terms of distinctiveness theory. Distinctiveness can be defined as the processing of differences in items relative to their surrounding context (Howe, 1998a). Schmidt (1991) qualifies the concept by stating "events are distinctive if the stored representation of the event shares few features with other items in memory" (p. 524). The basic premise of this theory is that information that is distinctive and unique will be more memorable than less distinctive information. Distinctiveness may enhance and better integrate a memory trace through improving encoding and storage, through improving retrieval by allowing the memory to remain unique against a background of other memories, or it may do both. Through learning the related information, the original information loses the characteristics that make it a unique and discriminable memory in storage (Howe & Wadhawan, 1998).

When items lose the characteristics that make them unique (e.g., through learning subsequent similar items) then the potential for interference to occur is greatly increased (Howe & Wadhawan, 1998). These characteristics are then shared by a second set of information that was learned after the first set. The related information interferes with the memory of the original information, possibly leading to a merging of the two sets or a misattribution of facts learned to the wrong set (Howe, 1999).

Although distinctiveness theory accounts for the results of many retroactive interference studies it is not without problems. A major area of concern is the definition and operationalization of distinctiveness. For example, an item may be distinctive in one context but mundane and common in a second context. Also, what is viewed as distinctive varies from individual to individual and even varies within the same individual across time. It is also difficult to quantify distinctiveness. Deciding whether or not one item is more distinctive than a second item is a very subjective process. Thus, at present there is not a definition of distinctiveness that is context and subject free. However, despite problems with distinctiveness theory it remains the most parsimonious explanation for retroactive interference research and will be discussed further with regard to the present study.

Many studies with adult participants have been conducted that demonstrate the role of distinctiveness in retroactive interference. One study that demonstrates the effect of learning two sets of highly similar information was done by Chandler (1993) who used a matching recognition test to study retroactive interference. Because recognition of similar information was examined it was expected that, in accord with distinctiveness theory, the recognition of this information should be poor. The participants were required to learn names, some of which were followed by similar names (e.g. Robert Harris followed by Robert Knight). After learning the names, participants were given lists of first names and surnames and were asked to match them according to what they had previously learned.

The results showed that the names that were followed by similar names were matched correctly less often than names that were not followed by similar names. The author concluded that memory for the target names is interfered with retroactively by learning related names. Participants made fewer errors matching the names that were unique within the list because they were not interfered with by the other names learned and remained distinct. The names that were followed in the list by similar names did not remain distinct and participants made more errors matching these names (Chandler, 1993).

Bower et al. (1994) conducted a series of experiments manipulating the degree of similarity between learned paired-associates with adults. They compared retroactive interference in standard lists of related pairs and other lists of unrelated pairs. All participants were trained and tested using the A-B, A-C paradigm. The experiment consisted of three different conditions and in each condition participants were required to learn a different type of list. In the first condition participants learned one of three forms of an all-same list where the items were either all two-digit numbers, all consonants, or all famous names. Each participant in this condition learned only one form of the possible three lists. For example, participants who learned the all-same list which consisted of all famous names were presented with the names 'Picasso, Lincoln, and Marx' within the A-B, A-C paradigm. In the second condition participants learned one of three congruent lists, which consisted of pairs of numbers, consonants, and famous names so that although the lists were made up of different types of items the pairs were of the same type. For example, three A-B, A-C pairs within the same list may be '79, 56, and 18', 'V, M, and R, and 'Picasso, Lincoln, and Marx'. In the third condition participants learned a mispaired list, which consisted of randomly scrambled pairs from the congruent lists, so that none of the A-B, A-C pairs were of the same type of item. After learning the lists the participants were given cues from the list and were asked to recall their associated pairs which was done in a MMFR (modified modified free recall) format where all items were recalled.

The results showed that recall of the second list learned was nearly identical for each condition. Recall for the first list learned was highest among participants in the second condition who learned the congruent list. Thus, participants in the all-same and mispaired lists conditions demonstrated the most RI. The authors explain these findings by examining the contexts of the three different lists. The all-same list contained items all from the same category so none of the pairs were distinctive within their all-same list. The mispaired lists contained random pairs so none of the items in a pair were from the same category. Again, the pairs were not distinct from each other. In contrast, the congruent lists contained only one or two pairs from each category so participants were able to distinguish among them. The authors conclude that "the difficulty of learning and later remembering a given paired associate depends greatly on the context of other materials that are being learned concurrently" (p. 60). Thus, the two lists that contained highly similar pairs, the all-same lists and the mispaired lists, were not recalled as well as the congruent lists which contained distinct pairs (Bower et al., 1994).

Chandler (1989) also examined the role of distinctiveness in retroactive interference. Participants took part in each of three conditions: control, experimental/standard, and experimental/modified. The participants learned three lists of pictures in a within-participant design with each person being tested on recognition of 16 scenes for each condition. Each list contained 16 pictures from nature scenes which were matched with pictures taken from the same scene in the other two lists. The matched pictures were similar but not identical. The control condition involved learning one list of nature pictures (labelled A) which were paired with new pictures (labelled A′) taken from the same nature scene at test. They were required to recognize the pictures they had learned as compared with pictures they had not learned. In the experimental/standard condition participants studied the same original pictures (A) as in the control condition and then learned a second series of pictures which were taken from the same scene (A″). At test they were presented with pairs of the pictures they had learned (A paired with A″) and were asked to identify the original pictures (A). Thus, they were presented with both sets of previously learned pictures and were asked to recognize those pictures from the first set (A) learned. The experimental/ modified condition involved learning the A pictures followed by the related A′ pictures. At test participants were asked to identify the A pictures they had learned which were paired with never learned but related A″ pictures (Chandler, 1989).

The results showed that in the control conditions participants correctly recognized

80% of the learned pictures compared to 60% correct recognition of learned pictures in the experimental/standard condition and 73% correct recognition in the experimental/modified condition. In the control condition there was no interference since only one set of pictures was learned, leading to highly accurate recognition. The interference was highest in the experimental/standard condition because participants were required to choose targeted pictures from two sets of similar, learned pictures. A moderate level of interference was observed in the experimental/modified condition where participants were asked to choose between two similar pictures of which only one was previously learned (Chandler, 1989).

In summary, retroactive interference has been demonstrated in paradigms using names (Chandler, 1993), paired associates (Bower et al., 1994), and pictures (Chandler, 1989) with adult participants. Interference was shown to be greatest when the two sets of learned information were highly similar and interference was least when the two sets were distinct. Through learning a second set of similar information the memory of the first set of information loses its unique properties in memory. This may lead to a merging of the two memories and a loss of information or increased competition and confusion at time of output (Howe, 1995).

