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Fuzzy trace theory and the development of interference in recognition and recall

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FUZZY TRACE THEORY AND THE DEVELOPMENT OF INTERFERENCE IN RECOGNITION AND RECALL

by

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As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Ryan Taylor Kneer

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ABSTRACT

This study addressed the free recall and recognition memory processes of elementary school children. It has been discovered that when children recall items from episodically related collections, a non-monotonic relationship is found between the memory strengths of those items and the order in which they are recalled. This relationship is known as cognitive triage, and it is not understood if the same phenomena would occur with recall involving semantic memory. Regarding recognition memory, experiments have tapped children's tendency to falsely remember words whose gist is the same as the gist of newly learned items. These past studies have focused primarily on a reversal of the standard false-recognition effect, where related distractors were easier to reject than unrelated distractors under some conditions. No research to date has ignored reversals and clearly examined the false-recognition effect itself. This study examined kindergarten, third, and sixth grade children's free recall organization and false-recognition of related distractors. The cognitive triage experiment examined semantic memory through having children recall exemplars from categories in Battig and Montague's (1969) lists. The recognition experiment examined developmentally the differential rate of false-recognition for related and unrelated distractors. Fuzzy Trace Theory (FTT) contends

that the ability to inhibit interference increases with age. Hence, younger children were hypothesized to show a weaker cognitive triage effect and more false-recognition than older children. The latter result was found, whereas the former result was not. False-recognition did decrease with age but although a triage effect was observed for category exemplar production, the effect did not vary developmentally. The principle difference between this triage study and previous research is that lists offering preexperimental measures of memory strength were employed. These lists were normed on adults and therefore cognitive triage may have been different for children. Thus, this study indicates that developmental effects are found for false-recognition of related distractors but not for category exemplar production when using Battig and Montague's (1969) lists.

CHAPTER 1

INTRODUCTION

Memory is very important in a child's personal, social, and academic functioning. Certainly, almost all tasks require memory processing in some manner. For example, playing baseball, remembering names and phone numbers, and performing academic tasks all neccessitate the storage and retrieval of data. Of primary relevance to educators is the variability in school performance that occurs from developmental differences in memory. Children of all grade levels are given academic tasks that involve memory processing. A kindergartner must be able to recall letters and numbers, in addition to common combinations of these such as his or her name and phone number (Lee, 1992). The demands on memory ability become much greater with each additional grade. By fifth grade, a student's memory must hold addition, subtraction, multiplication, and division facts and algorithms, names of presidents and explorers, important historic dates and countless other pieces of information, including a vocabulary of over 28,000 words (Houck, 1984). "Pupils must also retain rules for classroom and playground behavior, classmates' names, and school and classroom [physical] layouts" (Lee, 1992).

Free Recall Memory

The most commonly used paradigm in the memory development literature is free recall. This is likely a result of its similarity to naturalistic situations in which children must recall memories from episodically-related collections. It has been discovered that when children retrieve items in this fashion, their output sequences show a particular property that contradicts our intuitive psychological theories of recall. The property is a nonmonotonic relationship between the memory strengths of episodically-related items and the order in which children articulate those items during free recall (Brainerd et al., 1990b). This relationship is called the cognitive triage effect because of its resemblence to the common surgical procedure of treating the most difficult cases first.

Recognition Memory

False recognition is another important aspect of memory. The usual paradigm consists of subjects making yes-no distinctions about test items. These judgements are made after subjects are presented with a sequence of memory targets. A portion of the distractor items are redolent of specific targets. Others are not. The familiar outcome is that children falsely accept distractors that resemble targets at a higher rate than distractors that do not. This common finding is obtained for a number of different materials and a variety of forms of distractor-target resemblance. The finding has also been found to vary with age, which has led to the perspective that false recognition is an important aspect of cognitive development.

Statement of the Problem

Free Recall Memory

If memory strength is defined in either a commonsensical or theoretical fashion, it appears most probable that items with stronger memory representations will be accessed before items with weaker representations. Therefore, if the order of retrieval is plotted against some monotonic measure of memory strength, the intuitive recall order is stronger to weaker. Marbe's law (Marbe, 1901; Thumb & Marbe, 1901) was the first quantitative expression of this view. It stated that the length of time required to activate a word's memory representation is an inverse logarithmic function of its strength (see also, Osgood, 1953). A variety of contemporary theories also propose the stronger to weaker ordering (e.g., Bjorklund & Muir, 1988). It has been found by Brainerd et al. (1990b), however, that children never read out items in this order when their retrieval is unconstrained. On the contrary, departures from stronger to weaker (a) are evident at the earliest stages of item regeneration; (b) become more pronounced as learning unfolds; (c) increase developmentally; (d) correspond to a simple polynomial rule; (e) are retained across forgetting intervals; and (f) contradict adults' introspective analyses of their recall.

In past free recall experiments, the items that subjects have studied have been familiar items in the lexicon. These words are assumed to have core representations in children's semantic memories. These core representations or "fuzzy traces" will not support recall until they have been enriched with episodic information from the experiment (Brainerd et. al, 1990). In order to produce recall, the types of episodic information that must be added to these fuzzy traces are contextual cues and information about the core representations of other words in the target set. However, it is of interest to determine if the same triage relationship would occur with recall involving semantic memory itself. Semantic memory refers to the "organized knowledge a person possesses about words and other verbal symbols, their meanings and referents, about relations among them, and about rules . . . for the manipulation of these symbols, concepts, and relations" (Kail & Nippold, 1984, p. 944).

To date, however, all projects have measured relative memory strength via the error/success history of words. Therefore, there has been repetition of trials or examiner imposed variance in word list length. Rather than using this episodic memory activity, a shift to a more semantic memory inquiry is warranted. Thus, a dramatic change in methodology is required that asks what is the precise form of the retrievability versus access order relationship when open-ended retrieval sequences occur in response to exogenous inquiries ("What did you get for Christmas?")

A study that would investigate the triage pattern in situations resembling naturalistic, everyday remembering unfortunately presents no feedback concerning an item's relative retrievability. Therefore, how will the sheer retrievability of individual items be measured? It is not wise to study naturalistic output sequences unless both variables can be measured since the triage pattern is concerned with the relationship between retrievability and access order. This issue has not surfaced in multi-trial free recall because error-success data has provided on-line measures of item retrievability. Thus, if multiple study-test cycles will not be administered, preexperimental measures of retrievability must somehow be attained.

Recognition Memory

Brainerd et al. (in press) conducted five developmental experiments that showed a reversal of the standard false-recognition effect. Memory targets (e.g., CAT) were presented to prime subsequent presentations of related distractors (e.g., ANIMAL, DOG, PAW). According to fuzzy-trace theory, which uses intuition as its metaphor of the mind, false-recognition rates were predicted to decline relative to false-recognition rates for unrelated distractors (e.g., BOOK, TOWER). In addition, related distractors were easier to reject than unrelated distractors under some conditions. These results were found for distractors that were associates, category names, rhymes, and same-category exemplars of targets. False recognition reversals were found to vary with age, with amount of target repetition, with strength of target priming, and with length of retention interval.

To date, however, no recognition experiment has examined developmentally the differential rate of false-recognition for rhymes, category names, and same-category exemplars of targets. In essence, Brainerd et al. (in press) made reversals the issue of importance but did not concentrate on false-recognition itself.

An experiment that would investigate intuitive aspects of children's false recognition for new vocabulary items could employ the following: (a) an immediate test to examine their tendency to falsely remember words whose gist or physical sound is the same as newly learned items; (b) a delayed recognition memory test to measure how well children retain their original memories of presented words over an extended time interval.

Need for the Study

Free Recall Memory

The relationship between sheer retrievability and access order is a fundamental one that taps the aggregate impact of stored information. In previous research, multiple study-test cycles have offered on-line measures of item retrievability. However, in order to investigate the triage pattern in situations that resemble naturalistic remembering, preexperimental measures of memory strength must be attained. These measures are needed because in everyday remembering, multiple study-test cycles are usually not administered. Finally, it is crucial that this new format address whether any observed effects increase developmentally.

With the above points in mind, future research in this area may enhance the ability to control the triage process. This ability may lead to positive implications for everyday situations and more formal academic environments involving unconstrained, open-ended recall.

Recognition Memory

Few projects to date have investigated children's tendency to falsely remember words of the same sound or gist of newly learned items. Though Brainerd et al.'s (in press) experiments were quite similar in some respects, they focused primarily on the reversal effect. In addition, the amount of target repetition and strength of target priming was manipulated in their study. Contary to Brainerd et al.'s (in press) efforts, future work must recognize the importance of the differential rate of false-recognition for rhymes, category names, and same category exemplars of targets. Also needed is an examination of how children retain their original memories of presented words over an extended time interval.

With the above modifications to future research, a deeper understanding will be gained of the intuitive aspects of children's memory for new vocabulary items. More precisely, it is hoped that a deeper understanding is gained of how children become more likely to falsely recognize words of the same meaning or sound with age. This insight may have implications such that the prediction of gist versus verbatim memory styles could serve as an academic guide. Academic approaches or interventions could be tailored to particular children's needs (e.g., older children may be given tasks requiring a differing proportion of detailed versus intuitive skills than younger children).

Research Questions

This study will examine several issues pertaining to memory structure in normal achieving children at three age levels. Specifically, research questions address:

1. The development of unconstrained, open-ended recall:
    a. Are non-monotonic retrievability versus access order relationships observed for category exemplar production?
    b. Do children's retrievability versus access order relationships for category exemplar production obey a simple polynomial rule?

c. Do older children show a relatively stronger non-monotonic relationship in their recall than younger children?

2. The development of false-recognition:

a. Will children show evidence of remembering having learned vocabulary items that they actually have not learned?

b. Will younger children show less false-recognition than older children?

c. Will younger children have an affinity to falsely recognize words of the same sound while older children falsely recognize words of the same meaning?

d. Will females display a different false-recognition effect than males and will this effect change with age?

e. Are gender or age variables affected by an experimenter voice mismatch between presentation and testing?

f. Are any of the above mentioned possible effects retained over an extended time interval between presentation and testing?

CHAPTER 2

REVIEW OF THE LITERATURE

Introduction

This review will begin with an overview of the strategic approach to memory development, relating it to the subsequent basic processes movement, which will provide a foundation to discuss memory interference, fuzzy trace theory (FTT), and cognitive triage. Information processing theory will be adopted as a framework within which to discuss developmental differences in strategies as well as basic processes. This discussion will focus on both short-term and long-term memory tasks. The nature and objectives of the present study will be discussed at the conclusion of the review.

Short-term Memory (STM) and Long-term Memory (LTM)

Short-term memory is a system that stores information for current attention and in which actual information processing is carried out (Dempster, 1981). There is only a set amount of capacity that is available for both operations and data storage. Therefore, only rather limited combinations of activities and storage can be carried out at the same time. Long-term memory, though less ephemeral, is not a monolithic substratum either, being formed from various informational contents as well as strategies executed to maintain and process those contents. Baddeley

(1986) went further to state that whereas LTM has an enormous capacity for storage, coupled with relatively slow input and retrieval, STM is a limited capacity store with rapid input and retrieval. Theoretical work has offered arguments for this viewpoint.

At a theoretical level, attempts to design computers repeatedly pointed to the desirability of separating a rapid-access limited capacity working memory from the much larger capacity passive long-term memory banks (Baddeley, 1986). The architecture of the human computer, by analogy, was suggested to possibly emulate this advantage of having two distinct memory systems with dissimilar characteristics as well as functions. Hebb (1949) raised the possibility of a distinction between short and long-term memory, mainly on the basis of neurophysiology. He considered one storage system within the brain to have temporarily reverberating circuits, while another exemplified growth of links between nerve cells. This physiological approach to short- and long-term memory has for the most part been supplanted by more active research on cognitive aspects of memory.

At a more empirical level, during the mid-1950s, a number of studies conducted in Britain were illustrative of the separation between short- and long-term memory. Brown (1958) suggested that short-term retention relies upon memory traces that will spontaneously decay unless preserved by active rehearsal. Broadbent (1958) followed with the first major information processing model of short-term memory and short-term forgetting, in which the latter was regarded as trace decay.

Though Melton (1963) challenged Broadbent's assumptions by arguing strongly that STM also exhibits interference effects and Baddeley (1976) claimed that LTM may reflect trace decay, Broadbent's model has continued to prove influential (e.g., Atkinson & Shiffrin, 1968). In addition, current views of working memory have much in common with Broadbent's original formulation (Baddelely, 1986). By the early 1970s, a consensus was reached in the literature concerning the need for a separate short-term store, and a fair amount of agreement was obtained regarding its broad characteristics.

Strategic Approach to Short-Term Memory Development

Memory strategies have generally been defined as deliberate plans that are available to consciousness and are adopted to enhance performance (e.g., Brown, 1975; Hasher & Zacks, 1979; Naus & Ornstein, 1983). With regard to STM, the task being examined has usually been span of immediate recall. Ebbinghaus (1913) referred to this task as the maximum number of items he could reproduce perfectly immediately following a single presentation. Early research centered on the question of whether the task was a measure of general or specific abilities (Blankenship, 1938). This issue in memory span research was prevalent until the early

1970s. Recently, however, researchers have paid closer attention to underlying processes in span studies. This has led to progress in testing hypotheses about the sources of span differences (Chi, 1976; Dempster, 1978; Huttenlocher & Burke, 1976). The present discourse will briefly discuss these sources.

The memory strategies that are most often discussed in regard to short-term memory tasks (span) are rehearsal, grouping, chunking and retrieval strategies. Flavell, Beach, and Chinsky (1966) examined the development of rehearsal in a pioneering study. It was discovered that rehearsal increased with age. Rehearsal is also perhaps the simplest strategy that can be employed in a deliberate memory task. It is an iterative process, analogous to implicit speech (Chase, 1976), by which information in short-term memory is continually articulated or "refreshed" (Dempster, 1981). It performs two distinct functions: it suspends information in STM, and it assists in the passage of information to LTM by permitting items to be processed more elaborately.

A number of techniques have been used to examine rehearsal. The most prevalent are interitem pause times within the learning of a list (Belmont & Butterfield, 1969); labial movements, measured by electromyographic recordings (Garrity, 1975; Locke & Fehr, 1970); overt rehearsal, a device that involves the subject rehearsing aloud (Ornstein, Naus & Liberty, 1975); and finally, within serial position curves, the primacy effect (Hagen & Kingsly, 1968). Despite the primacy effect being questioned as an indicator of rehearsal (cf. Huttenlocher & Burke, 1976), findings from other instruments offer strong support for these conclusions: (a) There are developmental differences in style of rehearsal (Belmont & Butterfield, 1969; Ornstein, et al., 1975). (b) There are significant individual differences among children (Garity, 1975) and adults (Belmont & Butterfield, 1969) in rehearsal. (c) Rehearsal activity, such as sheer quantity of activity in 4- and 5-year olds (Garrity, 1975) and number of unique items rehearsed simultaneously in older children (Belmont & Butterfield, 1969; Naus, Ornstein, & Aivano, 1977; Ornstein, Naus, & Stone, 1977), shows positive correlations with the recall of supraspan lists. Supraspan lists are those in which the number of items far exceeds the capacity of STM. In short, children develop into more active rehearsers with age, and individual and developmental differences in rehearsal activity are correlated with accuracy in both serial- and free-recall tasks.

Taken at face value, these findings might imply that rehearsal is an important source of span differences (Dempster, 1981). However, none of the results was obtained through the use of a memory span task, and a sizeable number were obtained under conditions having much slower presentation rates and longer retention intervals than used in a typical span task. Additionally, other results suggest that the correlation between rehearsal activity and recall performances (at least in older children) is due to the enhanced retrieval of rehearsed items from long-term memory (Ornstein, et al., 1977), rather than short-term memory. Therefore, the experimental relationships found do not necessarily substantiate that rehearsal is a determinative variable in memory span performance.

The running memory span task has also been used to examine rehearsal processes. It is unlike the conventional memory span task in that lists of variable and unspecified supraspan length are presented, and subjects are expected to recall the maximum number of end items from the list. Unfortunately, it has been shown that active rehearsal is not a successful method of retaining items in the running memory span task (Dempster, 1981).

Research findings have been either indecisive or disconfirmatory regarding the correlation between rehearsal and individual differences in span. Cohen and Sandberg (1977) studied 13-year-old children, presenting 9 digits either visually or aurally with three different presentation rates. The subjects were expected to recall only particular items that were prompted by serial position cues. This task is called probed serial recall. Cohen and Sandborn concluded that the overalll pattern of correlations offered little evidence either for or against rehearsal as a source of individual differences in span.

Estes (1974) has suggested that grouping is a source of individual differences in span. Wundt (1912) defined grouping as a process of elevating successive elements into the focus of attention. The impact of grouping on short-term memory has been studied quite often, most frequently by presenting lists that have already been grouped in some manner by the experimenter.

Studies with children have involved this experimenter-imposed grouping (Frank & Rabinovitch, 1974; Harris & Burke, 1972; Huttenlocher & Burke, 1976; McCarver, 1972; Samuel, 1978). The results show that in children of all ages, span of recall is improved by experimenter imposed grouping. However, there are methodological problems that instill doubt regarding any actual age variance in grouping. Rohwer and Dempster (1977) held that span should increase with age in as much as older children are given the increased opportunity to do what comes naturally. The existence of ceiling and floor effects with older children has been the most serious problem in developmental studies of grouping, however. Lists have been barely above span and hence they can be reproduced almost perfectly when items are grouped (Dempster, 1981).