Historical Explanations of Retroactive Interference

In the past, two main explanations, one storage-based and the other retrieval-based, have been proposed as the source of retroactive interference in memory. The strongest version of the storage explanation involves the unlearning of the original information while the weaker version involves confusion between the two sets of information in memory. Thus, the memory trace of the original information may experience retroactive interference and decay in storage. The storage explanation states that the second material learned retroactively alters the memory trace of the original learned material, possibly making no longer available in storage. The second explanation of the source of retroactive interference is a retrieval explanation that involves response competition among the two sets of information learned. The second set of information is more recent in memory than the first set learned which makes it more prominent in memory and it will be recalled before the first set of information. The retrieval explanation states that although the two sets of information vary in degree of accessibility in memory the first set learned may still be accessible (Howe, 1995). This distinction between the two explanation enables them to be tested. If the first set of information cannot be recalled as well as the second set of information the storage explanation would be supported. However, if both sets of information can be recalled given the opportunity then the retrieval explanation would be supported.

Barnes and Underwood (1959), in a classic experiment, tested the unlearning and response competition hypotheses with adult participants. Altering the classic A-B, A-C list learning retroactive interference paradigm they used a Modified Modified Free Recall (MMFR) procedure. The authors proposed that if retroactive interference was a result of response competition at retrieval then allowing recall of both lists with no time limit should reduce competition and subsequently eliminate interference. However, if retroactive interference was a result of unlearning of the first list, then interference effects should still be observed. The results showed that although some unlearning effects were observed there were also instances where participants could recall items from both lists and identify which list each item recalled belonged to. The authors conclude that the interference observed was a result of both storage and retrieval effects (Barnes & Underwood, 1959).

More recent research examining storage and retrieval loci of retroactive interference has involved the use of mathematical modelling within the context of the trace integrity model. In a study of children's long-term retention, Howe (1995) estimated storage and retrieval contributions to retroactive interference within a paired-associate and a free recall paradigm. The trace integrity model is a nine-parameter mathematical model that estimates the theoretical processes involved in memory, which include forgetting, reminiscence, storage, and retrieval (for definitions of the parameters see Table 1). According to this model, if interference is due mainly to retrieval failure, the children in the retroactive interference conditions should show the greatest retrieval failures as compared to those in the control conditions and retrieval failures should be greatly reduced in the MMFR condition because response competition is eliminated (Howe, 1995).

The analyses showed that the majority of interference occurred as a result of storage failures. This was demonstrated in two ways: 1) through the trace integrity model, and 2) interference was not reduced in the MMFR condition. Therefore, the

Table 1

Definitions of the Parameters in the Trace-Integrity Framework

Process and Parameter	Description
Trace Forgetting	
S	The probability of storage failure
R	The probability of retrieval failure of information in storage
Trace Reminiscence	
a	The probability that information not in storage is redintegrated to a level above zero recall
r_1	The probability of two consecutive successes
r_2	The probability of three consecutive successes
r_3	The probability of four consecutive successes
f_1	The probability of a success following one error
f_2	The probability of a success following two consecutive errors
f_3	The probability of a success following three consecutive errors

Note. Adapted from "Misleading children's story recall: Forgetting and reminiscence of the facts", by M. Howe, 1991, Developmental Psychology, 27, p. 749.

results of this study support the storage-based explanation of retroactive interference (Howe, 1995).

The occurrence of retroactive interference has been well documented and the source of the interference is usually attributed either to an unlearning of the original information in storage, response competition between the two sets of information at retrieval, or both. Recently, studies with children using formal mathematical modelling techniques that provide reliable and independent measures of the processes involved have shown that the effects of retroactive interference are mainly located at storage.

Reducing Retroactive Interference by Recoding

Previous research, as discussed above, has extensively documented the effects of retroactive interference in memory. Researchers have also examined methods of decreasing the amount of interference experienced. One of the most prominent methods is the recoding of learned material. Participants learn two sets of information, as in typical retroactive interference studies, and prior to recall are given some sort of 'cue' or information about one of the sets that distinguishes it from the other set. Distinctiveness theory is frequently used as an explanation for the ability of a recoding cue to decrease retroactive interference. The two sets of information learned are usually highly similar leading to confusion and merging in memory. The recoding cue is typically a piece of information about one of the sets of information learned that enables the participants to reorganize and differentiate the two sets, leading to improved recall. Thus, the two sets of information which were initially highly similar become two distinct sets of information

(Bower & Mann, 1992).

One study that investigated whether or not a recoding cue can decrease retroactive interference was done by Bower and Mann (1992). Adult participants learned two lists of seemingly random letters. The second list actually spelled the phrase 'wealthybankersholiday' backwards, which served as the recoding cue. There were three conditions: 1) control which involved learning only List 1 and then recalling this list at test, 2) postinformed which involved learning List 1 and List 2 and then participants were informed of the recoding cue just prior to recalling List 1 and 3) uninformed which involved the same procedure as the postinformed condition except participants were not informed of the recoding cue. The authors hypothesized that if the recoding cue enables reorganization of the lists in memory then recall should be greater in the postinformed condition than in the uninformed condition.

The results confirmed the hypothesis that providing participants with a recoding cue improved recall of List 1. The postinformed group recalled more letters than the uninformed group but not more than the control group. Thus, providing participants with a way to reorganize List 2 increased their recall of List 1 even though the cue itself was not related to List 1 in any way. The authors concluded that "interference from learning a second set of material on a first set is substantially reduced by a postlearning cue enabling the learner to reorganize the interfering material" (Bower & Mann, 1992, p. 1317).

However, in a similar study examining the effects of a recoding cue no decreases in retroactive interference were found (Bower et al., 1996). The study consisted of a series of four different experiments, following the same basic procedure as the Bower and Mann (1992) study with variations in list content and type of recall. Participants learned two lists consisting of names of cities. The cities on the second list were also names of U.S. presidents (eg. Madison, Wisconsin) and this served as the recoding cue for those participants in the informed condition. None of the results of the experiments indicated any differences between the condition where participants were informed about the recoding cue and the condition where participants were not informed.

The authors offer two possible explanations for the failure to replicate the benefits of a recoding cue. First, in order to observe a reduction in retroactive interference in the postinformed condition there must be a high amount of interference in the uninformed condition which is used as a comparison and this did not occur in this study. Second, the recoding cue must be subtle enough that the participants in the uninformed condition will not automatically notice it but it must also be strong enough to allow participants in the postinformed condition to be able to use it to reorganize their memories of the list. This balance is difficult to achieve and may explain why the cues in this study were not useful in reducing retroactive interference (Bower et al., 1996).

Marsh, Landau, and Hicks (1996) proposed four main problems that must be addressed in an experiment examining the use of a recoding cue to reduce retroactive interference. The problems are 1) spontaneous awareness of the cue which could decrease interference in the uninformed group, 2) the use of an awkward or inefficient cue that could make reorganization difficult, 3) the use of experimenter cued recall (participants were given category of words to be recalled), which occurred in some studies of retroactive interference (e.g. Bower et al., 1996), could increase recall performance in the uninformed condition and 4) if the lists are highly similar leading to large amounts of inteference the recoding cue may not have an effect.

To examine the usefulness of a recoding cue Marsh et al. (1996) conducted three experiments with the goal of providing evidence that the postinformation effect can be reliably obtained by eliminating the four problems involved in earlier studies. The experiments followed the same general procedure of assigning participants to one of three conditions: uninformed, informed, and control. Participants were tested in small groups in Experiments 1 and 2 and individually in Experiment 3. The lists used in Experiments 1 and 3 were the same and the only difference between the two was that individual testing was done in Experiment 3. List 1 was composed of random words and List 2 consisted of words chosen from the song "Home on the Range". This served as the recoding cue for the participants in the informed condition. In Experiment 2, which was the same as Experiment 1 except the content of the lists was changed, List 1 was again composed of random words while List 2 was composed of nonredundant words from the nursery rhyme "Humpty Dumpty". This served as the recoding cue for the informed condition. For all three experiments there were large reductions in retroactive interference for the group that was informed of the reorganizing cue and the number of participants in the uninformed groups that automatically noticed the cue was very low. The authors concluded that "a postlearning cue about interfering material can improve the recall of earlier learned target information" (p. 1300).

Thus, it has been shown that a recoding cue given just prior to recall can decrease the amount of retroactive interference that originates when two sets of similar material are learned. However, for the recoding cue to be successful special consideration must be given to the occurrence of spontaneous awareness of the cue in the uninformed conditions, the type of cue, similarity of the lists and the procedure used during recall in any study examining the benefits of a recoding cue (Marsh et al., 1996). When these four points are followed, the cue allows participants to reorganize the two sets of information in memory as two distinct sets.

Retroactive Interference and Children's Memory

As can be seen through the previously discussed studies, interference in adult memory has been well researched. However, despite the extensive research many of the studies using adult participants have potential methodological shortcomings. First, the majority of the studies examining retroactive interference use immediate recall. Because retroactive interference increases over time recall immediately following acquisition provides a conservative estimate of interference. Second, recall in interference studies with adult participants usually consists of only one retention trial. Perhaps further trials would lead to increased recall.

Although only a few studies have examined the effects of retroactive interference in children's memory these methodological problems tend to be absent. For example, one study of children's memory four-, five-, and eight-year-olds participated in a series of paired associate tasks. The children learned two lists in an A-B, A-C format with a control group learning only one list. After a 24 hour retention interval the children in the retroactive interference condition were asked to recall the first list of pairs learned and the children in the MMFR condition were asked to recall both lists of pairs (Koppenaal, Krull, & Katz, 1964). The results of this early research indicated that children in the control condition recalled more items than the children in the retroactive interference and the MMFR conditions. This study demonstrates similar interference effects with children as have been found with adults (e.g., Bower et al., 1994). Also, age effects were observed whereby the youngest participants showed very little interference and the older participants, the eight year olds, showed the most interference (Koppenaal, et al., 1964).

In a more recent study, retroactive interference was examined in two experiments on children's memory. The first experiment consisted of a paired-associate recall procedure and the second experiment consisted of a free-recall procedure (Howe, 1995). Participants were four-year-olds and six-year-olds who were assigned to either a control condition which learned and a day later recalled one list, a retroactive interference group that learned two lists and a day later recalled the first list, or a MMFR group that learned two lists and a day later recalled both lists. The results showed no differences between the RI and MMFR conditions demonstrating that in this study interference was not the result of response competition at retrieval. The trace-integrity model was also used to determine the locus of interference effects in memory. What these analyses showed was that interference in both the RI and MMFR conditions was due to storage-based forgetting

(Howe, 1995). In addition, six-year-olds made fewer errors than four-year-olds, and younger children made more storage failures than older children. Thus, it was shown that children do experience retroactive interference, regardless of age and this interference is mainly a storage effect (Howe, 1995).

The study of retroactive interference and distinctiveness has also been examined with children, using a directed forgetting paradigm. Howe (1999) examined whether instructions to forget learned material could decrease interference with previously learned material. The participants, who were four-year-olds, were randomly assigned to one of four conditions: control, retroactive interference (RI), retroactive interference/directed forgetting at acquisition (RI/DF-acq) or retroactive interference/directed forgetting at long-term retention (RI/DF-ltr). Children in the control condition learned one story while the children in the other conditions learned two stories which differed in content but had the same structure and length. In the two directed forgetting conditions the experimenter told the children she had made a mistake by reading the second story and they should just forget it. The children were told this either immediately after acquisition or the next day, depending on the condition. Recall of both stories was assessed through a series of questions.

The results showed that compared to children in the control condition, children in the RI condition made more errors at recall demonstrating the effects of retroactive interference. Compared to children in the RI condition those in the RI/DF-acq condition made fewer errors but those in the RI/DF-ltr condition made the same number of errors.

Thus, directed forgetting decreased retroactive interference when the instruction was given at acquisition but not when it was given a day later, just prior to retention test (Howe, 1999). Trace-integrity analyses showed that retroactive interference effects for forgetting were mainly at storage and the decrease in interference due to directed forgetting in the RI/DF-acq condition was also based at storage (Howe, 1999).

Howe and Wadhawan (1998) also examined recoding effects with children using a conceptual cue. The conceptual lists consisted of names of toys (e.g., ball, yo-yo) with all the toys in the second list also being vehicles (e.g., car, boat). The participants were grade 2 and grade 4 students who were assigned to either a control group that learned and recalled one list, a retroactive interference/standard group that learned both lists and a day later recalled the first list, a retroactive interference/recoding at acquisition group that learned two lists and just after acquisition were informed of the second category present in the second list or a retroactive interference/recoding at long term retention group that learned the two lists and prior to retention test 24 hours later were told about the second category present in the second list.

The results were that the older children made fewer errors than the younger children and that the number of errors decreased across the four retention test trials. The control group made fewer errors than the RI groups. The older children in the recoding conditions showed a release from retroactive interference when they were informed of the cue regardless of whether they were informed at acquisition or retention. However, the younger children were able to benefit from the cue only when they were informed at acquisition. It is possible that the conceptual cue used in this study was too difficult or unfamiliar for the younger children to use to reorganize their memories when they were informed at long-term retention. That is, when informed at acquisition they were able to reorganize their memories but were unable to do so when informed 24 hours later.