In summary, the performance of subjects ranging in age from 4 years to adulthood has been enhanced by experimenter-imposed grouping. It is unresolved whether there is variance in the tendency to group spontaneously. To go further, of more concern is whether grouping is actually a source of individual or developmental differences in span.

Another potential source of span differences is a strategy known as chunking. Miller (1956) described it as the recoding of two or more nominally independent items of information into a single familiar unit. An example would be sequences of digits because they are used in counting, telephone numbers, zip codes, etc. Therefore, only sequences that are familiar are amenable to chunking; the greater the familiarity, the more easily a sequence can be chunked. Chunking differs from rehearsal and grouping in that it is a knowledge-specific strategy.

The importance of chunking is that it increases the amount of information that can be stored and processed (Chi, 1978; Simon, 1974). Thus, chunking should affect performance on any task in which the capacity of short-term memory is involved. Hence, many investigators have considered chunking as a source of both individual (e.g., Estes, 1974; Hunt & Lansman, 1975; Miller, 1956) and developmental (e.g. Chi, 1976, 1978; Dempter, 1976, 1978; Olson, 1973; Simon, 1974) differences in span.

A common measure of chunking is subjective organization (Tulving, 1962). In subjective organization, subjects are given unrelated lists over consecutive study-test trial and are expected to freely recall on each test trial. Chunking has led to two main research findings. First, within adults, chunking has shown individual and age differences; second, chunking correlates with amount recalled. Unfortunately, multitrial free-recall and memory span are very different procedures, which makes generalization hazardous.

To reiterate, chunking is useful in various situations where STM capacity is taxed. However, there is no compelling evidence that it is a source of span differences unless the stimuli consist of highly structured material, such as chess positions, certain symbol patterns, and possibly verbal units with strong natural language association.

Samuel (1978) held the view that developmental variations in memory span could be accounted for by increased efficiency of retrieval strategies. He proposed two particular strategies. The first was organization, the capability to "package" output in units that resemble the units stored in memory. The second was the greater capability older children have to carefully pinpoint items for retrieval that are relatively more accessible. Subjects who are younger, on the contrary, are less likely to discriminate and, therefore, more likely to attempt accessing all items, including the inaccessible ones. This results in a lack of success in recalling accessible items before decay or interference ensues.

Samuel (1978) concluded that selective retrieval strategies play an important role in developmental differences in span. However, his argument is far from compelling. A problem is that the response characteristics of the tasks enabled subjects to use retrieval strategies not appropriate in a conventional memory span task (Dempster, 1981). Children are expected to recall the units of information in the same sequence that they were presented. In the future, perhaps a better strategy would be to reproduce the items quickly, before forgetting ensues.

Stategic Approach to Long-Term Memory Development

The study of strategies in LTM has usually involved tasks such as free recall, cued recall, and associative recall. The voluntary retrieval of information is implicated in many complex mental operations, and the deliberate implementation of strategies, so critical to the development of free recall, characterizes many other aspects of cognition (Bjorklund & Muir, 1988). Thus, an understanding of free recall requires not only an appreciation of subordinate processes such as encoding, the activation of information in semantic memory, and so forth, but also facilitates our understanding of more superordinate operations that require the deliberate retrieval of information for their effective execution (Bjorklund &

Muir, 1988). Discussion in this section will focus on self-activated or "free" recall due to its popularity in past research. In addition, it is believed that experiments on free recall memory serve as powerful means for developmental examinations of strategic cognition in general.

The memory strategies that are most often discussed in regard to free-recall are subjective organization, rehearsal, and clustering. As a strategy proposed to explain developmental changes in the recall of unrelated items, subjective organization is considered an index of the extent to which people impose some individually determined structure on a set of materials in order to facilitate recall (Bousfield & Bousfield, 1966; Pellegrino, 1971; Tulving, 1962). The organization of information is assumed to be greater with evidently increased intertrial consistency in the order in which items are recalled. Research examining developmental increases in amount recalled have unfortunately found little or no attendant variance in levels of organization (e.g., Kokubun, 1973; Laurence, 1966; Nelson, 1969; Ornstein, Hale & Morgan, 1977; Ornstein et al., 1975; Shapiro & Moely, 1971). Contrary to these findings, other researchers have proposed exceptions with the idea that subtle differences in the instruments themselves may alter results (Rosner, 1971; Sternberg & Tulving, 1977, reanalyzing the data of Laurence, 1966).

Children in other studies have been instructed to sort items in a manner that will help them remember (Bjorklund et al., 1977; Corsale & Ornstein, 1980; Liberty & Ornstein, 1973; Ringel & Springer, 1980). These sort/recall techniques unfortunately do not change the fact that most 10-year-old children and younger do not group sets of unrelated items on the basis of meaning. However, the fact that children who actually do sort on the basis of meaning recall more items than those who do not (Bjorklund et al., 1977) lends at least some support to the role of organization. In addition, some children trained to organize information with respect to semantic properties displayed enhanced levels of recall (Bjorklund et al., 1977; Corsale & Ornstein, 1980; Lange & Griffith, 1977). It is not difficult to train a child to sort unrelated items by meaning and find attendant improvements in remembering. Yet, the concept of subjective organization alone demonstrates little power in explaining the developmental changes in children's recall; older subjects displaying no trace of organization during the sorting phase prior to recall still remember more than younger, non-strategic children (Bjorklund et al., 1977; Ringel & Springer, 1980).

Another source of free-recall differences is a strategy known as rehearsal. This has been the most studied variable known to influence the remembering of sets of unrelated items. Some researchers have gone as far as to say that their research confirms that, given the opportunity to rehearse, the absolute frequency of rehearsal increases with age and is related to amount recalled (e.g., Hagen & Kingsly, 1968; Kellas, McCauley & Mcfarland, 1975).

Style of rehearsal, seen equally as important as frequency of rehearsal, has been examined by Ornstein, Naus, and Liberty (1975) where they implemented an overt rehearsal procedure with third, sixth, and eighth grade children. The children's rehearsal was "made public" so to speak, giving the examiners the ability to determine how children differ developmentally when required to rehearse. Particularly, children were instructed to say aloud the most recently presented word. Ornstein et al., (1975) stated that although frequency of rehearsal was relatively equal across grades, the quality of rehearsal was found to differ. Whereas third graders usually rehearsed passively, repeating only one or two unique words per set, eighth graders usually rehearsed several unique words per rehearsal set. Hence, it has been concluded that the quality rather than the quantity of rehearsal has accounted for more influence in children's free recall (Ornstein et al, 1975; Cuvo, 1974, 1975; Kellas et al., 1975).

Differences in knowledge base have been purported to account for, at least in part, developmental variance in the use of strategies. Zember and Naus (1985) supported this position by using an overt rehearsal procedure, presenting third and sixth grade children lists of words differing in the aspect of familiarity. Grade differences in both quality of rehearsal and amount of recall were eliminated when younger children were administered a list containing unfamiliar words. The same nature of results has been reported by Tarkin, Myers, and Ornstein (as reported in Bjorklund & Muir, 1988).

Thus, young children will show evidence of strategy use and enhanced levels of recall, but only under highly favorable stimulus conditions (Bjorklund & Muir, 1988). With regard to older children, they will actively rehearse over a wider gamet of stimuli; but unfortunately, using unfamiliar items will consequently reduce their strategy use and quantity of recall.

When examining children's recall for related items, children are usually administered sets of pictures or words sharing the same conceptual relationship. In most experiments, items can be grouped sharing the same taxonomic category, including examples such as TREES, ANIMALS, and MUSICAL INSTRUMENTS. Here, the degree to which a child clusters their recall in terms of the list categories is examined. Clustering is considered high when a number of exemplars from the same category are recalled consecutively; regardless of whether they were initially shown together. When considering adults, studies have shown levels of clustering positively correlated with levels of memory performance, therefore alluding to a causal link between organization (as reflected by clustering) and recall (Bower, 1970; Mandler, 1967; Shuell, 1969).

Recall performance in children of items from well-defined taxonomies have been extensively studied, especially that of natural language categories. As expected, amount of recall increases with age, as do degrees of clustering (e.g., Bousfield et al., 1958; Cole et al., 1971; Moely et al., 1969). It is important to note, however, that a large number of the early studies implemented measures that confounded levels of recall and clustering (Murphy, 1979).

Most research examining alternative modes of clustering in young children had concentrated on nontaxonomic, conceptual organization (Bjorklund & Muir, 1988). It was proposed by Denny (1974) that young children organize data more easily through the aspect of complementary relations. Denny (1974) described a category based on complementary relations as those "composed of items that are different but share some interrelationship either in the subjects' past experience or in the experimental situation" (p.41). Incidentally, children between the ages of 6 and 9 years rotate from forming categories on the basis of complementary relations to constructing categories on the basis of similarity, inclusive of category relations of the taxonomic vein. Findings concerning clustering experiments contrasting children's recall and organization of complementarily/schematically organized versus taxonomically organized material have been mixed (Bjorklund & Muir, 1988). Here, other experiments on clustering have failed to exude the predicted findings, exhibiting either no variance in quantity of recall and clustering between lists arranged on the basis of complementary versus taxonomic (similarity) relations (Lucariello & Nelson, 1985; Siaw, 1984), or superior recall and clustering for the taxonomic lists (Bjorklund, 1980; Galbraith & Day, 1978).

Other sets of functional relations that young children likely apprehend as more salient than complementary relations are scripts (e.g., Lucariello & Nelson, 1985). Items that share the same function in a script, such as toast, cereal, and pancakes in a breakfast script, are referred to as slot-fillers, and Lucariello and Nelson speculated that slot-filler categories should precede broader taxonomic categories in development, and that this would be reflected in young children's recall and clustering (Bjorklund & Muir, 1988).

Lucariello and Nelson (1985) incorporated their hypothesis in two of their experiments with 3-and 4-year olds. The researchers found comparable recall and clustering in children administered the complementary and taxonomic lists, with performance significantly higher for children administered the slot-filler lists. Lacariello and Nelson proposed that it is from these highly constrained, script-derived categories that children develop the broader context-free categories by which older children and adults organize and recall information (Bjorklund & Muir, 1988).

In summary, Bjorklund and Muir (1988) state that in general, levels of recall and clustering increase with age. Absolute levels of clustering are low, often no greater than chance values, for children 7 years of age and younger, with substantial levels of clustering not found until the later elementary or early high school years (e.g., Arlin & Brody, 1976; Cole, Gay, Glick, & Sharp, 1971). Lucariello and Nelson (1985) have to the contrary, reported an exception with their particular categories, where highly associated items resulting from a specific context are clustered together. It is not entirely clear whether one can follow Lucariello and Nelson's (1985) assertions that the elevated clustering for these latter categories is a function of common script, or that the elevations are a consequence of strength in associative relations amongst items (Bjorklund, 1985; Lange, 1978). This question is in consideration of the two factors (associativity and script based) being closely related and quite difficult to separate.

The Shift From Strategic to Basic Process Theories

Recently, strategic process theories have been less prevalent in memory development research. The gradual decline of strategic theories cited in the literature is primarily due to the realization that the use of memory strategies does not predict memory development well. Quite clearly, this lack of relationship is evident repeatedly through strategic theories' inability to be supported by empirical findings.

The research taken as a whole offers little evidence that any of the strategic variables-rehearsal, grouping, chunking, and retrieval strategies-plays a role in memory span variance, except perhaps under extraordinary conditions and within relatively narrow age ranges (Dempster, 1981). To go further, evidence has even shown that chunking and retrieval strategies reduce memory span. Finally, strategic variables unfortunately appear to be sources of performance differences in other tasks but not span.

Strategic processes in free-recall have a long and gradual developmental history. In addition, at no age is the processing of data the same within an individual over different memory tasks (Flavell, 1982). Nevertheless, clear developmental patterns are discernable, with performance becoming more consistent over situations and less context dependent with age (Bjorklund & Muir, 1988).

Finally, as a last comment in this section, various failures in strategic theories' ability to predict memory development are illustrated in findings by Dempster (1985). He found that "potential sources of short-term memory improvement are structural, nonstrategic, and mechanistic in nature, in contrast to long-term memory. Therefore, short-term memory is content-free, and improvements occur only as a normal consequence of biological development" (p.222).

Basic Process Approach to Short-Term Memory Development

This section will now turn to evidence supporting the success of basic process theories in explaining short-term memory development. The basic processes that are most commonly discussed in short-term memory are capacity, pronunciation rate, item identification speed, and susceptibility to interference. Ample experimental evidence has shown that there is a finite limit to the extent of attentional capacity. This basic tenet of information processing theory is responsible for strictly limiting the amount of storage and processing operations that can occur simultaneously in short-term memory (cf. Mandler, 1975; Shiffrin, 1976). It seems that the notion amongst investigators that developmental changes in span reflect structural changes in capacity has, for a large number, the status of an established fact that warrants no formal endorsement.

At present, there are almost as many views of capacity as there are models of human memory, since in most of these models capacity is a central component (Dempster, 1981). An examination of capacity and its effect on performance has up to now been a central endeavor of the information processing approach. Capacity has been examined within many tasks and with a variety of techniques (cf. Shiffrin, 1976). Only two tasks, however, have been implemented in the examination of individual and developmental differences in capacity: tests of M-space and the actual memory task of span.

There are a number of tests available that tap M-space, including the digit placement task (Case, 1972), as well as the counting span task (Case et al., in press). Apparently, they were all devised to adhere to the confines of the theory of constructive operators (Pascual-Leone, 1970). Capacity, in this theory, is believed to increase with age (synonymous with increases in M-space or M-power) and dictates precisely the extent of the rate of increase - between ages 3 to 15 years, one unit every two consecutive years. Although one study's results were contradictory (e.g., Foellinger & Trabasso, 1977), all others evidenced the predicted rate of increase rather well, most certainly within the age range of 4-12. Support for this notion is derived from the similar norms yielded by a wide range of M-space tests, rather than from any singular experiment (cf. Case, 1978). All involve a degree of transformation of the input, in addition to suspending a certain sequence of events in memory. For example, within the counting span task, children are administered a set of arrays to count. The moment they have completed the counting they are required to remember the quantity of objects in each array. Arrays vary in number and the childs' M space is regarded as being commensurate with the total quantity of arrays they can count while maintaining perfect recall. Hence, counting is considered the transformation in this task.

Despite variations in the transformation within every test of M-space, they contain clear likenesses to the memory span task. This is primarily due to both being evaluated in terms of the total quantity of items that can be retained at the same time. Consistent growth patterns have not resulted from measures of M-space like those claimed by Pascual-Leone. However, they have yielded increased performance with age. Therefore, findings from the various M- space experiments have alluded to increases in capacity that are responsible for age related changes in span. Finally, the memory span task itself yields large developmental differences that are often posited to show capacity variance (e.g., Biggs, 1971; R. Brown & Frazer, 1963).

Another source of span differences is a basic process known as pronunciation rate. The general term refers to the contention that the degree of speed does not remain constant. Rather, it depends entirely on the experiential variables of practice and familiarity (e.g. Chi & Gallagher, 1982). Regarded in this manner, raising speed of information processing is possible through increases in a child's knowledge base. Raising speed of information processing is also possible through task differences affecting the accessibility of data from memory. For example, two types of tasks reflect speed differences that are associated with developmental changes in memory performance. Some tasks involve a child activating a long-term memory representation while other tasks involve the reactivation of a child's short-term memory representation.

A number of researchers have held the view that variance in the rate at which information administered is identified or named is an important source of developmental differences in short-term memory performance (e.g., Case, 1978; Case et al., 1982; Dempster, 1981). Various measures of identification/naming speed have been introduced, but those most commonly used have been vocalization rate and word recognition rate. In both instances, an item or a series of items is administered, the child then responds immediately. Reviews of experiments incorporating these procedures are available (e.g., Dempster, 1981). Viewed as a whole, they show significant decreases in latency from early childhood through adulthood. In addition, these decreases are associated with improved short-term memory task performance. Primarily, they are responsible for a majority of the within-age variance in span (Nicolson, 1981). In Nicolson's experiment, 8-12 yr. old subjects' memory span for a given set of words was commensurate with the quantity of words that could be successfully pronounced in 2's. Nicolson (1981) concluded that higher information processing speed is a sufficient source of span increases.

Another basic process or "nonstrategic variable" is item recognition speed. A number of researchers have stated that variances in the nonstrategic processes underlying the recognition of specific items may be a source of span differences (Chi, 1977; Huttenlocher & Burke, 1976; Spring & Capps, 1974). Most investigators believe that significant differences exist between subjects in the ease with which items are accurately perceived. Also important is whether the proper linguistic program is implemented (accessed from long-term memory) and the extent of automaticity in the identification process. A child who has difficulty identifying items will have relatively less capacity left over for storing items. Thus, he or she will have a shorter memory span than someone who identifies items with relative ease (Dempster, 1981). Research evidence for the proposed correlation between ease of identification and available capacity for storage is mentioned in an experiment by Rabbitt (1968): Items in the second half of a sequence were presented with background noise, making them harder to identify. As a consequence, there was a decrement in the recall of items from the first half, showing less available capacity.

Other investigators propose the hypothesis of ease of item identification (Chi, 1977); Huttenclocher & Burke, 1976). That is, the rate of item identification is regarded as a primary result of the automaticity of the process.