To summarize, retroactive interference in children's memory has been examined through a directed forgetting paradigm (Howe, 1999), a paired-associate paradigm and a free recall procedure (Howe, 1995). There has also been one study of children's memory involving the benefits of a conceptual recoding cue given just prior to recall in which retroactive interference was reduced. It was suggested that the recoding cue enables the children to distinguish between the two lists and maintain them as two distinct sets of information in storage (Howe & Wadhawan, 1998).

The Present Study

The present study replicates and extends the recoding study with children using a perceptual, rather than conceptual, cue (Howe & Wadhawan, 1998). Different word lists were used and there were two conditions that received the recoding cue, one after acquisition and one prior to the test of retention. The recoding dimension used in this study was perceptual in nature unlike the previous studies which used conceptual or semantic dimensions. Previous research has shown that the ability to categorize conceptually increases across childhood with older children performing better than younger children (e.g. Perruchet, Frazier, & Lautrey, 1995). Howe and Wadhawan (1998) used conceptual recoding (different semantic categories) and this may explain why the older children could benefit from the cue whether they were informed at acquisition or at long-term retention while the younger children could only benefit when they were informed at acquisition. They suggested that it may have been that the younger children were unable to reorganize their memories of the two lists using the recoding cue after the memories had been consolidated at long-term retention. Perhaps if a simpler perceptual cue were used instead of a conceptual one, even the younger children would be able to benefit from the cue regardless of timing of the recoding instructions.

The main purpose of the present study was to determine whether a recoding cue could decrease the amount of retroactive interference children experience during long-term retention. The hypotheses of the study were 1) both the younger and the older children would demonstrate a decrease in retroactive interference when informed of the recoding cue, 2) the amount of retroactive interference experienced would be decreased whether the children were informed of the cue after acquisition or prior to long-term retention, and 3) recall would increase for all children across retention trials. Also, the trace-integrity model was used to determine where the effects of the interference and the release from interference were localized, at storage, retrieval, or both.

Method

Participants

79 grade 2 (M age = 7 years 8 months, Range = 7 years to 9 years 2 months) and 73 grade 4 (M age = 9 years 8 months, Range = 9 years 2 months to 11 years) from a local St. John's elementary school participated in this study. The students were tested

individually at the school. Consent was obtained from themi school board, schools, teachers, the parents of each of the children participating in the study, and the children themselves.

Materials

The two lists that were used in this study consisted of ten words each (all words are from Posnansky, 1978). The same number of words per list as in the Howe and Wadhawan (1998) study was used. Each list was equated on word length and frequency. Each word was individually printed on the middle of a 3" X 5" index card. List 1 consisted of ten common foods and List 2 consisted of ten common foods which are all green in colour (see Appendix A). Also, each child was given distractor sheets of a symbol-matching task and a pencil.

Design and Procedure

This study consisted of five conditions: control, retroactive interference/control (RI/C), retroactive interference/standard (RI/S), retroactive interference/recoding at acquisition (RI/R-acq), and retroactive interference/recoding at long-term retention (RI/R-ltr). The design was a 2 (age: grade 2, grade 4) X 5 (condition: control, RI/C, RI/S, RI/R-acq, RI/R-ltr) mixed factorial at acquisition and a 2 (age: grade 2, grade 4) X (condition: control, RI/C, RI/S, RI/R-acq, RI/R-ltr) X 4 (trial: 1-4) mixed factorial at long-term retention. The variables age and condition are between-subjects and the variable trial is within-subject.

The study consisted of two phases, acquisition and retention, which took place over a two day period. The children were tested individually for each phase of the study. The acquisition, or study, phase involved learning either one or two lists, depending on the condition, to a criterion of two consecutive errorless test trials. Each child was told they were going to play a memory game and they would be asked to remember some words. The words were read by the experimenter at a 5 second pace and the child was shown the index card with the word printed on it. For each child the words were presented in a random order achieved by shuffling the index cards. After reading the first list the child performed a distractor task for 20 seconds which required them to match symbols. This served to eliminate potential short-term memory effects. Then the child was asked to recall as many words as they could. This process of study, distractor, and test continued until the child correctly recalled all of the words for two consecutive test trials.

For the children in the control condition the acquisition phase ended when criterion was reached for the first list learned. Half of the children in the control condition learned List 1 and the other half learned List 2 to eliminate any potential differences due to lists. The children in the RI/S condition learned List 1 to criterion and went on to learn List 2 to criterion. They were asked to recall List 1 a day later. For the RI/C condition the words from List 1 and List 2 were mixed and randomly assigned to form two new lists, List 1′ and List 2′ (see Appendix B). The children learned the two lists and were asked to recall List 1′ a day later. This condition was used as a comparison for the RI/S condition to provide an estimate of spontaneous awareness of the recoding cue. Thus, similar levels of RI were expected in both the RI/C and RI/S conditions if there was no spontaneous awareness of the perceptual recoding cue. If levels are higher in the RI/C condition it may be due to automatic awareness of the recoding cue in the RI/S condition.

The children in the recoding conditions, RI/R-acq and RI/R-ltr, went on to learn List 2 to criterion following the same process as with List 1. These two conditions follow the same procedure, learning List 1 and then List 2, with the only difference being those in the RI/R-acq condition were informed of the recoding cue following acquisition and those in the RI/R-ltr condition were informed prior to the test of long-term retention. Acquisition for the children in the RI/R-ltr condition ended when criterion was reached for List 2. The children in the RI/R-acq condition were asked if they noticed anything different about the two lists following acquisition. They were then told that the foods in the second list were all green in colour and that they could use this information to keep the two lists separate in memory. This information functioned as the perceptual recoding cue.

All the children were asked to recall List 1 twenty-four hours later on four successive retention trials with no further study opportunity. After each retention trial the children performed the same distractor task as at acquisition for 20 seconds. Those in the RI/R-ltr condition were asked if they noticed anything about the lists prior to recall and then were informed of the recoding cue prior to retention testing. Those in the RI/S condition were asked if they noticed anything after retention testing.

Results

Analyses of Variance and Covariance

The results were analyzed to determine if there were differences in learning List 1 as reflected in total errors at acquisition and recalling List 1 a day later using total errors per trial at long-term retention. First, total errors at acquisition were examined in a 2 (age: grade 2 vs. grade 4) X 5 (condition: control vs. RI/S vs. RI/C vs. RI/R-acq vs. RI/R-ltr) ANOVA. Both factors were between-subjects variables. This procedure revealed a significant main effect for age, $F(1, 142) = 13.70$, $p < .001$, with grade 4 children making fewer errors ($M = 6.68$, $SD = 4.71$) than grade 2 children ($M = 9.91$, $SD = 5.85$). Second, there was a main effect for condition, $F(4, 142) = 2.94$, $p < .05$. Specifically, the children in the control condition made more errors ($M = 11.10$, $SD = 6.72$) than the children in any of the other conditions.