Examination of this theory begins with evaluation of studies that have quantified the rate of item identification. A number of measures have flourished in the literature, but the most common are item recognition time and naming/vocalization latency.

Without a doubt, the easiest instrument to use in measuring item identification rate is item recognition time. This measure can be operationalized as the least quantity of presentation time required for a child to identify a stimulus approximately half of the time. Chi (1977) noted a drawback in that presentation time per se could significantly underscore maximum identification time. The presentation interval may simply be a measure of the amount of time necessary for the activation of perceptual units; full identification may not occur until after the stimulus has terminated (Dempster, 1981). Regardless, the majority of experiments implementing this measure have centered on comparisons across age. The empirical findings clearly show that recognition times decrease with development. In memory span experiments, for example, recognition times for frequently presented words decrease from approximately 44 msec to roughly 23 msec from age 10 to adulthood respectively (Samuels, Begy, & Chen, 1975-1976); with pictures, time decreases from about 139 msec to 26 msec from age 5 to adulthood respectively (Chi, 1977). Research on individual differences, on the contrary, has not yielded such clear results. Regardless, individual differences are significantly pronounced, at least with respect to reading proficiency. In one experiment, 10-year-olds with poor reading ability had recognition times of 69 msec, as opposed to about 46 msec for proficient readers of the same age level (Samuels et al., 1975-1976).

In conclusion, children who are capable of implementing item identification operations with relatively greater speed have increased capacity available for storing the products of these operations. This results in higher spans compared to other children who identify items relatively slowly.

A final basic process that is responsible for age-related changes in span is susceptibility to interference. This nonstrategic variable has been well supported by empirical findings. However, due to its special relevance with the studies to follow, it will be discussed in sufficient detail later.

Basic Process Approach to Long-Term Memory Development

The basic processes that are most commonly discussed with regard to long-term memory are capacity, pro-active as well as retroactive interference, and finally, inhibition. Information processing uses the idea of a resource or limited capacity pool. This has also been refered to as attentional capacity, mental effort capacity, and working-memory capacity. Proponents of the resources hypothesis believe that memory processes draw from a common pool of mental energy. Not only is this capacity pool expected to increase in size with age, but it can also be flexible in its ability to alocate capacity to a variety of functions (Brainerd & Reyna, 1988; Brainerd & Reyna, 1993). In addition, many investigators believe that developmental changes in the resource costs of memory tasks are largely responsible for age changes in performance.

The resource hypothesis has been examined in association with many aspects of memory development. A central issue in cognitive psychology at this point involves understanding the information processing system in relation to the well-established empirical findings of limited mental resources. However, attention has recently been focused on certain empirical findings that accompany dual-task paradigms. Possibly finding a different interpretation of dual-task data (such as the idea of independent specialized resources) would further the arguement against the conventional resources position. Therefore, discussion will turn to other basic processes-those of proactive and especially retroactive interference. Retroactive or "output" interference is of special concern due to Brainerd & Reyna's (1989) proposed alternative explanation of interference between independent processes. But first, the dual task paradigm will be addressed in more detail.

In the dual task paradigm, children must engage in two tasks concurrently. Usually a decerebrate motor task is coupled with a higher cognitive task. Almost without exception, a form of information processing (e.g., numerical comparison) is conjoined with a task that is not only decerebrate but irrelevant (e.g., finger tapping). This methodology was linked to theoretical work supporting the generic resources hypothesis (Baddely & Hitch, 1974; Kahneman, 1973). Superior performance on either task was viewed as supporting the notion that mental operations draw upon a limited pool of generic mental energy. An associated experimental result has been that the size of the dual-task deficit tends to become larger as the complexity of the concurrent task increases. This finding remains fundamental to the resources hypothesis. Resource theory predicts that processing capacity must be shifted from motor to reasoning performance when both are taking place at the same time. This is expected to lower the motor performance. Resource theorists expect age-related changes in capacity to show less effect on the primary task than the reasoning task. This is because more slack is assumed to be available in the generic processing resource when beginning with a primary task (Brainerd & Reyna, 1993). Contrary to the proliferation of studies on resources, a broad range of researchers have identified serious difficulties in the understandings drawn from these studies (e.g., Navon, 1984, 1985).

On-line interference and its association with dual-tasks has been broken down into two forms. One is called response scheduling (or proactive) interference and the other is referred to as feedback, output or retroactive interference. Scheduling noise comes about due to the fact that response outputs must be serially organized whereas processing leading to output is in parallel. This eventuates into a parallel to serial bottleneck. Brainerd and Reyna (1993) state that because items can only be spoken one at a time subjects must queue them for output and make sure they do not reenter and hamper readout of further words.

The second form of interference is called response feedback. This is released as responses are emitted; articulating a response produces irrelevent noise that propagates back through the system.

On-line interference as an alternate perspective has been shown to explain concurrent processing deficits. Contrary to resource theory, fuzzy trace theory (FTT) has gone along with this alternate perspective of accounting for these effects. On-line interference is seen as greater when a primary task is performed with an irrelevant secondary task than when performed alone. Therefore, age fluctuations in dual task deficits are understood as interference sensitivity changes. Hasher and Zacks (1989) found on-line interference to become less of a hinderance with age.

Finally, FTT attenuates the strength of the resource construct by its explanation of the assymetry of deficits. Resource theory expects reasoning tasks to require more borrowing from primary tasks than vise versa. Fuzzy trace theory sees reasoning tasks as more noise sensitive because of their complexity. Therefore, adding a secondary decerebrate task, such as finger tapping, to a reasoning task should be illustrative of greater interference. Up to now, experimental evidence has shown that FTT's prediction is true (that reasoning tasks are more affected by decerebrate tasks than vice versa) (Brainerd & Reyna, 1989).

Currently, there is disenchantment regarding traditional interpretations of cognitive development and aging. For example, the position that capacity varies with age has often brought considerable methodological problems (Halford, 1989), and it has been attacked with respect to its logical substrates (Hasher & Zacks, 1988; Reyna & Brainerd, 1989, 1991). Variations in the activation of resources are more effective in explaining developmental changes in cognitive competence than are differences in strategy use. Basic processing alternatives to existing explanations based on activation of resources are needed in order to provide a more complete picture of intellectual development and aging (Dempster, 1992). Therefore, it is offered that resistance to interference (i.e., the capacity for inhibition) is a strong variable in age-related differences. This factor is closely connected with the function of the frontal cortex of the human nervous system (Dempster, 1992).

There are three strong empirical correlaries that are associated with this claim. First, recent neuroscientific advances show that the frontal lobes are highly responsible for the ability to attenuate interference from both external and internal loci. This allows the subject to successfully inhibit or suppress stimuli or associations that are not conducive to the task in question. Second, the frontal cortex's development is notably very slow; this is also the first part of the brain to exhibit involution near the close of the lifespan. Third, the diversity of interference-sensitive tasks that necessitate the inhibition of irrelevant information for successful performance are much more numerous than is commonly assumed. In many situations, the ability to inhibit or deactivate stored information may be just as decisive as the availability of activation resources (Dempster, 1992).

While interference and inhibition have been topics of cognitive theorizing for many years, currently these concepts are the focus of great attention from developmental psychologists. For example, not long ago, interference and inhibition had been implemented as leverage to interpret age-related changes in particular memory phenomena. Bjorklund and Harnishfeger (1990) have held the position that more efficient working-memory processing is possible through neurologically based changes in the efficacy of inhibitive sorts of processing. Also, Reyna and Brainerd (1989, 1991) have stated that younger children's recall is more amenable to output interference than their older counterparts'. It is possible that resistance to inhibition is largely responsible for aspects of cognitive development. Unfortunately, this has been largely ignored.

The most prevalent explanation for age-related declines in performance was that older subjects experience the impact of interference to a greater degree. A preeminent study has been in the area of text processing. Hasher and Zacks (1988) proposed interpreting comprehension deficits in the elderly from an interference based perspective.

Several other current empirical patterns require the employment of a resistance to interference interpretation. First, the relatively high occurance of perseverative errors among both younger and older adults on the Wisconsin Card Sorting Test (WCST). Perseverative errors are best understood as symptoms of proactive interference (cf. Diamond, 1988). Second, field dependence seems to account for performance only on tasks that involve salient irrelevant stimuli. This gives credance to Pascual-Leone's (1989) position that field dependent subjects experience difficulty in "interpreting" the activation of potentially interfering or arbitrary stimuli. Third, implementing or witholding misleading information greatly affects success on illusion of judgement tasks. Finally, there is Doyle's (1973) investigation of selective listening, in which positive correlations between intrusions from the irrelevant message and retention shifted to negative correlations with advancing age during childhood (Dempster, 1992). Succinctly, the above mentioned findings and the cognitive triage effect found by Reyna and Brainerd (1991), are much easier to interpret in the presence of the concept of resistance to interference.

In consideration of the relatively generic nature of the current framework, it does offer a foundation for making predictions and for creating an agenda for future investigations, namely, that of free recall learning, due to its nature of being an interference-sensitive task (e.g., Postman & Keppel, 1967, 1977). Also, developmental improvements within childhood and declines in older subjects are well documented (Davis et al., 1990; Ornstein, 1978). Developmental variances in free recall learning are typically ascribed to differences in rehearsal and organizational processes (e.g., Ornstein, 1978; Smith, 1980). To the contrary, there is an amount of empirical support that these differences are partially a result of varying susceptibility to interference. A few cases in point are the investigations that have found that the ratio of inappropriate intrusions decreases developmentally through childhood (Harnishfeger & Bjorklund, 1990) and increases developmentally within adulthood (Bruning, Holtzbauer, & Kimberlin, 1975). Although there is no experimental support thus far that frontal lobe lesions are indicative of poorer free recall, results with frontal lobe patients are expected to be similar (Stuss & Benson, 1984).

Conditions relatively sensitive to interference that should show the most pronounced age differences: (a) are amenable to developing the rise of proactive or retroactive interference, such as the sequential administration of multiple lists (e.g., Postman & Keppel, 1967, 1977); (b) implement a distractor-filled delay between presentation and recall; and (c) hold information that is likely to cue related, but arbitray, associations, such as categories (e.g., Harnishfeger & Bjorklund, 1990). It is within these conditions that subjects will be forced to suppress responses not conducive to the task at hand.

The prediction that subjects having frontal lobe lesions will perform with difficulty in dual-task conditions is offered from the resistance to interference viewpoint. In addition, Reyna and Brainerd (1989) have interpreted developmental trends in dual-task deficits as illustrative of age changes in susceptibility to retroactive interference. Therefore, Dempster's (1992) position of using the frontal lobes as part of his framework is not in opposition to Reyna and Brainerd's interpretation, but gives a deeper causal explanation.

While the theory of the efficiency of the frontal cortex is in its early stages, it is a useful alternative to other nonstrategic processing perspectives to memory development and aging. With regard to the capacity version of the resource hypothesis, this new theory offers a convincing interpretation of the weak correlation between indices of capacity utilization and performance (Mitchell & Hunt, 1989). The present framework is also relevant to the speed of processing version of the resource hypothesis, especially the version which attributes age differences to simple speed differences (Dempster, 1992). There has been some huge disappointment with this notion. For example, the correlation associating activation rate measures (e.g., reaction time) and criterion measures seems to strengthen as the task complexity associated with the activation rate measure becomes larger (e.g., Larson & Saccuso, 1989). This suggests that other processes (e.g. strategic processes) are more important than activation rate (Dempster, 1992). However, it is wise to consider that task complexity may increase just as its attendent competing (i.e., arbitrary) information does similarly. Therefore, developmental variance in "processing efficiency" may often be a manifestation of the efficacy of the inhibitory mechanism in addition to the speed of activation. With regard to strategies, it is important to note that the present framework does not consider them to be primitive units of analysis. Instead, their construction and functional deterioration are regarded, in part, as by-products of a more primitive basic processing dimension, namely, resistance to interference (Dempster, 1992). In summary, in the late part of this century the time-honored concepts of interference and inhibition are given new applications by researchers.

Fuzzy Trace Theory

Until recently, there has been conflict among a variety of metaphors of the mind. In the 1960s, Piaget's logician-in-the-mind metaphor was quite prevalent. At that time, cognitive development was synonymous with the development of a child's logic. Subsequently, information processing utilized the metaphor of an abstract symbol manipulating machine. By 1980, cognitive development had taken on this metaphor (Siegler, 1981).

Fuzzy Trace theory (FTT), which entered the historical cycle, uses intuition as its metaphor. Intuition is seen as senses, patterns, or gist combined with construction rules. FTT evolved due to its ability to explain phenomena that other theories (information processing and Piagetian metaphors) have problems describing or explaining (Brainerd & Reyna, 1990b).

The intuition metaphor has generally been systematically applied to various research domains, reinterpretting and establishing new results along the way. In the section to follow, FTT's progress to date will be outlined, with discussion centered on five areas of research focus: encoding, storage, processing, output, and forgetting.

In traditional psycholinguistics, gist is considered the ghost of faded linguistic information. FTT employs this concept to describe an array of nonlinguistic, as well as linguistic, essences or patterns that reside in incoming data, particularly the preeminent background information that is associated with thinking, reasoning, and learning tasks. Proponents of FTT do not believe it to be simply the residue of input as time passes. Quite differently, it is understood to consist of memory representations that are extracted in parallel with the encoding of such information, and, once it has been stored, it is thought to operate independently of verbatim information (Brainerd & Reyna, 1993).

FTT assumes that encoding is controlled by a gist-extraction imperative, known as the reduction to essence rule (Brainerd & Reyna, 1990b). As detailed data is encoded, senses and patterns are also encoded. The substrate of reasoning and memory within cognitive science is seen as detailed, verbatim information, rather than as gist. There is strong agreement about the prevalence of gist extraction and pattern-like intuitive thought among numerous theorists. However, the usual assumption is to consider such abilities primitive and noisy, especially in regard to higher cognitive processes. This opinion is the main thrust of Piagetian investigators. These investigators belief that childhood reasoning tasks should be complexified to the point that solutions must be based on logical deductions from verbatim information (Reyna & Brainerd, 1990).

It is unlikely that a valid position could be held without the tenant of universal gist extraction, since it is prevalent in many areas of research, including animal memory. Textbook examples of animal memory are latent learning (e.g., Tolman & Honzik, 1930) and learning sets (e.g., Harlow, 1949). In latent learning, results have shown that the acquisition of spatial maps exerts strong forward control across sequences of maze learning. Apropos learning sets, Harlow (1949) reported that monkeys who were conditioned regarding to color, shape, and size discriminations and whose errors exceded 20, commited only one error in subsequent tasks after developing a learning set.

Probability judgement is a common paradigm used with humans whereby preschoolers, elementary schoolers, and adults typically extract prototypical forms of relational and nominal gist. The above studies have shown that gist representations are more enduring than traces of the verbatim numbers, and, more often than not, they are the basis for prediction (Brainerd & Reyna, 1993).

In the area of psycholinguistics, information concerning gist memory has inspired researchers to hypothesize that linguistic inputs always lead to the encoding of particular kinds of gist. For example, Kintsch et al. (1990) held the belief that theories of text recall are confined, at least, to assume that text eventuates into three amalgamate domains of representation in memory: "At one level, a text is characterized by the exact words and phrases used. . . . At another level, not the exact wording but the semantic content of the text must be represented. The situation model is the third level. . . . What is represented is not the text structure proper, but the situation described in the text, detached from the text structure proper, and embedded in preestablished fields of knowledge" (p. 135).

FTT considers gist memories of central importance and therefore concerns itself with the time of their deposit. For example, in experiments where the background data is numerical, at what time during the background phase is relational input rather than nominal input stored? Brainerd and Reyna (1990b) assert that two common perspectives are held by researchers toward this issue. Case in point, children might delay extraction until the background portion is finished, storing only gist that is conducive to every fact available. This sequential gistification of detailed information has the advantage of being efficate and precise; and it is consistent with the traditional view of linguistic gist as degraded verbatim information (e.g., Jarvella, 1971). Alternatively, children could draw an array of potentially relevant gist from every detailed fact as it is encoded. Brainerd and Reyna (1990b) have examined results of various studies that allow differential tests of serial versus parallel gistification. Taken broadly, both empirical and theoretical positions support the parallel scenario above (Brainerd & Reyna, 1991). Empirically, evidence from a variety of sources shows that information in many tasks is sufficiently redundant and pattern-like that subjects begin to extract relevant patterns from the incoming verbatim flow before all of that information has been presented (Reyna & Brainerd, 1990; Townsend, 1990). Such gist is commonly stored following only two or three premises. In addition, the fluidity of this mechanism increases with development.

From a theoretical perspective, there are at least two arguements in support of gist extraction. First, initial gist extraction receives instant benefit of consistencies and repetitions in incoming data. This is a mechanism that the circuitry of the human nervous system seems well equipped to do. Obviously, this means that children can sense essence sooner by drawing relevant gist from the beginning. Second, memory for details is frequently found to be unstable. Relying on unstable information is surely risky. It is commonly found that detailed information escapes from recall more rapidly than gist (Brainerd & Reyna, 1990b; Kintsch et al., 1990). Furthermore, a prodigious amount of research indicates that verbatim traces are more affected than are gist traces by interference from the overlap of other encoded traces, and also from processing (Brainerd & Reyna, 1989; Brainerd et al., 1990a).

Sequential gistification operates within the confinement of a strict memory factor that demands that encoded information be suspended intact until the moment of reasoning, which is rarely possible. Fortunately, parallel gistification is hypothetically favored because it processes unstable detailed traces instantly, before they are lost, in order to develop a useable array of gist. However, it is stipulated that accumulating a usable store of gist requires the exclusion of senses that are conducive to early inputs but are mismatched to later inputs.

FFT proposes the notion of a verbatim to gist shift. This shift may occur because verbatim and gist are actually separate ways of processing information. Gist is not the ghost of degraded verbatim information (Brainerd & Reyna, 1993). FTT assumes that gist and verbatim information operate independently, as extraction of memory representations in parallel with the encoding of verbatim information. The ability to extract gist is present in the very early part of a child's life. For example, the ability to extract fairly abstract patterns is apparent in very young children. Two year olds have been found to retrieve nonverbal analogies. Various research with animals has also indicated that gist is very primitive (Reyna & Brainerd, 1990; Wagner et al., 1981).

Research has been undertaken that considers developmental trends of a reliance on gist. For example, it has been found that when subjects encode isolated elements of a statement or its pattern, younger children are able to retrieve the isolated elements whereas adults and older children remember the patterned statements more accurately. Also, it has been demonstrated that as children grow older they are able to concentrate more on facial configurations than on individual facial components (Carey & Diamond, 1977).

There is more emphasis on gist in the years following late preschool and early elementary school. This shift is seen as consisting of three interconnected ideas or premises: Systems in the brain that support storage of verbatim information peak in efficiency in the mid-elementary school years; Those processes that support retention of gist come about very slowly; Therefore, during early childhood one would find the largest discrepancy in their growth functions. These claims have been posited in the research by Reyna and Brainerd (1991) in published papers about age changes in short-term memory span, recognition versus recall, and the development of mnemonic strategies. The domain of storage also contains the concept of on-line gist editing. Brainerd et al. (1990c) state that the instability of verbatim traces favors the hypothesis that gist is drawn in parallel with the encoding of surrounding data. However, arriving with an array of potential gists from early information, rather than postponing by selecting only gist that is consistent with every unit of information, creates the dillemna of possible local-global gist mismatches (Brainerd & Reyna, 1991). In particular, patterns can be drawn from initial data that are inconsistent with information to follow, which allows unwanted representations to accrue that are locally valid but globally wrong.

Because gist is sustained through time, parallel extraction requires an on-line editor that revises the store of patterns by deactivating locally valid representations as they progressively become globally incorrect. An array of various gist would be developed from the beginning. The editor would then focus on globally consistent gists while the background phase unfolds. In light of the experimental support of both infantile and infrahuman gist extraction, it would be theoretically desireable if the editor were a basic, structural aspect of memory, rather than a metacognitive device requiring levels of inferential understanding that might be attributed to older children and adults (Brainerd & Reyna, 1993). Kintsch (1988) developed the idea of a promising candidate mechanism in association with discourse analysis known as the construction-integration model. This theory espouses that "dumb" encoding rules affect the entering verbatim information and withdraw a large gamet of representations, many of which are incorrect. This is described as the construction stage, which is vaguely similar to FTT's parallel gist extraction. The representations that are created by these dumb rules are absorbed into a surrounding semantic network. As items are continually received, activation is allocated to portions of the network than hold proper representations, thereby deactivating incorrect representations. This is the integration stage which corresponds to FTT's on-line editing. Elaborate simulations of the construction-integration model and some lesser associated models that demonstrate FTT's assumptions have been reported by Kintsch (1988) and Kreindler and Lumsden (1991), respectively.

Given the common occurence of gist extraction and editing, a host of task-relevant traces will accrue. This takes place as surrounding background facts are continually encoded. Some traces are only partially similar to the initial detailed information. Brainerd and Reyna (1988) contend that fuzzy-to-verbatim continua will be developed because these traces vary in specificity. At one boundary are verbatim traces--richly detailed, well-articulated, crystallized representations that conserve recently encoded information with exactitude (Brainerd & Reyna,1993). At the other extreme are schematic, degraded, fluid representations known as fuzzy traces that withold only the patterns within previously encoded stimuli. In between these boundaries are traces that differ in their proximity to either the detailed or schematic extremes. The importance of fuzzy-to-verbatim continua in relation to cognitive functioning is that it maximizes options that permit memory and reasoning to sidestep some frequently occurant pitfalls.

It is reasonable to expect that the memorial decline of the levels within a fuzzy-to-verbatim continuum will be intimately associated, assuming that gist is stored and editied in unison with the verbatim information. Yet, both functional and structural independence of verbatim and gist traces have abounded against this contention from both behavioral and neuropsychological data respectively (Brainerd & Reyna, 1990b).

When considering behavioral data, it is useful to note that these results show evidence of immediate gist storage, and that the storage of details follows. Additionally, other results which include independent rate of declines for verbatim and gist traces must be noted. Reder (1982) has proved that subjects occasionally make judgements about sentences that are believed to require gist processing, prior to any precise verbatim memory test performance. Lamb and Robertson (1989) conducted experiments on pattern perception entailing global pattern detectors. These detectors withdraw associations as local operators process features. Additionally, the Reicher-Wheeler effect, wherein the letters that form words are identified much slower than the whole words themselves (Ankrum & Palmer, 1989), must also be noted.

The rates of forgetting for verbatim and gist traces also appears to vary. For example, Zimny (1987) examined this issue quite thoroughly by implementing Kintch et al.'s (1990) three levels of representation (a segment of their theory for text memory). Zimney created strategies for quantifying each level within the surrounding context of sentence memory recognition. Next, she determined the relative preponderence of data at these levels throughout a 4-day span, and detected a dissimilar rate of decay for each. Consequently, this result supports separate forgetting rates for verbatim versus gist traces.

Experiments on both (a) animals and (b) humans provide pertinent data of neuropsychological consequence. In light of (a), the previously discussed latent learning and learning sets are satisfactory examples of infrahuman gist extraction. These paradigms are also useful in examining whether or not detailed information and gist are located in separate neurological areas. Granger and McNulty (1986) as well as Staubli et al. (1984) have reported findings that clearly support a strong case for independent structures. For example, Staubli et al. state that when connections between the dorsomedial nucleus of the hypothalamus and the frontal cortex are cut, rats' memory for specific cues is conserved but their memory for the learning sets are destroyed. Upon surgically lesioning the hippocampus, the reverse is evident: memory for specific cues is destroyed, while memory for learning sets is retained.

Although these research strategies cannot be ethically applied to human subjects, the development of noninvasive brain imaging techniques has made it commonplace to find fluctuations in nervous system activity. These fluctuations exemplify performance on particularly dissimilar memory tasks, namely those results recently reviewed by Carr (1990). Specifically, in respect to FTT, as subjects grow progressively accustomed to a task and detect gist embedded within verbatim details, new neurological structures are activated while previously active structures grow inactive.

The law of over determination is another tenant within FTT. Since, by definition, traces that are not in storage cannot be processed, it would be highly desirable, for the sake of accuracy, if there were multiple memorial substrata that thinking and reasoning could draw upon to achieve their objectives (Brainerd & Reyna, 1993).

Such memorial options are afforded by fuzzy-to-verbatim continua informationally over determining any reasoning task. Brainerd and Reyna (1990b) and Kreindler and Lumsden (1991) regard the increased genetic fitness that would accumulate from such over determination as a crucial variable in the evolution of the human brain. A case in point is the prevalence of redundancy in the anatomy of the human brain (e.g., Estes, 1991), which is likely the neurological foundations of gist extraction. Due to the existence of such continua (memory contains more data than the actual detailed surrounding facts), the loss of access to any particular unit of information is rarely considered catastrophic. Thus, reasoning can accommadate on-line to faulty memory by tuning itself to whatever data is still remaining.

FTT contains the idea of a fuzzy-processing preference within the domain of processing. FTT understands cognition as favoring processing that is nearest to the fuzzy or gist end of fuzzy-to-verbatim continua. Supporters of this theory contend that flexible and schematic thought is prevalent amongst people as though there were a great affinity to it. Other theorists therefore differ greatly in their position, compared to one which considers imprecise thoughts as the preeminent form of processing (Brainerd & Reyna, 1993).

Intuitive thinking does not lead to inaccurate or sloppy products, as recent research has shown. When considering whether or not subjects prefer to use precise information or gist in the presence of both, research indicates that all ages prefer gist (Reyna & Brainerd, 1990) and that accurate responses can eventuate out of these gist-like impressions. Estes considered that gist-like processing could make a person an improved general purpose thinking machine (Brainerd & Reyna, 1993). Verbatim traces are understood to be not always accurate. Research has shown this to be true because of the great amount of information that is required to be processed in some situations (such as a 30-term transitive inference task). The terms are so numerous that they exceed short-term memory capacity (Brainerd & Reyna, 1990b).

The processing domain within FTT contains the features of task constraints and formatting. Considering that a hierarchical aspect of gist is formed from identical baseline data, the location in such a hierarchy where thinking is pinpointed is reflected by task variations. The form of the response that subjects must produce (e.g., point estimates vs. two choice preference tasks) and the amount of uncertainty that is inherent in the background information are issues that fix the level of specificity at which reasoning operates (Reyna & Brainerd, 1990).

Given these task considerations, it is believed that the fuzzy-processing preference manifests itself whereby thinking tunes itself into the lowest level possible in a fuzzy-to-verbatim continuum. Brainerd and Reyna (1988) and Reyna and Brainerd (1989) have found through their experiments to date that distinctions without difference in background inputs are ignored. Hence, reasoning moves toward the extreme in a fuzzy-to-verbatim continuum where the quantity of distinctions that can be ignored is greatest.

The fuzzy-processing preference can be affected by formatting manipulations that focus on or deemphasize particular kinds of gist at the expense of others. This is despite the affinity of reasoning to the most degraded level in a fuzzy-to-verbatim continuum that will ensure correct performance. Standard class-inclusion and framing problems are illustrative (e.g., Kahneman et al., 1982; Tversky & Kahneman, 1986). The presentation format of class-inclusion problems causes numerical data to become more salient and inclusional gist to embedd itself into the background, which leads humans of all ages to succumb to such illusions. Concerning framing, findings show that subjects' preferences are logically inconsistent with each other: their selections are neither consistently risk seeking nor risk averse. Additionally, subjects are not indifferent, despite the options being mathematically the same. Therefore, choices rely on how choices are framed.

Another feature held by FTT that warrants discussion is the idea of the independence of memory from reasoning. Common sense and traditional theories of cognitive development predict a relationship through which better memory for background facts leads to increased reasoning accuracy. In a standard problem, such as probability judgement, reasoning-remembering dependence can be broken down horizontally, vertically or experimentally. Horizontal variations occur where memory affects reasoning within subjects of the same age. Vertical variations are related to increases in memory whereby increasing age produces better reasoning. Experimental variations assume that affecting memory in a positive manner will increase reasoning ability (Brainerd & Reyna, 1993).

Fortunately for FTT's credibility, no horizontal, vertical or experimental dependence have been found in studies to date. With transitive inference, for example, young elementary schoolers' reasoning does not depend on their memory for background information. Also, age improvements with respect to memory for premises have not shown simultaneous improvement with respect to judgement outcomes. Finally, when manipulating memory for premises, increased accuracy for transitive inferences were not found (Brainerd & Kingma, 1985; Brainerd & Reyna, 1993).

Proponents of FTT believe memory and reasoning problems involve distinct processing operations. Therefore, because no processing overlap is assumed, there is structural and functional independence in performance.

Does the tendency to reason intuitively change with age? Like the ontogeny of gist extraction, FTT provides a rather complex explanation, namely that it principally depends on separating representational age-related changes from those of processing development. The fuzzy-processing preference per se may be developmentally invariant as long as the relevant gists can be extracted (Brainerd & Reyna, 1990b). However, Brainerd and Reyna (1993) understand that from an entirely normative position, the power and frequency of expression of the fuzzy-processing preference becomes greater with age.

This claim is based on age-related changes in representation as opposed to processing. Gist processing seems to be simpler than verbatim processing, thereby allowing gist-processing strategies more accuracy compared to verbatim processing strategies. Additionally, because they are less complex, gist-processing operations may come about earlier in life. For example, preschoolers are known to possess the ordering and classificatory operations that are necessary to process relational and nominal gist in probability judgement (Brainerd, 1981). Callahan (1989) stated that ratio operations that process verbatim numbers are usually not apparant before late childhood. Likewise, with transitive inference, Brainerd and Kingma (1984) report that perceptual mechanisms that process "flow" gist are detectable in preschoolers. Many researchers have understood the finding that verbatim-processing operations are more slow in developing than gist-processing operations to prove the opposite of FTT's contention that reasoning becomes increasingly more intuitive developmentally. The central opinion in the literature, embedded in Piaget's (e.g., 1967) definition of the preoperational stage as "intuitive" and the concrete- and formal-operational stages as "logical", is that intuition is a primitive form of thought that children must suppress or otherwise overcome if their thinking is to become truly logical (Brainerd & Reyna, 1993). This interpretation fails to take into account that because intuitive reasoning operations require less specific knowledge constraints than logical operations, it is rather obvious that the former tend to come about earlier. The preeminent question is whether or not, providing the availability of both kinds of reasoning operations in some domain, intuitive reasoning likely grows more dominant developmentally.

Another aspect of age-related changes in memory that apparently supports FTT's answer to this question is the phenomena of verbatim decline. This is the finding that memory for details begins its degradation much sooner in life than memory for gist, and therefore, thinking is sent in the direction of intuition by default. Illustrative of this position are parents whose semantic and situational grasp of sentences and stories is vastly superior to their children's, and who cannot remember verbatim sentences nearly as well as their children can. It appears that preschoolers' memories are highly tuned for storing and recalling verbatim traces. Although memory for details increases continually thereafter, it starts to fade before physical maturity, when gist memory has much development to forego.

The tradition has been that investigators of aging are primarily the ones concerned with memory deterioration. As a result, there have been few experiments documenting verbatim decline by child development researchers. Nonetheless, there are two research areas that lend support. First, there are studies of both verbatim and gist memory that are examined spanning early childhood through young adulthood. These studies have frequently shown that memory for gist increases developmentally; They have also occasionally shown that memory for details declines following childhood (Perner & Mansbridge, 1983; Marx, 1986).

The second and more elaborate source of support is offered by studies of language development, particularly first versus second language acquisition. Becoming proficient in a language requires strong verbatim memory skills (Miller, 1979). Johnson and Newport (1989) have shown that it becomes increasingly difficult to develop a lexicon following middle childhood, a finding that has frequently been examined with respect to second language learning. This decline has usually been understood as supporting critical periods in the course of language development (e.g., Lenneberg, 1967). Furthermore, FTT interprets the decline as a side effect of age-related changes in memory, particularly as a side effect of declining verbatim abilities.

Within the FTT domain of output are features such as on-line interference, concurrent processing deficits, and cognitive triage. Because the first two features have been previously discussed in the "shift" section, they will not be mentioned here to avoid redundancy. Cognitive triage, however, due to its central relevance to the experiments in question, will be discussed in greater detail later in its own section. At present the domain of forgetting will be examined.

There have been only a few empirical studies on age-related changes in forgetting. Considering the amount of theoretical interest in forgetting, this is probably because such investigations failed to find robust developmental variances.

In the discussion to follow, the common research findings of developmental invariance will be examined.

Then, what has long been the fundamental theoretical distinction in forgetting research, forgetting from memory (or trace unavailability or storage failure) versus forgetting in memory (or trace inaccessibility or retrieval failure) (Brainerd & Reyna, 1993) will be considered. Next, FTT's examination of age-related changes in forgetting will be outlined. Finally, a summary of results from recent studies associated with this examination will be presented.

The common device for examining age-related changes in forgetting is the Ebbinghaus long-term retention paradigm. This standard tool utilizes a minimum of three phases. The first phase consists of children learning a set of target materials, known as the acquisition session. The second phase is known as the forgetting interval, where children spend a few days or weeks resuming their daily lives. Incidentally, it is imperative that the second phase continue for at least a few days due to a period known as the consolidation interval. This interval lasts between a few hours to a few days, when recall may actually improve before forgetting ensues (Howe et al., 1991). In the third phase, known as the retention session, children are administered a series of memory tests to tap what they encoded during the first phase. A central aspect of these tests is that no opportunities to relearn the information are allowed; the purpose is entirely to measure retention. The decrease in memory performance between the close of the acquisition session and the retention session itself is the measure of forgetting.

Many investigations of age differences have implemented this paradigm but have failed to detect developmental variances in forgetting. Despite what appears to be unanimous agreement for such claims, a countervailing arguement, which results from closer analyses of these studies' designs, is that an isolated number of variables could have disguised age differences in forgetting. The three most prevalent variables are floor effects, recognition insensitivity, and stages-of-learning confounds.

When considering each variable, certain things need to be kept in mind. For example, with regard to floor effects, it is likely that unless an experiment induces some forgetting, it will surely be unable to show age-related changes in forgetting. In terms of recognition insensitivity, if the purpose is to detect some property of memory development, memory tests that are insensitive to age differences must be put aside. Finally, apropos stages-of-learning confounds, it is a truism that younger children will learn almost anything more slowly than older children. This means that older children will have reached more advanced stages of learning than younger children by the end of an acquisition session (Brainerd & Reyna, 1993).