Next, total errors at long-term retention were examined using a 2 (age: grade 2 vs. grade 4) X 5 (condition: control vs. RI/S vs. RI/C vs. RI/R-acq vs. RI/R-ltr) X 4 (trial: 1-4) ANCOVA with total errors at acquisition serving as the covariate. Grade and condition were both between-subjects factors and trial was a within-subject factor. The covariate was significant, $F(1,141) = 4.00$, $p < .05$, $R^2 = .03$. Second, there was a significant main effect for condition, $F(4, 141) = 14.26$, $p < .001$(see Table 2). Pairwise comparisons indicated that the children in the control condition made fewer errors than any of the other four conditions, and children in both the RI/R-acq and the RI/R-ltr conditions made fewer errors than children in the RI/C condition. Third, there was a main effect for trial with the total number of errors decreasing from trial 1 to trial 4, $F(3,423) = 8.70$, $p < .001$. Specifically, more errors were made on the first recall trial (adjusted $M = 5.50$, $SE = .15$) than the following three trials and more errors were made on the second trial (adjusted M = 5.12, SE = .14) than on the final trial (adjusted M = 4.94, SE = .15).

Table 2

Total Errors at Long-term Retention for Each Condition

Condition	M[a]	SE	n
RI/S	5.525	.299	31
RI/R-acq	5.213	.304	30
RI/R-ltr	5.462	.304	30
RI/C	6.327	.306	30
Control	3.161	.308	31

a. Evaluated at covariate: total errors at acquisition

In sum, the results of these analyses demonstrated that 1) the children in the RI/S condition committed more errors at long-term retention than those in the control condition, 2) the children in the recoding conditions, RI/R-acq and RI/R-ltr conditions, committed fewer errors than those in the RI/C condition, and 3) the number of errors committed by the children in each condition decreased across the four retention trials. The same pattern of results was demonstrated for each age group, as was expected, and there were no differences between the two age groups except at acquisition where the younger children made more errors than the older children. Thus, as expected the children in both recoding conditions experienced less retroactive interference than the children in the RI/C condition.

It is possible that some of the children in the RI/S condition became spontaneously aware of the perceptual recoding cue. The amount of retroactive interference experienced by the children in the RI/S condition was not different from the amount experienced by the children in the recoding conditions. However, the children in the RI/C condition experienced more retroactive interference than the children in both of the recoding conditions which demonstrated the benefits of the recoding cue. The exact locus of these effects was investigated further using the trace-integrity model.

Trace-Integrity Analysis

The trace-integrity model was used to estimate the theoretical processes, such as storage, retrieval, forgetting, and reminiscence that underlie children's long-term retention. There are three main advantages of the trace-integrity analysis: 1) the effects at long-term retention can be separated from the effects at acquisition, 2) the nine-parameter mathematical model makes observable the theoretical processes that underlie retention, and 3) previous studies have successfully applied the same model to examine children's long-term retention. Prior to applying the trace-integrity model to the data the goodness of fit of the model to the data must be evaluated and the numerical estimates of the parameters involved in the model must be obtained (for a complete review see Howe &

O'Sullivan, 1997).

The theory behind the trace-integrity model is based on the disintegration/redintegration hypothesis and states that memory traces consist of primitive elements bound together into cohesive structures. Early in trace formation at acquisition primitive elements are encoded and a stable representation of the to-be-remembered item is established. After this process is completed, a reliable retrieval route is formed. Memorability of the item is determined by the degree of cohesiveness among the trace elements (Howe & O'Sullivan, 1997).

The parameters in the trace-integrity framework allow the memory processes involved in a study of retroactive interference to be estimated. Forgetting of learned information can be a result of either storage (S) or retrieval (R) failures. Forgetting due to a storage-based failure is a result of disintegration of bonds binding trace features together. Forgetting due to a retrieval-based failure is the result of an inability to access the trace in storage. The trace still exists but the means to obtain the trace has disintegrated. This disintegration of the memory trace can be caused by such processes as trace decay, interference, or a dissolution of bonds uniting the traces. Thus, it is important to determine whether forgetting effects are due to the disintegration of bonds binding elements of the trace together (i.e., storage failures), or due to an inaccessibility to the trace in memory (i.e., retrieval failures).

The storage parameter, S, represents the probability that an item is no longer available for recall. The probability that items are available but are not accessible is represented by the retrieval parameter, R. The model also includes seven parameters that represent reminiscence processes. Reminiscence occurs when trace elements are reinstated, possibly by internal or external cuing. One reminiscence parameter, a, represents the probability of trace redux in storage, and the remaining six parameters represent retrieval reminiscence following a success, r_i, or following an error, f_i (Howe & O'Sullivan, 1997).

The first step in this process is to translate the data space into an empirical probability space and the a posteriori probability of obtaining the data is derived. The data space in a four-trial experiment, such as the present one, consists of 16 possible outcomes: $C_1C_2C_3C_4$, $C_1C_2C_3E_4$, . . . , $E_1E_2E_3C_4$, $E_1E_2E_3E_4$, where C represents a correct response, E represents an error, and the subscripts 1-4 represent the four recall trials for each item or word. By assigning probabilities to each of the 16 possible outcomes the data space can be changed to an empirical probability space: $p(C_1C_2C_3C_4)$, the probability that the item is correctly recalled for all four trials, $p(C_1C_2C_3E_4)$, the probability that the item is correctly recalled for the first three trials and that an error is committed on the fourth trial, . . . , $p(E_1E_2E_3C_4)$, the probability that errors are committed on the first three trials and that the item is correctly recalled on the fourth trial, and $p(E_1E_2E_3E_4)$, the probability that errors are committed on all four trials. Next, using maximum likelihood theory, a function that expresses the a posteriori likelihood of any data sample is written. This function has 15 degrees of freedom and is expressed by:

$L_{15} = \{p[C_1C_2C_3C_4]^{N[CCCC]} \text{ X } p[C_1C_2C_3E_4]^{N[CCCE]} \text{ X} \ldots \text{X } p[E_1E_2E_3C_4]^{N[EEEC]}$

$\text{X}\, p[E_1E_2E_3E_4]^{\,N[EEEE]}\}.$ (1)

The second step in applying the trace-integrity model to the data involves translating the empirical probability space to a mathematical space through expressing each of the 16 empirical probabilities in terms of the model's parameters (see Table 3). This process converts the unobservable theoretical events underlying memory performance into observable, empirical events (the 16 error-correct patterns). The theoretical likelihood is derived by substituting the equations in Table 3 (denoted in Equation 2 by the term h) for the 16 terms in Equation 1. The result is an equation with nine degrees of freedom (since the 16 expressions are based on only nine parameters) and is expressed by:

$\text{L}_9 = \{h(p[C_1C_2C_3C_4])^{\,N[CCCC]}\ \text{X}\ h(p[C_1C_2C_3E_4])^{\,N[CCCE]}\ \text{X} \ldots \text{X}\ h(p[E_1E_2E_3C_4])^{\,N[EEEC]}$

$\text{X}\ h(p[E_1E_2E_3E_4])^{\,N[EEEE]}\}.$ (2)

The third step involves counting the number of times each of the 16 possible outcomes occurred in the obtained data. This is done by summing across subjects, and items for each condition. Then these sums are inserted in the relevant exponents in Equation 2 and the function is maximized by using a standard computer optimization routine (e.g. SIMPLEX). The optimal solution gives numerical estimates of the model's nine parameters and, also, the value of the likelihood function L_9. The value of the L_9 likelihood function (which is more commonly estimated with the log transform $-2\ln L_9$) is used to evaluate the model's goodness of fit in the fourth step and to examine hypothesized differences in the numerical estimates of the parameters, which is the fifth step.