Brainerd et al. (1985) and Brainerd and Reyna (1990a) have reported a sequence of experiments in which these three design pitfalls have been corrected. Ceiling effects have been eliminated by such tools as longer retention intervals (e.g., 2 weeks rather than 1-2 days) and more cumbersome materials (e.g., words rather than pictures). Recognition insensitivity has been greatly attenuated by changing to some form of recall (e.g., associative, cued, free). Stages of learning confounds have been dealt with by alternating to criterion learning. Here, mathematical models are used that tap the ratios of children who display varied learning levels. When controls of this kind are applied, age declines in forgetting rates are repeatedly shown from early childhood to young adulthood.

The fundamental question in the study of forgetting has been whether or not acquisition-retention declines are due to an inability to gain access to otherwise intact traces (the retrieval-failure hypothesis) or the fact that traces do not remain intact (the storage-failure hypothesis) (Brainerd & Reyna, 1993). Both hypotheses have come in a number of versions. When deliberating the retrieval-failure hypothesis, Hoffding (1891) saw that interference from subsequent experiences made it increasingly more cumbersome for perception to access previously stored traces. Freud, on the other hand, spoke of the importance of repressed past experiences that have emotionally distasteful associations. The gestalt psychologists Wulff (1922) and Hans Kohler (1929) have understood storage failure as spontaneous reorganization that creates trace mutations over time. Traces are reshaped in leuw of gestalt perceptual principals. Until now, storage-failure models have been of two simple types, eradication metaphors and fading metaphors. The former assume that traces are physically destroyed through either complete or partial erasure by subsequently stored traces (Brainerd & Reyna, 1993). The concepts of substitution and destructive updating are examples of complete and partial erasure, respectively (Loftus, 1979; Loftus & Hoffman, 1989). The long held concept of trace decay, the gestalt notion of reorganization, and FTT's own concept of episodic disintegration are illustrative of fading metaphor exemplars.

Loftus and Loftus (1980) have pointed out that the retrieval-failure hypothesis could be considered the textbook example of forgetting. The first line of major empirical support for this view was a series of brain stimulation experiments conducted in the 1940's. These experiments supposedly demonstrated how subjects could vividly recall long-dormant memories. Reminiscence, as a second line of evidence, refers to the actual finding that subjects are often capable of recalling items at time 2 that failed to be remembered at time 1. This occurs even though there is no opportunity for refamiliarization with the material during the interim. In long-term retention experiments, the reminiscence effect is the finding that performance steadily improves across a retention session even though only memory tests (e.g., free recall) are being administered (Brainerd & Reyna, 1993).

Although the retrieval-failure hypothesis is very popular, whether forgetting is exclusively or entirely as a result of an increasing inability to make contact with intact traces is an issue that is hardly resolved. The problem with brain stimulation data is a lack of verification as to whether or not these "vivid" memories are actually induced hallucinations (Loftus & Loftus, 1980). In addition, with the reminiscence effect, a lack of support for the retrieval-failure hypothesis surely prevails if memory traces are affected by memory tests to any degree. However, findings have been reviewed that suggest that memory tests create trace redintegration. This may be responsible for the improvement in recall between time 1 and time 2.

In order to explain the disintegration/redintegration hypothesis, one must consider that developmental investigations of forgetting have focused on the issue of episodic forgetting. In FTT, learning entails enriching core (gist) representations with enough episodic information that these representations can be successfully retrieved in the experimental context. On the other hand, because core representations are not unstable, forgetting entails deactivating these episodic-semantic bonds. Thus, FTT's employment of these general ideas is the disintegration/redintegration hypothesis.

FTT believes that during an acquisition session, episodic traces are created through a process of featural integration. This process involves the bonding of encoded episodic features to core gist. The speed of featural integration relies on the strengths of items' core representations, where faster integration is a result of stronger representations.

During a forgetting interval, a sort of counter process, featural disintegration occurs. Incidentally, FTT considers this to be the forgetting mechanism. This is where bonds between episodic features and core gist weaken to the point of traces fading out against the background of memory noise. Brainerd et al. (1990a) propose two reasons to account for the attenuated featural integration levels. First, a forgetting interval usually does not entail a continued joint activation of episodic features and core gist, which is likely necessary to suspend integration. Second, the episodic features that are stored in certain traces may be jointly activated with other core gists during the forgetting interval. Conversely, the core gists of certain traces may be jointly activated with other episodic features (Brainerd & Reyna, 1993). Therefore, through the process of featural disintegration, traces become increasingly less salient in the experimental context. It is important to note that the assumption of acquisition-retention declines are almost entirely a result of changes in trace properties. This is illustrative of a storage-failure point of view. The strength of the core gist to which episodic features are bonded is assumed to affect the rate of featural disintegration; higher strength means slower disintegration. Developmentally, disintegration is expected to show variations that closely follow those for strength.

FTT contends that during a retention session, featural redintegration operates on memory tests (Brainerd et al., 1990a). This is a process that is similar to acquisition-session integration. A portion of a trace's features are activated when efforts are made to retrieve it on memory tests, even in the case of failed retrieval. Here, activation spreads outwardly, both within activated features and those nonactivated features that are tenuously bonded to the activated features. Thus, efforts to retrieve traces on retention tests serves as a sort of catalyst in starting a redintegration process. This process then eventuates into net featural integration improvements. This is how FTT accounts for the reminiscence effect.

A number of predictions of episodic forgetting and its development are outlined by the disintegration/redintegration hypothesis. FTT makes some predictions that are of special interest when considering previous research. First of all, in contrast to the popular retrieval failure hypothesis, forgetting should be more of a reflection of storage failure than of retrieval failure. Second, in contrast to the commonly assumed developmental invariance pattern, forgetting rates are expected to decrease during age ranges when core gist is growing (ie., birth to young adulthood) and increase during age ranges when core gist is growing weaker (ie., young adulthood to late adulthood). Third, since retention tests induce featural redintegration of traces, it should be quite reasonable to assume that during a retention session, some of the traces that have experienced storage failure will be restored. This is the case even if the target material is not restudied.

An initial obstacle must be hurdled before such predictions can be examined. The predictions involve the behavioral properties of theoretical processes, namely storage and retrieval failure, rather than tangible aspects of the data. Therefore, to put them under scrutiny, we construct a mathematical model which contains parameters that tap these processes. Additionally, these parameters should be amenable to estimation from the performance data of long-term retention sessions (cf. Brainerd, 1985). Such a model, the trace-integrity model, has been cleverly designed. Also, the statistical underpinnings that are necessary to apply it to long-term retention data have been formulated (Howe & Brainerd, 1989). The model taps four kinds of theoretical machinery that are embedded in the disintegration/redintegration hypothesis: storage failure, retrieval failure, restorage, and retrieval relearning. Brainerd et al. (1990a) and Howe and Brainerd (1989) applied the trace-integrity model to a sequence of forgetting experiments in which the subjects ranged from age 7 to 70. The values found concerning the trace-integrity model's parameters fulfilled all of the predictions above.

In closing, one last property must be acknowledged in regard to FTT. This is the process through which both memory development and higher reasoning development are pitted against each other. For example, the fuzzy processing preference focuses on reasoning while cognitive triage focuses on memory (which will be discussed in the next section). The investigation of each are thought to assist in understanding the other. Therefore, one finds reasoning processes to account for memory development and memory processes to account for the development of reasoning (Brainerd & Reyna, 1993).

Cognitive Triage

Though it is important to describe previous phenomena such as dual task deficits, it is also commendable, if possible, to be able to predict unexpected phenomena. Fortunately, the interference principle achieves both. It does this within a frequently examined area in memory development: free recall. The particular area of results, the cognitive triage effect, is involved with the association between the order or sequence in which subjects retrieve items on free recall tasks and the memory strengths of those items. In order to understand the interest surrounding the triage effect, a discussion of what common-sense and classical memory theories contend regarding the strength-ordering relationship will take place first. Next, the actual triage effect will be described, as will the manner in which it is forecast by FTT. Finally, a report will be presented of various experiments which attempt to gain more stable conclusions regarding the developmental relationship between memory strength and the order of recall.

The idea of memory strength, that words can be distributed on a subjective magnitude axis and that their locations on this axis control memory performance on examinations, has been prevalent as long as psychology has been a discipline. The concept was implemented in studies by Ebbinghaus and Marbe (see Osgood, 1953), and it is included in practically any contemporary theory (e.g., Shiffrin & Murnane, 1989). It is natural to suppose that during unconstrained recall, words of higher memory strength become available to consciousness before words of lower strength. This ensures a stronger --> weaker strength ordering relationship. Marbe's Law (Marbe, 1901; Thumb &

Marbe, 1901) states that the activation speed of a memory representation is a logarithmic function of the representation's strength. This forecast has been utilized in a number of theories (e.g., Shiffrin, Ratcliff, & Clark, 1990). Because memory strength is a dimension of theory, a measure that is monotonically associated with strength must first be operationalized in order to test the stronger --> weaker prediction. The standard device is known as recall accuracy. Thus, in free recall tasks, the association between accuracy and ordering is implemented to measure the association between strength and ordering.

However, when this device is administered, the apparent relationship is not found to be stronger --> weaker. Brainerd et al. (1990b) have reported a sequence of experiments that actually show evidence favoring a counter-intuitive strength-ordering relationship, which they refer to as the cognitive triage effect. The complete scenario consists of four results. (a) On trial 2, at the beginning of free recall learning, if words retrieved are categorized as "strong" or "weak" based on the criteria of Trial 1 accuracy (i.e., strong = recalled on trial 1, weak = not recalled on trial 1), weaker words are accessed significantly before (on average) stronger words. (b) If words recalled on subsequent trials are assigned values with respect to their extent of memory strength as determined by the extent of earlier trial accuracy (e.g., strongest = no prior errors, next-strongest = 1 prior error, and so forth), a nonmonotonic strength-ordering relationship results. Particularly, the words of weakest magnitude (all errors on previous tests) are initially recalled, followed by the words of highest strength (all successes on previous tests) and then by the next-strongest words (1 error on previous tests), etc.. (c) If we classify words recalled at criterion (when performance shows no errors) with respect to memory strength using their entire record of accuracy on precriterion trials, the comprehensive strength-ordering relationship will likely display a weaker --> stronger --> weaker output queue. (d) Results a-c vary developmentally so that each finding tends to become increasingly sturdy in older children and adults compared to their younger counterparts.

FTT forecasts these findings since it presumes that recall order is not mitigated by a stable memory-strength factor but, on the contrary, it is a result of the dynamic interdependency of three variables: memory strength, episodic activation, and on-line interference. Units of information that are suspended in memory during free recall studies (nouns, pictures) have, within semantic memory, core representations that contain only the unit's gist. Therefore, this makes them in a respect "fuzzy". The elaborateness of items' core representations may differ due to a variety of reasons (e.g., level of redundacy in the lexicon, amenability to imaging). Since traces are fuzzy, they must be made more elaborate with episodic information prior to being retrieved and while embedded in a specific task context. Although items' relative memory strengths is understood as stable throughout the majority of free recall investigations (cf. Dagenbach, Horst, & Carr, 1990), the other two variables--episodic activation and on-line interference--differ in magnitude systematically through the course of an experiment.

Episodic activation has been considered a priming mechanism that is operative during tests of recall. More specifically, the recall of a given word triggers cognitive information that serves as a catalyst for accessing other words. More elaborate episodic networks are formed as a result of words with higher memory strengths than words of lower memory strengths. Hence, retrieving a strong word results in more priming than retrieving a weak word and the overall rate of priming during a free recall test will depend on the strength-ordering relationship. Recall studies addressing reminiscence effects (e.g., Brainerd et al., 1990a) indicate that such priming takes place in a negatively accelerated fashion. The effect weakens if it is not "recharged" by the retrieval of more words (assuming that other things are equal).

As discussed previously, on-line interference is an inhibitory process. When words are spoken at output, offtask noise such as proactive and retroactive interference (specifically known as scheduling effects and feedback effects) is developed. This occurs along side episodic activation. This noise or interference is understood by FTT through two beliefs. First, the recall of weaker words is more likely attenuated by on-line interference than is the recall of stronger words. Second, as in priming, interference dissipates in temporal course following its release. Neither activation nor interference levels are set on an inexorable course as the quantity of recalled words rises. On the contrary, levels of each grow higher or lower depending on the strength-ordering relationship.

FTT interweaves these concepts in a certain manner in order to forecast the triage effect. Namely, the traditional monotonic strength-ordering relationship has the weakness of being a function set in stone, where the influences of dynamic factors such as episodic activation and on-line interference are not accounted for. Therefore, a more accurately descriptive relationship is one in which recall is finely tuned to the present interference level. This is so that recall of weaker words occurs when interference levels are low. This optimal relationship expects words of higher memory strength to be recalled under conditions of higher interference. There are two junctures in a free recall protocol when accumulated interference in low (Brainerd & Reyna, 1993). First, it is low at the beginning of a protocol, which allows weaker words to be recalled. Second, on-line interference is low following a sequence of strong words. This is because such words derive large quantities of episodic activation and smaller quantities of interference in and of themselves. This permits temporal leeway for accrued interference to dissipate.

From FTT's point of view, retrieval could be greatly accentuated if subjects commence recall with weaker words, then supplant them with stronger words as interference accumulates. Subjects would then end with weaker words as episodic activation rises and interference finally dissipates. Thus, the underlying strength-ordering relationship predicted by FTT is weaker --> stronger --> weaker. This is the apparent surface relationship as well. More protracted sequences (e.g., weaker --> stronger --> weaker --> stronger --> weaker) of this relationship could prevail only occur if there were a host of accumulate/ dissipate cycles for on-line interference. Lastly, age-related trends in the cognitive triage effect are understood by FTT to be illustrative of the previously discussed evidence. Specifically, this evidence showed that vulnerability to scheduling or feedback interference varies with age. It is evident that the central age difference lies in the initial weaker --> stronger portion of the strength-ordering relationship. This portion happens to be significantly smaller in younger children. The strength of this portion of the relationship is a function of the subjects' skill in enduring the initial influence of rapidly accruing interference from weak word output. Because younger subjects are more vulnerable to interference than their older counterparts, they will be able to withstand less. This necessitates an earlier rotation to stronger words.

In order for FTT's optimization model to operate efficiently, dependable data inputs must be present. These inputs must permit subjects to make on sight determinations of words' relative memory strengths. Brainerd et al. (1991) have suggested that the common error-success feedback bestowed in free recall studies is a reliable source of such information. Because weaker words are more difficult to retrieve, deciphering words according to their error-success histories is equivalent to deciphering them according to their relative memory strengths. Frequency memory, which has been found to be highly accurate even in preschoolers (Brainerd, 1981), can be exploited to attain such discriminations (Brainerd & Reyna, 1993). As study and recall trials accrue, so do error-success frequency counts for particular memory items (Ekstrand et al., 1966). These frequency counts permit more salience in discriminating frequencies (and, therefore, in discriminating strengths as well). The finding of more robust triage protocols with age is significantly associated with the fact that frequency memory also improves with age. This is understood as a result of informational inputs in cognitive triage growing more reliable developmentally.

The following experiments by Brainerd et al. (1991) will be discussed in order to clarify conclusions regarding the developmental relationship between memory strength and order of recall. Nine studies will be discussed in total; the order in which the studies are reported includes an initial trio of experiments preceding a second trio and a final trio of experiments. Their scientific rational, construction, and preeminent results will be outlined briefly.

The first three experiments targeted the issue of whether stronger or weaker words appear first in children's free recall. When stronger words appear first in protocols, using FTT's more specific forecasts makes sense. In these experiments, 7-year-olds and 12-year-olds were given two study-test cycles with lists comprising 12 words (Experiment 1), 16 words (Experiment 2), or 24 words (Experiment 3) while given free recall instructions. The sequence of recall concerning weak versus strong words on the second trial of the two free recall tests was the focus of interest; words recalled on the second test were identified as to memory strength depending on performance within the first test (strong = success on Test 1, weak = error on Test

1). Support was evident in Experiments 1 and 2 for FTT's forecasts: Weak words were located in earlier mean positions in recall sequences. Contradicting the presumption that strong words would occupy earlier positions, the 24-word lists showed that weak and strong words did not vary in their average recall location. A lack of effect by age was the one finding that was contrary to FTT's predictions: the spread in location between weak and strong words was identical for children of both ages (7 or 12-year-olds). Two artifactual explanations were also ruled out; one claimed that the early appearance of weak words was due to recency effects and the other that it was due to primacy effects (Brainerd et al., 1991).

The first purpose of the next three studies was to progressively pursue the relationship between recall order and memory strength over a concatenation of memory interrogations. The second purpose was to ascertain whether developmental variances would eventuate on subsequent interrogations. It was reasonable to assume that the recall-order-memory-strength relationship could vary as words became more elaborately learned. Of note was the likelihood that the findings in the first three studies were narrowly associated with early learning and that strong words would be recalled prior to weak words as learning solidified. However, this hypothesis was not substantiated.

Younger children (7-year-olds) and older children (12-year-olds) committed to memory 12-word (Experiment 4), 16-word (Experiment 5), or 24-word (Experiment 6) lists through the course of five study-test cycles. After words were separated in a polarized fashion in terms of strength (strong = success on the prior trial, weak = error on the prior trial), retrieval favored the preceding of weak words to strong ones again. This was the case in both age levels, on every memory test, and for each of the three list lengths. Contrary to the first three experiments, developmental trends showed that the early emergence of weak words strengthened developmentally, as FTT predicts. Furthermore, a learning effect was evident since the triage protocol was accentuated on later trials as opposed to earlier trials, also as FTT predicts. This learning scenario was more robust in older children, which was an etiological factor in bringing about the age trend in cognitive triage.

The relationship between recall order and memory strength was found to vary systematically across trials (Brainerd et al., 1991). On any particular free-recall trial, words that occupied the beginning of the recall protocol were essentially words that had failed to be accessed on preceding trials. On following free recall trials, these same words usually were projected towards the final recall positions. Consistent with FTT, words were systematically deciphered in their relative error-success histories as the trials continued. They were also allotted locations in the recall protocol that were consistent with the weaker--> stronger--> weaker ordering. This pattern of intertrial shuffling of recall positions also ruled out a third artifactual explanation based on the notion of error-driven effortful processing (Brainerd et al., 1991).

The purpose of the final three studies was to investigate the relationship between the location of words recalled and their attendant memory strength when all words were retrieved at criterion. Both younger and older children committed to memory 12-word lists (Experiment 7), 16-word lists (Experiment 8), or 24-word lists (Experiment 9) to a criterion of two consecutive errorless free-recall tests (Brainerd et al., 1991). When recall location was plotted against memory strength at criterion, the predicted FTT relationship of weaker--> stronger --> weaker was evident within both age levels. The plots were well fit by a general quadratic equation of the form

$$Y = a - bX + cX \text{ ,}$$

where Y represents a word's location in the recall sequence at criterion, X is some identification of its total recall accuracy (e.g., overall errors to criterion, trial number of the final error), and a, b, and c are all free parameters (Brainerd et al., 1991). Although this relationship was shown in both younger and older children, its geometry displayed interesting age-related perturbations. These changes were consistent with FTT's contention that the propensity to create memory-strength impressions shows a positive trajectory developmentally. These impressions supply the informational underpinnings of cognitive triage.

The relationship between sheer retrievability and access order is a fundamental one that taps the aggregate impact of stored information. This means that its form is a question of considerable research interest. As with the research studies previously described, the triage project in question is also employed to examine variables that control the relationship between the sheer retrievability of stored items and the order in which those items are accessed. This research enhances our theoretical understanding of the nature in which stored information influences thinking, reasoning, and decision making at various age levels. It also enhances our ability to control this process.

Specifically, the triage experiment in question differs from the previously discussed projects in that relative memory strength is not measured by the error/success history of words. Therefore, there is no repetition of trials or examiner imposed variance in word list length. This dramatic change in methodology asks what is the precise form of the retrievability versus access order relationship when open-ended retrieval sequences occur in response to exogenous inquiries ("What did you get for Christmas?").

Unfortunately, there have been no studies that investigate the triage pattern in situations that resemble naturalistic, everyday remembering (e.g., answering a teacher's question in the classroom). In the triage experiment in question, not only is there no repeated retrieval of items but items are not presented for study. Feedback is also not presented concerning an item's relative retrievability. However, a key methodological question must first be answered if more naturalistic retrieval is to be studied: How shall the sheer retrievability of individual items be measured? It makes no sense to study naturalistic output sequences unless both variables can be measured since the triage pattern is concerned with the relationship between retrievability and access order. Because error-success data provide on-line measures of item retrievability, this problem has not come up in multi-trial free recall. Therefore, preexperimental measures of retrievability must somehow be attained if multiple study-test cycles will not be administered.

In the present experiment these measures are obtained by investigating childrens' unconstrained oral production of category exemplars. Norms based on large subject samples [e.g., the Battig and Montague (1969) norms] provide preexperimental measures of the sheer retrievability of individual category exemplars. For example: a child who is asked to remember the names of 10 musical instruments produces the sequence BANJO, OBOE, FLUTE, DRUM, PIANO, VIOLIN, TRUMPET, SAXOPHONE, GUITAR, CELLO. These same items can also be ordered in terms of their sheer retrievability by simply noting the proportion of subjects in normative samples who gave each of these items as an exemplar of the category musical instruments. For example, based on Battig and Montague's 442 subjects the relevant proportions are: .174, .326, .557, .729, .744, .613, .631, .398, .523, .201.

The present study prompts subjects to state seven exemplars of various categories that come to mind as category names are presented. Hopefully, this new format addresses the question of whether nonmonotonic retrievability versus access order relationships are observed through a more naturalistic exemplar production. It is also hoped that this format addresses whether the observed effects increase developmentally.

The purpose of the second experiment in question is to investigate intuitive aspects of children's memory for new vocabulary items. This experiment investigates children's tendency to falsely remember words whose gist (or meaning) is the same as the gist of newly learned items. A list of 74 words is presented to each child on the tape recorder. Some items are presented more than once. The child is then given an immediate recognition memory test in which they are asked whether each word (some actual targets, some words that approximate the same sound, while others are words of the same meaning) was previously presented. One week later another recognition test is administered. The purpose of this test is to measure how well children retain their original memories of presented words over an extended time interval.

Although this experiment is quite distinctive in its methodology, one related study may warrant mentioning. Brainerd et al. (in press) conducted five developmental experiments, presenting a memory target (e.g., CAT) to prime subsequent presentations of related distractors (e.g., ANIMAL, DOG, PAW). According to fuzzy-trace theory, false-recognition rates were predicted to decline relative to false-recognition rates for unrelated distractors (e.g., BOOK, TOWER). Also, related distractors were to be easier to reject than unrelated distractors under some conditions. Results showed a reversal of the standard false-recognition effect for distractors that were associates, category names, rhymes, and same-category exemplars of targets. False recognition reversals were found to vary with age, with amount of target repetition, with strength of target priming, and with length of retention interval.

Brainerd et al.'s experiment differs from the present study in that reversals were the issue of importance in Brainerd et al.'s study. Though both studies include false-recognition, the present study takes special interest in this area. Namely, the present study recognizes the importance of the differential rate of false-recognition for rhymes, category names, and same-category exemplars of targets. In addition, relatively speaking, the amount of target repetition and strength of target priming is not manipulated in this study.

The available literature supports the idea that the propensity to create memory-strength impressions when supplying the informational underpinnings of cognitive triage shows a positive trajectory with age. In addition, false-recognition reversals vary with age, with amount of target repetition, with strength of target priming, and with length of retention interval. It is expected that the same nonmonotonic relationship is found for category exemplar production in the present cognitive triage experiment. In the gist-intrusion experiment, it is predicted that children become more likely to falsely recognize words of the same meaning with increasing age. It is hoped that the results of the first experiment have positive implications for many everyday situations involving unconstrained, open-ended recall. It is hoped that the results of the second experiment suggest implications such that the prediction of gist versus verbatim memory styles may serve as a guide for tailoring academic approaches or interventions to particular childrens' needs (e.g., older children may be given tasks requiring a differing proportion of detailed versus intuitive skills than younger children).

CHAPTER 3

METHODOLOGY

Method

The methodology used in gathering the data is described in this chapter, beginning with subject selection, materials, and procedures.

Subjects

One hundred eighty five children (62 kindergartners, 63 third graders, and 60 sixth graders) from public elementary schools in the Tucson metropolitan and Douglas areas served as subjects in the two experiments. Most children in these districts come from lower-to-middle-income families. The districts serve pupils from diverse linguistic and ethnic backgrounds, such as Hispanic, Native American, African American, and white. In an effort to lesson the effects of language and cultural differences, only children who were fluent speakers of English were referred by their teachers. No subjects were in adaptive education or gifted programs. All were selected with the expectation that they posessed average intelligence and were not learning disabled.

Upon receiving permission from the Districts' Director of Research, individual school principals were contacted and asked to be involved in the experiments.

Materials

Experiment 1

In experiment 1, triage data was gathered in one session. Subjects were auditorally presented (via the examiner's voice) questions concerning exemplar categories. Exemplar categories were selected based on Battig and Montague's (1969) lists. These lists contained preexperimental measures of the sheer retrievability of individual category exemplars. Eight exemplar categories were chosen and printed on a sheet, upon which the examiner recorded each child's responses.

Procedures

Experiment 1

In the cognitive triage experiment, children were seen only in one session. All subjects were asked to generate category exemplars. The stimuli involved the researcher presenting each subject with eight exemplar categories: "I'm going to give you the names of some things that you know about and I'm going to ask you to remember as many of those things as you can. For example, I might ask you to, 'tell me the names of all the flowers you can think of,' and you might say ' DAISY, ORCHID, ROSE, PETUNIA, CARNATION, TULIP, VIOLET.'" Once it was evident that the subject comprehended the task, verbal instruction was offered only as required. Eight exemplar categories were chosen from Battig and Montague's (1969) category norms: colors, animals, birds, musical instruments, fruits, vegetables, trees, and sports. Categories were presented auditorally in a random fashion to all subjects. Subjects' consecutive responses (up to seven) were tape recorded and hand written by the experimenter. One minute was allowed for subjects' recall following each category probe. Kindergarten, third, and sixth grade children were all given the same procedures.

Materials

Experiment 2

In experiment 2, data was collected in two sessions. Materials for the first session consisted of a tape recorder that was played to subjects, presenting a vocabulary list of targets (see Appendix A), 74 words were previously recorded on to the tape player in one of either two voices: one being that of the experimenter's voice, consistent with the yet to mention recognition session, and one being completely different from the examiner. This was to create a voice mismatch between list presentation and recognition session. A "Where's Waldo" Handford (1987) book was briefly read by students as a short-term memory buffer after which a recognition session took place. In this session children were asked whether or not they heard a particular word on the study list previously heard on the tape player. The researcher recorded the subjects' responses on a sheet printed with various actual target and distractor items (see Appendix B). Finally, a week later another recognition test was administered which resembled the first one. The researcher again recorded the subjects' responses on a printed sheet (see Appendix C). It is important to note that during each session in both experiments the examiner used a different tape recorder to record all subjects' responses.

Procedures

Experiment 2

Experiment 2 was performed in two sessions. In the beginning of the first session, each subject was presented a list of 74 words on a tape player. Some items were presented more than once. Children were asked to "listen very, very carefully to the tape as I play it. Listen carefully to each word and try to remember it because later on I'm going to give you a test to see how many words you can remember." Subjects were randomly assigned to either voice condition: one presenter voice on the tape recorder previously recorded in the same voice as the experimenter and the other in a distinctly different voice (that of the experimenter's advisor, in this case). Following the presentation, a short-term memory buffer was employed by asking each child to search for a hidden person in pictures from a "Where's Waldo" Handford (1987) book. One minute was spent in this activity for each child. Upon finding the missing person ("Waldo"), children were asked to continue to the next page of the book.

Children were then given an immediate memory test. On this test, they were presented with words that were previously presented (targets) and words that were not previously presented (distracters). Some distracters sounded like a previously presented word, and others had the same meaning as a previously presented word. Words were randomly presented in blocks containing targets and their attendant gist and verbatim distracters. The child was asked whether each word was previously presented: "I am going to read you some words that I have written down on this sheet. Some of the words will be ones that you heard when you listened to the tape. Other words will be new ones that you did not hear when you listened to the tape. As I read each word, say YES if you heard the word when you listened to the tape. Say NO if you did not hear the word when you listened to the tape." Subjects' responses were hand written and tape recorded by the experimenter.
Finally, one week later there was another recognition test that completely resembled the first session in this experiment.

CHAPTER 4

RESULTS

Introduction

The first set of analyses performed on the data yielded scores reflecting the organization of children's category exemplar production. Means of the relative frequency were generated and subsequently tested using a chi-square procedure. The second set of analyses performed on the data yielded scores reflecting children's discrimination of targets and distractors. Multivariate analyses of variance (MANOVA) were used on the proportions of yes responses across the various levels of variables of interest.

Experiment 1

Data for the eight different exemplar categories was pooled for each subject. Mean exemplar frequencies and percent of items retrieved are presented separately for each retrieval position (1 through 7) and for each grade (kindergarten, third, sixth) in Table 1.

The means above seem to reflect a monotonic decreasing function between frequency and retrieval position for all grades. Also, as expected, older subjects were able to retrieve a larger percentage of exemplars in later positions.

Table 1

Mean Exemplar Frequency With Percent of Items Retrieved

Retrieval Position	Kindergartners	Third Grade	Sixth Grade
1	240.39 (92.97)	260.29 (98.77)	293.30 (100.0)
2	225.94 (85.94)	248.74 (97.37)	266.05 (99.38)
3	197.81 (78.52)	213.61 (94.47)	206.23 (96.46)
4	176.16 (64.45)	173.14 (88.11)	194.76 (93.80)
5	165.48 (49.80)	167.82 (75.61)	156.80 (87.50)
6	186.63 (36.72)	153.13 (63.73)	150.88 (79.38)
7	160.63 (29.69)	134.07 (52.05)	127.40 (71.88)

The problem with this method of examining response frequencies is that it averages over potentially interesting patterns in individual subjects' exemplar retrieval. That is to say, although the overall frequency at each position decreased, it does not necessarily mean that each individual subject's frequencies decreased also. Thus, a chi-square analysis was performed in order to detect any individual variations in retrieval.

For each subject, if an item was recalled in the next position with a lower frequency than the current item, a zero would be assigned to that comparison. If the next item was recalled at a higher frequency than the current item, a number 1 was coded before analyses were performed. For example, for the category of birds, if a particular subject recalled robin in the first position (frequency = 346), then bluejay in the second position (frequency = 82), a value of 0 would be assigned to that comparison. If that subject then recalled sparrow in the third position (frequency = 224), a value of 1 would be assigned to that comparison. This weaker/stronger analysis was therefore done on actual data. It was then pooled over each subject, arriving at a mean percent of 1's and 0's.

The chi-square analysis makes a comparison of probability that either position will be noted as a 1 or a 0 variable. In other words, this chi-square analysis is a comparison of comparisons, through which the direction of individual frequency changes across positions may be determined. In Table 2, the probability percentages are only described pertaining to a value of 1, not 0. For example, within kindergartners, 41.6 percent was the probability that the next item of position 1 was more frequent (1) than the next item of position 2. 58.4 was the percentage of probability that the next item of position 1 was less frequent (0) than the next item of position 2. However, only the probability percentage of 41.6 was reported in Table 2 due to it pertaining to a value of 1. Reporting 0 values is redundant since adding probability percentages amounts to 100 percent.

Table 2

Probability That Next Item is More Frequent Than Current Item

Kindergartners

Comparison A		Comparison B	Probability [%] (A)	Probability [%] (B)	Chi-square
Position 1	vs.	Position 2	41.6	38.2	30.30**
Position 2	vs.	Position 3	39.4	42.6	32.76**
Position 3	vs.	Position 4	44.8	44.8	27.11**
Position 4	vs.	Position 5	47.5	50.3	19.46**
Position 5	vs.	Position 6	56.4	37.1	5.00*

* p < .05 ** p < .001

Third Graders

Comparison A		Comparison B	Probability [%] (A)	Probability [%] (B)	Chi-square
Position 1	vs.	Position 2	42.2	42.3	13.67**
Position 2	vs.	Position 3	42.3	35.2	17.62**
Position 3	vs.	Position 4	36.5	47.1	18.66**
Position 4	vs.	Position 5	47.3	37.3	27.70**
Position 5	vs.	Position 6	39.3	42.6	21.54**

** p < .001

Sixth Graders

Comparison A		Comparison B	Probability [%] (A)	Probability [%] (B)	Chi-square
Position 1	vs.	Position 2	36.9	33.4	13.67**
Position 2	vs.	Position 3	33.6	43.6	34.39**
Position 3	vs.	Position 4	43.8	36.3	18.29**
Position 4	vs.	Position 5	38.0	42.8	26.16**
Position 5	vs.	Position 6	43.6	40.6	24.97**

**p<.001

The above probability values appear to form a trend. It appears that they alternate in order of magnitude from (A) to (B) with repeated comparisons of ascending positions. For example, regarding sixth graders, probability (A) was greater than probability (B), being 36.9% compared to 33.4%. These were the values for position 1 versus position 2. However, probability (A) was less than probability (B), being 33.6% compared to 43.6% for position 2 versus position 3. This trend was pervasive for all grade levels. There were significant effects for every comparison. F values were all at a significance level of $p < .001$ except for position 5 versus position 6 for kindergartners. This comparison had a significance level of $p < .05$.

Experiment 2

Separate MANOVAs were calculated for targets, related distractors, and unrelated distractors. In the case of targets, a three-way MANOVA was run with grade (kindergarten/third/sixth) as the between-subjects variable. Time of testing (immediate/delayed) as well as number of presentations (one/three) were the within-subject variables. Results of this analysis are presented in Table 3.

Table 3

MANOVA for Discrimination of Targets

Dependent Variable: Targets

Source	DF	Mean Square	F
Grade	2	0.21	3.93*
Time of Testing	1	7.55	369.26**
Number of Presentations	1	4.15	175.55**
Grade x Time of Testing	2	0.06	2.75
Grade x Number of Presentations	2	0.01	0.39
Time of Testing x Number of Presentations	1	1.24	102.49**
Grade x Time of Testing x Number of Presentations	2	0.01	0.65

* $p < .05$ ** $p < .001$

Concerning targets, there was a main effect for grade $F(2, 182) = 3.93$, $p < .05$, with third graders (75.8) having a significantly higher mean acceptance percentage than both kindergartners (70.7) and sixth graders (70.8). A main effect was also found for time of testing $F(1, 182) = 369.26$, $p < .001$, with immediate testing having a significantly higher mean than delayed testing (82.5% vs. 62.3%). A final main effect was found for number of presentations $F(1, 182) = 175.55$, $p < .001$, with 3 presentations having a significantly higher mean than 1 presentation (79.9% vs. 64.9%).