The fourth step consists of evaluating the goodness of fit of the model to the data. This is done by maximizing (using the log transform above) Equation 1 for the same data as Equation 2. The result is an estimate of the likelihood of the data obtained prior to

Table 3

Mathematical Expressions Defining the Empirical Outcome Space

Outcome	Expression
$p(CCCC)$	$(1 - S)(1 - R)r_1r_2r_3$
$p(CCCE)$	$(1 - S)(1 - R)r_1r_2(1 - r_3)$
$p(CCEC)$	$(1 - S)(1 - R)r_1(1 - r_2)f_1$
$p(CECC)$	$(1 - S)(1 - R)(1 - r_1)f_1r_1$
$p(ECCC)$	$Sa(1 - R)r_1r_2 + (1 - S)Rf_1r_1r_2$
$p(CCEE)$	$(1 - S)(1 - R)r_1(1 - r_2)(1 - f_1)$
$p(CECE)$	$(1 - S)(1 - R)(1 - r_1)f_1(1 - r_1)$
$p(ECCE)$	$Sa(1 - R)r_1(1 - r_2) + (1 - S)Rf_1r_1(1 - r_2)$
$p(CEEC)$	$(1 - S)(1 - R)(1 - r_1)(1 - f_1)f_2$
$p(ECEC)$	$Sa(1 - R)(1 - r_1)f_1 + (1 - S)Rf_1(1 - r_1)f_1$
$p(EECC)$	$S(1 - a)a(1 - R)r_1 + SaRf_1r_1 + (1 - S)R(1 - f_1)f_2r_1$
$p(CEEE)$	$(1 - S)(1 - R)(1 - r_1)(1 - f_1)(1 - f_2)$
$p(ECEE)$	$Sa(1 - R)(1 - r_1)(1 - f_1) + (1 - S)Rf_1(1 - r_1)(1 - f_1)$
$p(EECE)$	$S(1 - a)a(1 - R)(1 - r_1) + SaRf_1(1 - r_1) + (1 - S)R(1 - f_1)f_2(1 - r_1)$
$p(EEEC)$	$S(1 - a)^2a(1 - R) + S(1 - a)aRf_1 + SaR(1 - f_1)f_2$ $+ (1 - S)R(1 - f_1)(1 - f_2)f_3$
$p(EEEE)$	$S(1 - a)^3 + S(1 - a)^2aR + S(1 - a)aR(1 - f_1) + SaR(1 - f_1)(1 - f_2)$ $+ (1 - S)R(1 - f_1)(1 - f_2)(1 - f_3)$

Note. C = correct response; E = incorrect response. Each probability in the left column appears in the empirical likelihood function. In the likelihood function for the trace-integrity model, these probabilities are replaced by the corresponding expression in the right column.

Adapted from "Misleading children's story recall: Forgetting and reminiscence of the facts", by M. Howe, 1991, Developmental Psychology, 27, p.570.

introducing the model (i.e. with all empirical probabilities free to vary, L_{15}). Since Equation 1 exhausts all the information in the data, the value of L_{15} will always be the maximum likelihood for the data set. And because the trace-integrity model does not exhaust all of the information (having 9 degrees of freedom as compared to 15) the estimated likelihood of Equation 2 will always be smaller in value. The goodness of fit between the model and the data is assessed with likelihood ratio tests that determine whether or not the difference between the likelihood obtained in Equation 1 and the likelihood obtained in Equation 2 is statistically reliable. This test evaluates the null hypothesis that the model fits the table and is expressed by:

$$X^2\,(6) = (-2\text{In}L_9) - (-2\text{In}L_{15}). \tag{3}$$

The trace-integrity model provided a good fit for the data obtained in the present study.

And finally, the fifth step consists of testing hypotheses about the theoretical processes underlying retention (see Table 4 for numerical estimates of the model's parameters). The parameter estimates can be used in direct tests of hypotheses regarding differences both between and within conditions in the rates of forgetting and reminiscence as well as the storage and retrieval loci of these differences. The statistical process involves a series of likelihood-ratio tests known as an experimentwise test, conditionwise tests, and parameterwise tests. The experimentwise test, as with the omnibus F test, evaluates the null hypothesis that, on average, the parameters of the model do not vary between conditions. For the present study the value of the experimentwise test statistic was $X^2(81) = 211.33$, $p < .001$.

Table 4

Parameter Estimates for the Trace Integrity Model

Age/condition	S	R	a	r_1	r_2	r_3	f_1	f_2	f_3
Grade 2									
Control	.31	.06	.05	.90	.95	.91	.59	.21	.00
RI/S	.51	.22	.05	.91	.95	.93	.35	.00	.00
RI/C	.41	.41	.00	.88	.93	.90	.31	.10	.09
RI/R-acq	.38	.28	.01	.84	.91	.91	.72	.25	.03
RI/R-ltr	.37	.36	.00	.89	.97	1.0	.21	.22	.14
Grade 4									
Control	.33	.04	.16	.95	.93	.94	.41	.00	.07
RI/S	.52	.16	.08	.88	.93	.93	.53	.50	.02
RI/C	.38	.48	.00	.86	.98	.90	.33	.25	.13
RI/R-acq	.33	.26	.00	.94	.92	.96	.33	.33	.15
RI/R-ltr	.34	.35	.00	.93	.93	.94	.45	.13	.21

The conditionwise tests were performed to evaluate the null hypothesis that the values of the parameters do not vary between specific pairs of conditions. A total of 17 conditionwise tests were performed, 5 to evaluate age differences (one for each of the five conditions), and 6 within each age group to test differences among the relevant conditions.

All 5 of the age comparisons indicated no differences between the grade 2 and grade 4 children for each condition, $X^2(9)$, range = 5.81 to 16.88.