The only significant two-way interaction was between time of testing and number of presentations $F(1, 182) = 102.49$, $p < .001$. Means for this first-order interaction are presented in Table 4. Targets that are repeated three times are accepted at a higher percentage rate than those presented only once. However, the interaction of target repetition with time of testing shows that the repetition effect is larger on the immediate test than on the delayed test.

Table 4

Mean Acceptance Percentages for Time of Testing versus Number of Presentations

	Immediate	Delayed
1 presentation	70.9	58.9
3 presentations	94.0	65.7

Findings for related distractors are presented in Table 5. Here, a four-way MANOVA was run with grade (kindergarten, third, sixth) as the between-subjects variable. Time of testing (immediate/delayed), number of presentations (one/three), and positions after the target (one/four/five) served as the within-subject variables.

Table 5

MANOVA for Discrimination of Related Distractors

Dependent Variable: Related Distractors

Source	DF	Mean Square	F
Grade	2	2.68	8.41**
Time of Testing	1	13.19	178.89**
Number of Presentations	1	0.14	3.98*
Positions After the Target	2	0.62	16.62**
Grade x Time of Testing	2	0.19	2.64
Grade x Number of Presentations	2	0.09	2.54
Grade x Positions after the Target	4	0.10	2.55*
Time of Testing x Number of Presentations	1	0.01	0.22
Time of Testing x Positions After the Target	2	0.23	7.06*
Number of Presentations x Positions After the Target	2	0.55	15.76**
Grade x Time of Testing x Number of Presentations	2	0.15	4.16*
Grade x Time of Testing x Positions After the Target	4	0.02	0.55
Grade x Number of Presentations x Positions After the Target	4	0.02	0.67
Time of Testing x Number of Presentations x Positions After the Target	2	0.04	1.24
Grade x Time of Testing x Number of Presentations x Positions After the Target	4	0.03	0.77

$* p < .05$ $** p < .001$

Concerning related distractors, there was a main effect for grade $F(2, 182) = 8.41$, $p < .001$, with kindergartners (31.7) having a significantly higher mean acceptance percentage than third graders (23.2), followed by sixth graders (20.2). Another main effect was found for time of testing $F(1, 182) = 178.89$, $p < .001$, with delayed presentation having a significantly higher mean than immediate presentation (32.9% vs. 17.4%). The next main effect was for number of presentations $F(1, 182) = 3.98$, $p < .05$, with distractors related to targets presented once being very slightly more likely to be accepted than distractors related to targets presented three times (26.0% vs. 24.4%). The last main effect was for positions after the target $F(2, 364) = 16.62$, $p < .001$. It seems the more items there were between the target and the related distractor, the more likely the distractor was to be accepted (21.9 vs. 26.1 vs. 27.4).

A significant two-way interaction was found between grade and positions after the target $F(4, 364) = 2.55$, $p < .05$. Means for this first-order interaction are presented in Table 6. Younger children falsely accept related distractors at a higher rate. The false acceptance rate for kindergarteners is not strongly correlated with position. However, older children show a strong trend in false acceptance rate versus position.

Table 6

<u>Mean Acceptance Percentages for Positions After the Target versus Grade</u>

	1 position	4 positions	5 positions
Kindergartners	29.7	33.8	31.6
Third Graders	18.7	23.2	27.6
Sixth Graders	16.9	20.9	22.8

There was another significant two-way interaction found between time of testing and positions after the target $F(2, 364) = 7.06$, $p < .05$. Means for this first-order interaction are presented in Table 7. Related distractors are accepted at a higher rate during delayed rather than immediate testing. The difference in rates of false acceptance is greater for less positions.

Table 7

<u>Mean Acceptance Percentages for Positions After the Target versus Time of Testing</u>

	1 position	4 positions	5 positions
Immediate	12.2	19.0	21.1
Delayed	31.6	33.3	33.8

Another significant two-way interaction was found between number of presentations and positions after the target $F(2, 364) = 15.76$, $p < .001$. Means for this first-order interaction are presented in Table 8. If the target was presented only once, the false acceptance rate increased with position. However, when targets were repeated thrice the false acceptance rate was not strongly correlated with position.

Table 8

Mean Acceptance Percentages for Positions After the Target Versus Number of Presentations

	1 position	4 positions	5 positions
1 presentation	21.8	24.8	31.3
3 presentations	22.1	27.5	23.6

The only significant three-way interaction for related distractors was between grade, time of testing, and number of presentations $F(2, 182) = 4.16$, $p < .05$. Means for this second-order interaction are presented in Table 9. Related distractors are accepted at a higher rate during delayed rather than immediate testing. However, the interaction of time of testing with target repetition and with grade shows the retention interval effect is larger when kindergarteners are presented the target once.

Table 9

Mean Acceptance Percentages for Grade versus Number of Presentations Versus Time of Testing

	1 presentation	3 presentations
Kindergartners		
Immediate	21.7	24.2
Delayed	41.1	39.8
Third Graders		
Immediate	16.3	13.0
Delayed	34.0	29.6
Sixth Graders		
Immediate	16.9	11.8
Delayed	25.1	27.0

Findings for unrelated distractors are presented in Table 10. Here, a two-way MANOVA was run with grade (kindergarten, third, sixth) as the between-subjects variable. Time of Testing (immediate/delayed) served as the within-subject variable.

Table 10

MANOVA for Discrimination of Unrelated Distractors

Dependent Variable: Unrelated Distractors

Source	DF	Mean Square	F
Grade	2	0.38	7.63*
Time of Testing	1	3.94	270.52**
Grade x Time of Testing	2	0.04	2.74

* $p < .05$ ** $p < .001$

Concerning unrelated distractors, there was a main effect for grade $F(2, 182) = 7.63$, $p < .05$, with kindergartners (32.6) having a significantly higher mean acceptance percentage than both third graders (28.5) and sixth graders (21.6). A main effect was also found for time of testing $F(1, 182) = 270.52$, $p < .001$, with delayed presentation having a significantly higher mean than immediate presentation (38.0% vs. 17.3%). However, the interaction of these two variables was not significant.

CHAPTER 5

DISCUSSION

Introduction

Various findings in these two experiments were consistent with those of previous works. Non-monotonic retrievability versus access order relationships were observed for children's free recall. Children also showed evidence of falsely remembering vocabulary items that they actually have not learned (Table 5). This false-recognition effect was found to vary with age (Table 5). Other significant variables resembling findings in false-recognition reversal experiments were found in this study, such as the amount of target repetition and the length of the retention interval. Unfortunately, the variance due to the position of a distractor following a target has no base of comparison to previous works. However, a particular finding in the former experiment was contrary to that of previous works. Older children showed a relatively equal cognitive triage effect in their recall compared to younger children. A discussion of children's free recall of category exemplars begins the discussion, followed by an examination of children's false-recognition of words of the same meaning. Findings and possible explanations will be integrated into previous studies and well-established theory. The relevance of the above study's findings to educators will then be examined. Limitations of these studies follow. Finally, the dissertation is concluded with areas for future research.

Children's Free recall

Non-monotonicity

Previous research has shown a non-monotonic relationship between the memory strengths of episodically-related items and the order in which children articulate those items during free recall (Brainerd et al., 1990b). Thus, it was expected that children in this study would show the same effect. This was the case, regardless of previous projects having measured relative memory strength via the error/success history of words. The current experiment involved semantic memory rather than episodic memory. An inspection of Table 2 shows that all grades formed a trend with regard to probability values. It seemed that they alternated in memory strength from one exemplar item to the next with repeated comparisons of ascending positions. All comparisons of positions for all grades reached statistical significance using a chi-square analysis. Thus, it appears in this study that non-monotonic relationships are found in situations resembling naturalistic, everyday remembering. Hence, fuzzy-trace theory's conception of interference in cognitive triage is therefore supported by this new methodology and its respective findings. Preexperimental measures of retrievability (Battig and Montague's (1969) lists) have been instrumental to these findings for category exemplar production. In sum, methods involving both semantic and episodic memory result in non-monotonic relationships in triage.

Younger Versus Older Children

Previous research has shown a general developmental trend in children's cognitive triage. Older children have been found to exhibit a more pronounced oscillatory relationship in their recall than younger children (Brainerd et al., 1990b). This is generally the view predicted by FTT, where children become less susceptible to interference with age. In addition, the informational underpinnings of triage become more salient with development (Brainerd et al., 1990b). Thus, it was expected that children in this study would show a stronger non-monotonic relationship in their recall of category exemplars with increasing grade level. This was not the case, however. An inspection of Table 2 shows that all grades showed relatively equal chi-square values across positions. That is to say, kindergartners, third graders, and sixth graders showed relatively the same amount of alternation. This alternation was in order of memory strength from one exemplar item to the next with repeated comparisons of ascending positions. Unfortunately, although non-montonic relationships are found in situations resembling naturalistic remembering, these findings do not increase developmentally. It is speculated that some methodological factor in previous works (measuring memory strength via error/success history of words on previous trials) was not available in the current study to draw out this developmental effect. Other limitations, such as the age level that the preexperimental memory strength norms were based on, may have been responsible for this lack of an age effect.

Children's Recognition Memory

False Recognition

The familiar outcome in previous research has been that children falsely accept words that resemble targets at a higher rate than words that do not. Thus, it was expected that children in this study would show a differential rate of false-recognition for related distractors than for unrelated distractors. This was the case, as can be seen with an inspection of Tables 5 and 10. If one considers that mean acceptance percentages were relatively similar for both related and unrelated distractors, Tables 5 and 10 still show differential false-recognition rates. This is so because related distractors had more within subject variables to contribute to significant acceptance percentage differences. For example, while time of testing showed a main effect for unrelated distractors (Table 10), number of presentations of a target and positions after the target made an additional significant impact on the acceptance of related distractors (Table 5). This is not to mention the additional significant first and second order interactions for related distractors. Thus, it appears in this study that children had an affinity to accepting words of the same sound or meaning. This is consistent with fuzzy-trace theory's hypothesis that interference from the gist of related distractors makes a child more likely to misrecognize distractors as targets.

Younger Versus Older Children

Previous research has shown that children's false-recognition exhibits a developmental trend. That is to say, younger children have falsely accepted distractors that resemble targets at a higher rate than distractors that do not. Thus, it was expected that older children in this study would have an increasing affinity to falsely accept words of the same sound or meaning as a target. This was the case, as Tables 5 and 9 illustrate. Grade level showed a highly significant F value in Table 5. According to Table 9, kindergarteners, of all grades showed the highest significant mean acceptance percentages for distractors that resemble targets. Therefore, experimental evidence shows remembering unlearned vocabulary is more frequent in younger children. This finding is consistent with another of FTT's hypotheses and work by Dempster (1992) that children become less sensitive to interference with age. More precisely, older children are better able to inhibit interference. This is afforded by older children's more developed frontal lobes, which are anatomically responsible for this ability. It is reasonable to assume that this cross talk or interference extended from related distractors was more likely to effect younger children's choices.

Other Findings

Brainerd et al. (in press) in previous research conducted five pertinent developmental experiments. Targets (e.g., CAT) were presented to prime subsequent presentations of related distractors (e.g., ANIMAL, DOG, PAW). According to fuzzy-trace theory, related distractors were to be easier to reject than unrelated distractors. Indeed, results showed a reversal of the standard false-recognition effect for related distractors. These reversals were found to vary with age, amount of target repetition, strength of target priming, and with length of retention interval.

The above five experiments are worth mentioning because significant within-subject variables in the current recognition study are similar. Namely, those are, amount of target repetition and length of the retention interval. Regarding the former, an inspection of MANOVA Tables 3 and 5 show significant main effects as well as one-way and two-way interactions. That is to say, MANOVA's for targets and related distractors involving amount of target repetition showed significant F values in Tables 3 and 5 respectively. According to Table 4, targets were specifically accepted at a higher percentage with three presentations of a target rather than one, especially during immediate testing. Concerning target repetition, the much higher significance levels reached with targets rather than related distractors is also consistent with fuzzy-trace theory. It is hypothesized that greater repetition of targets makes a child very clear on discriminating actual targets during testing. However, it also seems to attentuate the gist interference exuded by related items through making their falsity more apparent.

Concerning length of the retention interval (Time of Testing), an inspection of MANOVA Tables 3, 5, and 10 clearly shows the highest significant main effects in this experiment. First, regarding targets, the length of retention interval was negatively correlated with higher acceptance percentages. Regarding related and unrelated distractors, acceptance percentages were much lower for immediate testing. While it seems that immediate testing helps distinguish targets to children, it nonetheless also helps children to avoid falsely recognizing related distractors. This finding is also consistent with FTT, where temporal strengthening of memory for targets makes children more able to combat interference from the essence of related distractors.

Also, concerning time of testing, an inspection of Tables 3 and 5 shows significant first and second order interactions. A very significant interaction was found between time of testing and number of presentations for discrimination of targets. Again, immediate testing resulted in higher acceptance percentages (Table 4). Also, for discrimination of related distractors, acceptance percentages were much lower than for discrimination of targets. Like the main effects, immediate testing influenced lower acceptance percentages (Tables 7 and 9). The interaction for targets was much more significant than the interactions for related distractors as well. That is to say, while interactions involving time of testing help children discriminate targets, they have less power in helping children decipher related distractors. Unlike the main effects, this finding is inconsistent with predictions of FTT. Fuzzy-trace theory expects immediate presentation to diminish the likelihood of falsely accepting a related distractor through attenuating gist interference. Perhaps in this experiment, the increased salience of actual targets is a by-product of distractors being falsely rejected.

One last significant within-subject variable has no basis of comparison to previous works. This variable is the number of positions after the target. An inspection of Table 5 shows one main effect and three two-way interactions for related distractors. Though the main effects of ordinal position reached significance levels, it was much weaker than the main effect of time of testing. That is, children's likelihood of falsely recognizing a word they have not learned is more effected by the time of testing than the number of positions a distractor followed the target. Fuzzy-trace theory would describe positions after the target as not greatly reducing the level of gist interference posed by these related distractors. Regardless, the data shows that the fifth position after the target showed the highest false-recognition.

Concerning interactions, it was generally found for all that distractors following targets by five positions were most likely to be falsely recognized (Tables 6, 7, and 8). Fuzzy-trace theory would describe the fifth position as reducing the salience of the actual target and increasing the gist interference from the related distractor. The interaction with number of presentations showed the highest significance level. It appears, therefore, that the quality of the initial encoding of items into memory has more bearing on false-recognition than length of the forgetting interval (in combination with positions after the target). Finally, we note that third graders showed the strongest interaction with positions after the target. Fuzzy-trace theory has instead predicted sixth graders to be most capable in using temporal cues in distractor presentation to their advantage. Regardless, kindergarteners experienced unchanging and generally higher false-recognition across all positions after the target.

<u>Summary</u>

In summary, non-monotonic retrievability versus access order relationships were observed in this experiment for children's free recall of category exemplars. Non-montonic relationships for free recall were observed for semantic memory data similar to data from episodic memory. Children also showed evidence of false-recognition. This false-recognition effect was found to vary with age. Various other variables contributed to the false-recognition of related distractors. The above results are generally consistent with findings of previous works. The FTT explanations of previous works can therefore be applied to these current studies, giving central importance to the concept of interference. In the first experiment, this interference takes the form of scheduling and feedback interference which impede the recall of weak memories. In the second experiment, gist interference is the factor which leads a child to falsely recognize a related disractor as an actual target. However, in the cognitive triage experiment older children showed a relatively equal non-monotonic relationship in their recall compared to younger children. This is contrary to findings of previous works and to the predictions of FTT. The most likely explanation for this result relates to the meaningfulness of the items, despite several possible explanations. Perhaps younger children found exemplar categories to be quite meaningful; they generate them with as much ease as an older child. Higher memory strength of exemplars will accentuate the triage pattern because they will enhance the informational underpinnings of triage. "Regardless of age, meaningfulness is the key to memory organization, rather than specific category or associative structure. While certain items will share membership in categories or associations by frequency, meaningfulness seems to superimpose itself and predominate as the bond which connects items in memory" (Lee, 1992). The developmental differences found in previous cognitive triage experiments might have been a result of stepping around the issue of meaningfulness. This is possible by not using category exemplar production but instead measuring memory strength through the error/success history of words over trials. This may ensure greater control over item meaningfulness. Regardless, the results of the aforementioned recall and recognition memory studies, for the most part, conclusively answer the questions of nonmonotonicity and false-recognition.

Educational Implications of the Study

For several years educators have considered the importance of children's memory processes in maximizing their academic performance. The effectiveness of multiple choice or essay tests has been examined when tapping children's retention of previously learned material. Teachers have considered children's memory processes not only during testing but also when introducing new concepts and material. Performance is improved when a student can apply what he/she has previously learned to new tasks (for example, Landis, 1982). Thus, one could say that memory for prior knowledge influences memory for future knowledge. Educators have appreciated the importance of their students' background knowledge and have considered numerous methods for activating it for future tasks, such as brainstorming, pre-reading and schema activation strategy (Lee, 1992; Bos & Vaughn, 1991).