The 6 within-age condition comparisons for the grade 2 children revealed 5 significant differences [$X^2(9) = 34.58$, $p < .001$ for the control vs RI/C conditions; $X^2(9) = 26.81$, $p < .01$ for the control vs RI/S conditions; $X^2(9) = 22.98$, $p < .01$ for the RI/S vs RI/C conditions; $X^2(9) = 21.57$, $p < .05$ for the RI/S vs RI/R-acq conditions; $X^2(9) = 19.68$, $p < .05$ for the RI/S vs RI/R-ltr conditions; and $X^2(9) = 8.29$, ns for the RI/R-acq vs RI/R-ltr conditions]. The 6 within-age condition comparisons revealed 5 significant differences for the grade 4 children as well [$X^2(9) =48.54$, $p<.001$ for the control vs RI/C conditions; $X^2(9) = 20.42$, $p < .05$ for the control vs RI/S conditions; $X^2(9) = 17.09$, $p < .05$ for the RI/C vs RI/S conditions; $X^2(9) = 16.96$ for the RI/S vs RI/R-acq conditions; $X^2(9) = 17.05$, $p < .05$ for the RI/S vs RI/R-ltr conditions; and $X^2(9) = 4.56$, ns for the RI/R-acq vs RI/R-ltr conditions]. Finally, parameterwise tests were conducted to isolate the specific parameter or parameters whose estimates differed between conditions. Each of these X^2 tests has 1 degree of freedom and, due to the fact that they are typically tedious and space consuming to report only those pararmeterwise differences that were statistically reliable ($p < .05$) are discussed next.

The primary locus of the differences between the conditions for both age groups was in storage-based forgetting (parameter S). Those in the control condition experienced the least amount of forgetting due to storage failures (.31 for grade 2, .33 for grade 4) and those in the recoding conditions (RI/R-acq: .38 for grade 2, .33 for grade 4, and RI/R-ltr:

.37 for grade 2, .34 for grade 4) experienced less forgetting due to storage failures than those in the RI/S (.51 for grade 2, .52 for grade 4) condition. There were also differences among the conditions in the amount of retrieval-based forgetting experienced (parameter *R*). The children in the control condition experienced very few retrieval failures (.06 for grade 2, .04 for grade 4) and the children in the RI/R-ltr condition experienced more failures due to retrieval-based forgetting than those in the RI/S condition (.36 vs .22 for grade 2, .35 vs .16 for grade 4). For the grade 2 children, those in the control (.59) and RI/R-acq (.72) conditions had more successes following one error (f_i) than those in the RI/S (.35) condition. For the grade 4 children, those in the RI/S (.50) condition had more successes following two failures than those in both of the recoding conditions (RI/R-acq = .33, RI/R-ltr = .13). There were no reliable differences in the r_i parameters.

In sum, the results of the trace-integrity analyses revealed a) the probability of storage failure was greater in the RI/S condition than all the other conditions, and b) the probability of experiencing a retrieval failure was greater in the RI/R-ltr condition than in the RI/S condition. The same pattern of results was obtained for both age groups with no age differences in the estimates and no differences within the reminiscence parameters. The results from the analyses of covariance did not reveal any differences between the amount of interference experienced by the children in the RI/S condition and the children in the recoding conditions. In contrast, the trace-integrity analyses revealed that the children in the RI/S condition experienced more storage-based failures than the children in the all of the other conditions, including the recoding groups.

Discussion

The main goal of the present study was to demonstrate a reduction in retroactive interference due to a perceptual recoding cue. The hypotheses of the study were that 1) all of the children informed of the recoding cue would experience a decrease in retroactive interference, 2) the children informed of the recoding cue would demonstrate a decrease in interference whether they were informed following acquisition or just prior to long-term retention, and 3) amount recalled would increase across the four retention trials for all children. The results showed a decrease in retroactive interference, as compared to the RI/C condition, when the children were informed of the recoding cue. This decrease in retroactive interference was observed for both the younger and the older children whether they were informed following acquisition or prior to long-term retention.

Retroactive interference is typically experienced when a person learns a second set of information that is highly similar to a previously learned set of information. By learning the second set of facts the first set learned loses the characteristics that make it unique and discriminable from the rest of the memories in storage. The memory of the second set interferes with the memory of the first set which could lead to a merging of the two sets or a misattribution of information (Howe, 1998b).

One way to reduce the amount of retroactive interference created through learning two groups of similar information is to provide participants with some means of discriminating between the two groups. A recoding cue serves to make the two groups of information unique and distinct again. Since the two sets of facts are now distinct from each other the interference between them is decreased.

Global Analyses

The present study examined the effect of a perceptual recoding cue on retroactive interference in children's memory. Children learned two lists of foods with all the foods in the second list being green in colour which served as the recoding cue. The results of the present study support the first hypothesis that both younger and older children can experience a decrease in retroactive interference if they are informed of a perceptual recoding cue. In a similar study, Howe and Wadhawan (1998) also found that a recoding cue could lead to a decrease in retroactive interference. However, the recoding cue in their study was conceptual in nature.

The results of the present study also support the hypothesis that there will be a decrease in retroactive interference for both younger and older children regardless when they were informed of the recoding cue following acquisition or prior to long-term retention. Unlike the present study, Howe and Wadhawan (1998) did not find a decrease in retroactive interference when the younger children were informed just prior to long-term retention. The younger children were only able to benefit from the cue when they were informed following acquisition while the older children were able to benefit from the cue whether they were informed following acquisition or just prior to long-term retention.

The main difference between the present study and the Howe and Wadhawan (1998) study is the nature of the recoding cue. The cue used in the present study was perceptual, colour to be specific, while the cue used in the Howe and Wadhawan (1998) study was conceptual or semantic in nature. The conceptual cue required the children to categorize the words as either toys or, as in the recoding conditions, as one list of toys and one list of vehicles. The younger children were unable to utilize the recoding cue when it was given at long-term retention. However, in the present study both ages were able to utilize the recoding cue to decrease retroactive interference regardless of time of instruction. The nature of the perceptual cue may have been more familiar to the children and easier to understand which allowed them to distinguish between the two lists on the basis on the recoding cue both at acquisition and at long-term retention.

Further support for the proposal that the perceptual recoding cue was easier for the children to understand than a conceptual cue comes from the lack of age differences observed in the amount of words recalled. It had been expected that the older children would recall more words than the younger children since memory performance usually increases with age. This trend was not observed in the present study. It is possible that the perceptual nature of the lists made the task easier for the younger children.

Howe and Wadhawan (1998) did find age differences in recall with the younger children recalling less than the older children regardless of condition. Again, the use of a conceptual category may have less familiar and more difficult for the younger children. In a previous study examining interference effects in children's long-term retention of lists of pictures no age differences were observed when the lists were presented in a paired-associate manner. However, when the children were required to free-recall the pictures the younger children recalled less than the older children (Howe, 1995).

Marsh et al. (1996) proposed that in order for a recoding cue to be successful first those in the uninformed conditions must not be able to become spontaneously aware of the cue. Second, the cue should not be awkward or inefficient for the participants to use. And third, highly similar lists could lead to a large amount of interference that may not be reduced by reorganization due to recoding. In the present study all of the children were capable of using the recoding cue to decrease retroactive interference when they were informed both following acquisition and prior to long-term retention. The older children did not spontaneously recognize that all the foods in the second list were green in colour more often than the younger children. Also, the lack of age differences suggests that the younger children were able to use the recoding cue to reorganize the lists in memory just as well as the older children. Thus, the perceptual recoding cue did not lead to age differences in the levels of spontaneous awareness in the uninformed conditions, and the cue was not awkward or inefficient for even the youngest participants.

As previous research has shown (e.g., Howe, 1995; Howe, & O'Sullivan, 1997) the amount of information recalled usually increases across multiple recall trials. This trend was observed for both age groups regardless of condition in the present study. This result further demonstrates the importance of providing multiple test opportunities in research involving children's long-term retention. Previous research investigating the use of a recoding cue in children's recall found decreases in interference only in trials 3 and 4 (Howe & Wadhawan, 1998). The present study found benefits of the recoding cue across all four retention trials and recall did increase across the trials.

In sum, the analyses of variance and covariance show support for the main three hypotheses. First, both the younger and the older children demonstrated a decrease in retroactive interference when informed of the recoding cue. Second, both ages demonstrated a decrease in retroactive interference whether they were informed following acquisition or just prior to long-term retention. Third, recall increased across the four recall trials regardless of age or condition.

Trace-Integrity Model Analyses

The trace-integrity model was used to differentiate the exact locus of forgetting effects in the present study. Specifically, it was found that the recoding instructions decreased the probability of experiencing a storage-based failure for both ages of children. The amount of storage failure in the recoding conditions was decreased almost to the level of storage failure in the control condition. The amount of storage failure was greater in both the RI/S and the RI/C conditions. Thus, when the children were told the recoding cue they were able to reorganize the two sets of information in storage to prevent forgetting. The uninformed groups did not have this information which led to more storage-based forgetting. In addition, the children in the RI/C (mixed list) condition experienced a greater amount of retrieval-based forgetting than the children in any of the other conditions.

When investigating the locus of interference effects in preschool and kindergarten children Howe (1995) found that forgetting was a result of storage failures for both age groups. Thus, when two sets of similar information are learned the second set interferes with the first set when both sets are in storage. The interference is not simply a result of competition between the two sets at recall.

Reductions in retroactive interference due to a decrease in storage-based failures was also observed in a study examining directed forgetting effects (Howe, 1999). When children were told to 'forget' the first story heard just after acquisition all of the children showed less forgetting due to storage failures. The children who did not receive these instructions experienced more storage failures. The children did not experience any release from retroactive interference when the directed forgetting instructions were given just prior to long-term retention. In the present study reductions were found for even the youngest children regardless of time of instruction.

Because the older children experienced less storage failure than the younger children when instructed at long-term retention it was concluded that older children may be more flexible in terms of using the forgetting instruction to reorganize information (Howe & Wadhawan, 1998). The finding in the present study that both ages experienced fewer storage failures due to recoding instructions given at long-term retention shows that young children can be just as flexible in reorganizing information as older children are when the cue is simple.

Thus, it can be concluded that a perceptual recoding cue reduces retroactive interference by decreasing the probability of storage failure for even young children. It is possible that the children use the recoding information to reorganize the two groups of words in storage so that they become distinct from each other. When the two sets of information are reorganized and become two distinct sets the chance of remembering each set is increased.

Conclusions

In summary, three main conclusions can be reached from the results of the present study. First, the children demonstrated a release from retroactive interference when they were informed of the recoding cue. This release was observed when the children were informed at acquisition as well as when they were informed at long-term retention after a 24-hour delay.

Second, the release from retroactive interference was observed for both age groups, regardless of time of instruction. A previous study which used a conceptual recoding cue found that the younger children were unable to benefit from the cue when it was given at long-term retention (Howe & Wadhawan, 1998). The success of the cue in the present study suggests the perceptual nature of the cue may have been more familiar and easier for the younger children to understand. It is possible that younger children may be less flexible in using new information, such as a recoding cue, to reorganize information in storage. Reorganizing new information may be even more difficult for younger children after it has been consolidated (Howe, 1999).

And third, the effects of the recoding cue were mainly at storage, as was indicated by the trace-integrity model. Thus, the results of the present study support the storage explanation of the source of retroactive interference. This explanation states that the second set of information learned retroactively alters the memory trace of the first set of information learned. Learning two highly similar groups of material leads to a large amount of retroactive interference. The recoding cue serves to make the two groups distinct, keeping them separate and unique in storage. Little support was found for the retrieval, or response competition, explanation of retroactive interference.

The conclusions of the present study have at least two practical implications. First, with more and more children being asked to participate in legal cases these results have direct applications to concerns about children's suggestibility. Often, when children are required to testify in court or to give information in an investigation they are questioned many times possibly by different individuals. Because it has been shown that even young children can use a recoding cue to eliminate interference and maintain information in memory it may be useful to provide children with a means of keeping information distinct in legal situations.

And second, the benefits of a recoding cue can be applied to many learning situations that involve young children. Often children are required to learn many types of information, right after one another (e.g. information presented in a history lesson may be followed by information presented in a language lesson). These two sets of information may interfere with each other and become merged and confused in memory. A recoding cue could enable the child to keep the information separate and enhance the information learned and remembered.

The main finding of the present study, that young children can use a recoding cue to decrease the amount of retroactive interference produced by learning two sets of similar information, contributes greatly to development memory research. Children as young as 7 years of age can reorganize information in storage even when they are informed of the cue just prior to long-term retention provided the cue is easy enough for them to understand. A simple recoding cue, such as one of a perceptual nature, could be used in real-life situations to improve the accuracy of children's memory recall.

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Appendix A

Lists Presented to Children in the control, RI/S, RI/R-acq and RI/R-ltr Conditions

List 1	List 2
banana	grape
peach	pear
cherry	celery
coconut	cabbage
plum	broccoli
tomato	lime
carrot	cucumber
corn	peas
grapefruit	spinach
pineapple	lettuce

Appendix B

Lists Presented to Children in the RI/C Condition

List 1´	List 2´
broccoli	banana
cabbage	carrot
cherry	celery
coconut	cucumber
grape	corn
lettuce	grapefruit
peach	lime
pineapple	pear
peas	plum
tomato	spinach