"Brainstorming is a technique in which the teacher provides a stimulus word and children are asked to list all the words or phrases that they can associate with the stimulus" (Lee, 1992). All of the students' items are then listed on the board by the teacher. Children may even be assisted to discuss, organize, or categorize the information. "Pre-reading involves introducing a topic; having students generate and list associations; asking children to reflect upon their responses (such as "what made you think of______?") to become aware of their prior knowledge and how it relates to the concept, reformulating the knowledge by providing children with a chance to articulate how the discussion may have altered or enhanced their previous knowledge of the topic, as well as the benefit from the other students' comments" (Lee, 1992). A pre-reading discussion is also utilized in schema activation strategy, emphasizing how story characters resemble students' personal experiences. Central ideas from the story are then offered and children once again relate their own experiences to these. Next, children are then required to imagine an event from their personal experience that might happen in the story. After the prereading discussion and the actual reading of the story, the teacher asks inferential questions about the text, requiring children to support their answers with information from the story or with their prior knowledge (Bos & Vaughn, 1991 in Lee, 1992).

Therefore, it appears that the idea of emphasizing students' memory for personal knowledge is not new to educators. However, the results of this cognitive triage experiment emphasize the importance of considering children's interference processes when designing tasks that require accessing categorical items from students' own learning histories. Particularly, interference is assumed to be responsible for the non-monotonic output sequences found in this experiment. This finding is relevant because prior non-monotonic output sequences were found only with repeated study/test cycles. In addition, the present free recall study found the important result of an equal non-monotonic relationship in younger children. Prior works using repeated study/test cycles found an increasing non-monotonic relationship with age. This incongruent finding is a result of younger children overcoming interference especially well when personally relevant items are being tested. Since Battig and Montague's (1969) norms were based on adults' retrieval, exemplar protocols may be different for young children.

If it is agreed that an increased cognitive triage effect is indicative of more efficient recall, educators must therefore allow younger children to overcome interference as best they can. Considering the results of this study, activities and testing that involve a child's most meaningful personal knowledge will result in increased recall of classroom information. "When teachers assume that youngsters recognize relationships between items, they may be relying more on their own, adult conceptions and failing to recognize that children's minds may hold different information" (Lee, 1992).

As for recognition memory tasks, the present false-recognition experiment found interference which depended on a host of variables. False recognition of related distractors occured most strongly in younger children. Gist interference is likely most operant on younger children's recognition memory because they lack the primitive, basic process of inhibition. Also, gist interference impaired children's memory to a greater degree with longer retention intervals, more positions between related distractors and targets, and, finally, with fewer repetitions of targets.

Thus, in light of the present study's findings on gist interference, educators must keep in mind that younger children's recognition will be more inaccurate. Since recognition is a factor in multiple choice testing, younger children may have more difficulty on these tests because they have inferior abilities to discriminate gist information. Educators would be wise to mimic this sort of free recall because younger children performed as well as older children in the category exemplar production study. Thus, avoiding multiple choice testing in a classroom setting would be more advantageous with younger children.

Other findings in this study need to be considered by educators. For example, the higher levels of gist interference found with delayed testing with more positions after the target warrant consideration by teachers before introducing new material or testing children more frequently. Also, more accurate performances (i.e. less misassociation with further information) can be expected when educators repeat a particular item several times. This was shown in the present false-recognition experiment, in which children experienced more gist interference from related distractors when targets were not repeated.

Limitations of the Study

A common problem memory researchers encounter in learning disabled (LD) children is the selection of subjects. "A child's participation in a resource program for LD students does not guarantee his/her possessing a diagnosed learning disability" (Lee, 1992). Likewise, a child's lack of participation in a resource program does not guarantee him/her to not possess a learning disability. In both studies, all subjects were selected with the expectation that they possessed average intelligence and were not learning disabled. Perhaps some children were having academic difficulties or were exhibiting giftedness. Thus, these children may not have been formally tested by a school psychologist yet and placed in a special program. Unfortunately, some special children may for years avoid being detected and referred for assessment. Obviously, this is a problem that affects the results of these studies. We would prefer to give each child an extensive psychoeducational battery to ensure reliable selection of subjects. Unfortunately, this was not possible. Thus, results of this study may not fully generalize to exclusively "normal" children.

Another limitation of these studies concerns the applicability of the results to higher levels of learning. Subjects' memory processes were examined through the recall or recognition of individual words. Findings based on these methodologies may not apply to higher-level academic functioning, which entails recognizing much more complex relationships between more extensive material (Lee, 1992).

Additionally, the constraints imposed upon these experiments by geography and culture should be noted in interpreting and generalizing the findings. Most children in this study were from lower to lower-middle socioeconomic groups and their cultural backgrounds were not uniform. While the samples were representative of the school districts from which they were taken, the sample is unlikely to be representative of every district across the country.

Other significant limitations are only associated with one experiment or the other. First, regarding the cognitive triage study, the Battig and Montague (1969) category norms were based on undergraduate students from the University of Maryland and Illinios. There is a concern that younger subjects might respond to the categories differently. Therefore, in the triage study the high non-monotonic relationships found with younger children may have been a result of higher mean frequencies for exemplars disguised in adult norms. In other words, certain categories and exemplars may have held more meaning and therefore more memory strength for younger children.

Also in the triage experiment, memory strength (addressed using preexperimental measures) may have influenced different output sequences than error/success histories from repeated study/test cycles. This is because items from category exemplar production are considered remnants of semantic memory whereas items from repeated study trials are not. Thus, previous works have arrived at output sequences primarily from measuring episodic memory.

Theoretically, cognitive triage treats the weakest memories first to maximize total memories recalled like surgical triage treats the weakest patients first to maximize lives saved. Therefore, assuming fixed resources, there would be some candidates who are not only weak but who are beyond help and would be left to die. This idea seems intuitively plausible in both surgical and cognitive triage. However, this issue was not addressed or realized in the current experiment.

Another limitation concerns the procedures used for the first portion of the false-recognition experiment. The ability of children to correctly accept targets was assessed by asking the children to say whether or not various items were previously presented. A few children appeared to have trouble making a response or seemed to blindly perservere, indiscriminately accepting or rejecting all items. It is possible that the task demands and/or instructions were unclear to some children. Thus, these subjects' true false-recognition rates may have been corrupted by their lack of understanding of this test.

Finally, the speed of activation of subjects' responses was not measured in the false-recognition experiment. This may have been another useful measure of children's resistance to gist interference. "Increases in task complexity may be accompanied by competing (i.e., irrelevant) stimuli. Thus, age-related changes in 'processing efficiency' may often reflect the efficiency of the inhibitory mechanism as well as the speed of activation" (Dempster, 1992).

Directions for Future Research

We identify four areas for future research in cognitive triage. The first step in future research should be a replication of this triage experiment. This replication is needed because while the results of these studies are generally consistent with those of other similar works, the lack of a developmental effect in triage with the category exemplar production study is an exception. Additionally, the same procedures and materials should be implemented with different samples of students, primarily children from other socioeconomic and cultural backgrounds. This experiment usually incorporated students from lower-socioeconomic groups. Comparing current results with those obtained from students in other geographical regions is also of interest, especially to determine the extent of influence of geography on student's responses to categories such as animals, vegetables, and clothing.

Another area for future research with cognitive triage is the influence of different preexperimental norms than the ones used in this experiment. Battig and Montague's (1969) categories were normed on college level students.

Therefore, it would be advantageous to use exemplar norms that apply to children. We need to determine if younger children would find certain categories more personally meaningful. Also, different frequencies across children may be found for various exemplars compared to college level students. Thus, these possible differences would suggest different memory strength values and therefore diffferent access-order relationships for children.

Combining semantic with episodic measures of the triage relationship is another area for future research. This could entail using children's exemplars obtained from categories over repeated study/test trials. Error/success counts could therefore be tabulated using the child's own responses to more naturalistic inquiries. Since we know that the triage relationship appears similar in either semantic or episodic tasks, this new method would give leverage to examine the interaction between the two.

A final area for future research concerning cognitive triage involves operationalizing a measure of memory candidates. It is important to measure those candidates that are too weak to manage and which are ignored. Assuming fixed resources in both the memory research and surgical scenarios, this treatment of weak candidates should allow the most efficient recall or life preservation. We hope future research can determine if the above theory pertaining to cognitive triage is valid.

Other research ideas apply to both experiments. Future work could employ speed of processing as a measure of interference. Children's response latencies during cognitive triage could be measured in future exemplar production inquiries. Response latencies could be easily measured during false-recognition as well. Timing would begin during testing once a word is presented and continue until the moment a child makes a resonse (yes/no). Age-related changes in reaction time may offer further support for the inhibition of interference.

Each experiment would benefit if made more applicable to higher levels of learning. Rather than using recall or recognition of words in future methodologies, tasks should entail the recognition of more complex relationships between large sums of information. Unfortunately, this is not an easy task. Any developments, however, would certainly benefit generalizability.

Finally, one last area for future research is the use of learning disabled students in both free recall and recognition memory studies. It would be very interesting to discover any different findings for this population. Perhaps these children would show a different cognitive triage or false-recognition effect. These possible effects would likely have various conditions or underlying variables to sustain them. Of particular interest, is the ability of learning disabled children to inhibit interference and how this ability affects memory development.

The results of these studies raise many issues regarding the intuitive aspects of children's memory and the inhibition of interference. Future research must explore memory development further, with a sensitivity to their responses involving category exemplar production and false-recognition. Such research may offer essential insight into children's memory processes. New insights will spur modifications in educational practices and materials, enabling all children to learn and reason as efficiently as possible.

APPENDIX A

HUMAN SUBJECTS PERMISSION LETTER

THE UNIVERSITY OF
ARIZONA
HEALTH SCIENCES CENTER

Human Subjects Committee

1690 N. Warren (Bldg. 526B)
Tucson, Arizona 85724
(602) 626-6721 or 626-7575

December 14, 1992

Suzanne E. LeRoy, M.A.
Charles J. Brainerd, Ph.D.
John E. Obrzut, Ph.D.
Department of Educational Psychology (Room 615)
Main Campus

RE: **HSC A91.10** LEARNING-DISABLED (READING) AND NON-DISABLED LEARNER: COGNITIVE TRIAGE, FORGETTING, AND DICHOTIC LISTENING

Dear Investigators:

We received Dr. C. Brainerd's 8 November 1992 letter for your above referenced project. Changes involve addition of Ryan Kneer, M.A., a predoctoral student as a co-investigator, and inclusion of 40-60 kindergartners, 40-60 third, and 40-60 sixth graders for investigation of age-related changes in fee-recall memory [parental and assent forms submitted for review; also, permission from school districts to be obtained subsequent to HSC approval]. Approval for these changes is granted effective 14 December 1992.

The Human Subjects Committee (Institutional Review Board) of the University of Arizona has a current assurance of compliance, number M-1233, which is on file with the Department of Health and Human Services and covers this activity.

Approval is granted with the understanding that no further changes or additions will be made either to the procedures followed or to the consent form(s) used (copies of which we have on file) without the knowledge and approval of the Human Subjects Committee and your College or Departmental Review Committee. Any research related physical or psychological harm to any subject must also be reported to each committee.

A university policy requires that all signed subject consent forms be kept in a permanent file in an area designated for that purpose by the Department Head or comparable authority. This will assure their accessibility in the event that university officials require the information and the principal investigator is unavailable for some reason.

Sincerely yours,

WFDenny

William F. Denny, M.D.
Chairman
Human Subjects Committee

WFD:rs

cc: Departmental/College Review Committee

APPENDIX B

STUDY LIST

Study List:

1. Banner
2. Hospital
3. Vision
4. Hurricane
5. Metal
6. Weapon
7. Pencil
8. Dog
9. Magazine
10. Charter
11. Color
12. Gratitude
13. Photograph
14. Table
15. Spray
16. Gallery
17. Fruit
18. Democracy
19. Rattle
20. Hammer
21. Ignorance
22. Ankle
23. Sports
24. Errand
25. Kiss
26. Shirt
27. University
28. Deduction
29. Money
30. Photograph
31. Foam
32. Bird
33. Comparison
34. Joke
35. Corn
36. Marriage
37. Discipline
38. Fly
39. Happiness
40. Twilight
41. Flower
42. Oxygen
43. Fortune
44. Oak
45. Ambassador
46. Illusion
47. Fish
48. Glory
49. Loyalty
50. Milk
51. Event
52. Reflection
53. Metal
54. Dog
55. Fruit
56. Hammer
57. Money
58. Corn
59. Flower
60. Oak
61. Journal
62. Necessity
63. Hammer
64. Dog
65. Money
66. Metal
67. Flower
68. Fruit
69. Oak
70. Corn
71. Temple
72. Oats
73. Hillside
74. Emergency

APPENDIX C

VERBATIM-GIST INTERFERENCE EXPERIMENT

DATA SHEET FOR FIRST TESTING SESSION

VERBATIM-GIST INTERFERENCE EXPERIMENT

DATA SHEET FOR FIRST TESTING SESSION

NAME____________________________ CHILD'S BIRTHDATE_____________

CHILD'S GRADE: K 3 6 READING VOICE: BRAINERD'S KNEER'S

DATE OF TESTING________________________________

Block #1:			Block ___		
Deduction	Y	N	Color	Y	N
Beggar	Y	N	Blue	Y	N
Illusion	Y	N	Temple	Y	N
Golf	Y	N	Banner	Y	N
			Cellar	Y	N
Block _____			Block ___		
Metal	Y	N	Table	Y	N
Copper	Y	N	Furniture	Y	N
Charter	Y	N	Emergency	Y	N
Hint	Y	N	Shadow	Y	N
Kettle	Y	N	Cable	Y	N
			Chair	Y	N
Block _____			Block _____		
Dog	Y	N	Shirt	Y	N
Animal	Y	N	Socks	Y	N
Marriage	Y	N	Weapon	Y	N
Lecture	Y	N	Factory	Y	N
Fog	Y	N	Clothing	Y	N
Cat	Y	N	Hurt	Y	N
Block _____			Block _____		
Hammer	Y	N	Fruit	Y	N
Nails	Y	N	Suit	Y	N
Errand	Y	N	Twilight	Y	N
Economy	Y	N	Ghost	Y	N
Tool	Y	N	Apple	Y	N
Slammer	Y	N			
Block _____			Block #10		
Sports	Y	N	Oxygen	Y	N
Forts	Y	N	Impact	Y	N
Journal	Y	N	Hurricane	Y	N
Cigar	Y	N	Mammal	Y	N
Football	Y	N			

APPENDIX D

VERBATIM-GIST INTERFERENCE EXPERIMENT

DATA SHEETS FOR SECOND TESTING SESSION

VERBATIM-GIST INTERFERENCE EXPERIMENT

DATA SHEETS FOR SECOND TESTING SESSION

NAME_______________________________ CHILD'S BIRTHDATE_______________

CHILD'S GRADE: K 3 6 READING VOICE: BRAINERD'S KNEER'S

DATE OF TESTING_____________________________________

Block #1:			Block ___		
Deduction	Y	N	Color	Y	N
Beggar	Y	N	Blue	Y	N
Illusion	Y	N	Temple	Y	N
Golf	Y	N	Banner	Y	N
			Cellar	Y	N
Block ______			Block ___		
Metal	Y	N	Table	Y	N
Copper	Y	N	Furniture	Y	N
Charter	Y	N	Emergency	Y	N
Hint	Y	N	Shadow	Y	N
Kettle	Y	N	Cable	Y	N
			Chair	Y	N
Block ______			Block ______		
Dog	Y	N	Shirt	Y	N
Animal	Y	N	Socks	Y	N
Marriage	Y	N	Weapon	Y	N
Lecture	Y	N	Factory	Y	N
Fog	Y	N	Clothing	Y	N
Cat	Y	N	Hurt	Y	N
Block ______			Block ______		
Hammer	Y	N	Fruit	Y	N
Nails	Y	N	Suit	Y	N
Errand	Y	N	Twilight	Y	N
Economy	Y	N	Ghost	Y	N
Tool	Y	N	Apple	Y	N
Slammer	Y	N			
Block ______			Block #10		
Sports	Y	N	Money	Y	N
Forts	Y	N	Dollars	Y	N
Journal	Y	N	Gratitude	Y	N
Cigar	Y	N	Piano	Y	N
Football	Y	N	Honey	Y	N
Block ______			Block ______		

Corn	Y	N	Fly	Y	N
Vegetable	Y	N	Insect	Y	N
Pencil	Y	N	Ambassador	Y	N
Bowl	Y	N	Toast	Y	N
Horn	Y	N	Sky	Y	N
Carrot	Y	N	Ant	Y	N
Block ______			Block ______		
Oak	Y	N	Milk	Y	N
Maple	Y	N	Water	Y	N
Vision	Y	N	Glory	Y	N
Umbrella	Y	N	Hillside	Y	N
Tree	Y	N	Drink	Y	N
Poke	Y	N	Silk	Y	N
Block ______			Block ______		
Bird	Y	N	Flower	Y	N
Word	Y	N	Tower	Y	N
Reflection	Y	N	Discipline	Y	N
Drama	Y	N	Opportunity	Y	N
Robin	Y	N	Rose	Y	N
Block ______			Block ______		
Fish	Y	N	Oxygen	Y	N
Trout	Y	N	Impact	Y	N
Photograph	Y	N	Hurricane	Y	N
Infection	Y	N	Mammal	Y	N
Dish	Y	N			

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