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Development of long term memory retention processes among learning disabled and non-disabled children

Brown, Kim Freidah, Ph.D.

The University of Arizona, 1988

DEVELOPMENT OF LONG TERM MEMORY

RETENTION PROCESSES AMONG LEARNING DISABLED

AND NON-DISABLED CHILDREN

by

Kim Freidah Brown

_____

A Dissertation Submitted to the Faculty of the

DIVISION OF EDUCATIONAL FOUNDATIONS AND ADMINISTRATION

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As members of the Final Examination Committee, we certify that we have read

the dissertation prepared by _Kim Freidah Brown_

entitled _Development of Long Term Memory Retention Processes_

Among Learning Disabled and Non-Disabled Children

and recommend that it be accepted as fulfilling the dissertation requirement

for the Degree of _Doctor of Philosophy_   .

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Final approval and acceptance of this dissertation is contingent upon the
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I hereby certify that I have read this dissertation prepared under my
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ABSTRACT

This study investigated the development of acquisition and long term retention processes in Learning Disabled (LD) and Non-Learning Disabled children aged 7-12. One hundred six subjects were randomly assigned to memorize either a list of unrelated words (with free recall), or a list of taxonomically related words (with recall cued by category). Each subject had a 16 word list presented in visual and auditory modes. The repeated recall paradigm alternated study and test trials, with a buffer activity between trials. The acquisition phase ended when the subject reached 100% criterion. After an interval of two weeks, each subject was given 5 additional recall tests.

Acquisition results indicated significant main effects for age, group (LD, Non-LD) and list type (unrelated, categorized) on measures of trial-of-last-error and total-errors. Overall, the groups which acquired the lists most quickly were the older and Non-LD subjects, with the categorized list. There was a List x Group interaction on the trial-of-last-error. With the categorized list, only age was significant, and conversely, with the unrelated list, only group was significant.

On the retention measures, there were main effects for list and group, with a List x Group interaction. The only

significant age effect was with total-words on the

categorized list. Over the five trials (repeated measures),

there was a significant effect for trials. A consistent

hypermnesia effect (increase in net recall) was predominant.

Further model-based analyses (Brainerd, Kingma, Howe, &

Reyna, 1988) revealed storage failure, rather than retrieval

failure to be the major action in children's forgetting.

Learning Disabled children had significantly more storage

failure than the Non-LD children. Both groups had more

storage failure on the unrelated lists. There was retrieval

relearning with all groups. Results are discussed within

the framework of the disintegration/redintegration theory,

which pertains to the gradual weakening and redintegration

of bonds that unite features to form a trace.

CHAPTER 1

INTRODUCTION AND REVIEW OF THE LITERATURE

This chapter will present a general introduction to
long term memory research with children who experience
Learning Disabilities followed by a Statement of the
Problem, Need for the Study, Purpose of the Study, Research
Questions, Definition of Terms, Limitations of the Study,
and Review of the Literature. Within the literature review,
hypotheses and theories are proposed for long term memory
differences established in recall tests of Learning Disabled
children, with the corresponding empirical evidence
considered. The matters of taxonomic relatedness of lists
and age changes will be highlighted. In addition, the
review will consider the development of long term retention
and forgetting in children. Although other theories are
discussed, the review will focus particularly on the
stochastic models developed by C. J. Brainerd and
colleagues. These models are within the framework of
disintegration/redintegration theory, which will be
described.

Introduction

The importance of long term memory processes to
instruction and the process of schooling cannot be

understated. Far more crucial than how children acquire knowledge is how they remember it after a time - their long term retention. Children who experience Learning Disabilities (LD) present an opportunity to study these retention processes. This group, by definition, has failed at making academic progress at a rate commensurate with their intellectual ability. While research from a variety of academic and theoretical perspectives has investigated long term memory with this quite diverse population, the vast majority of research has concentrated on the acquisition phase, rather than long term retention phase. In spite of the fact that there is significant research demonstrating that acquisition and retention are not symmetrical processes (Howe & Hunter, 1986), psychologists and educators have continued to apply acquisition research findings to retention. At the present time, there is a significant void in our understanding of the retention abilities of LD children. The current study is an effort to begin to understand this rather large, complex topic.

The focus of study on children with "specific learning disabilities" has traditionally concentrated on their very specific, rather than more generalized impairments. Recently, however, there has been an acceleration in interest and research into potential deficiencies on more basic memory, cognitive, and neuropsychological performance.

Brainerd, Kingma, and Howe (1986) noted that this trend has both conceptual and empirical implications for the future of LD research. Conceptually, there is at least an implicit rejection of the traditional view of a LD child as one with otherwise normal intelligence, "selectively impaired" with a very specific dysfunction pertaining to printed words, oral language, or arithmetic, in the absence of more global deficits as found in the mentally retarded, for instance. One implication of this trend is that our increasing knowledge of the more basic processes may help us identify higher level deficits in memory, cognition, and overall brain functioning in general, which may in time explain the specific task deficits that have already been documented in the LD literature.

Growing evidence of general long term memory deficits in LD children has been emerging from the literature. For example, when compared to non-disabled peers, LD children recall less information (Ceci, Lea, & Ringstrom, 1980), make inefficient use of their limited-capacity attentional resources (Chi & Gallagher, 1982), remember fewer items in free-recall experiments (Torgesen, 1977a), utilize less elaborative rehearsal strategies (Bauserman & Obrzut, 1981), and utilize less purposive semantic processing in recall (Ceci, 1984). The effect of the organization of material to be memorized is another important issue. Wiig and Semel

(1984) and others in the speech and language field have long
discussed the problems that many LD children experience in
categorizing material.

Statement of the Problem

While there is considerable research concerning long
term memory functioning in LD children, almost all of it
concerns the acquisition phase, rather than long term
retention. Therefore, theories built upon such acquisition
research may be severely limited in their applicability,
generalizability, validity, and completeness in explaining
long term retention. Recent models of memory by Brainerd
and colleagues (e.g., Brainerd, Kingma, Howe, & Reyna, 1988;
Brainerd & Reyna, 1988) have examined long term retention
processes in normal children. Brainerd and Reyna (1988)
have found that during the elementary school years,
hypermnesia and reminiscence increased with age, and amnesia
and forgetting decreased with age. Retention was also
affected by the degree of taxonomic relatedness.

Although teachers often make reference to how much
their LD students forget what they've learned, there is very
little empirical evidence of these alleged deficits. These
new models of Brainerd and colleagues offer significant
promise in their application to LD children, to better
pinpoint the processes where their retention breaks down, if
indeed it does, so that in the future these alleged

problems of retention might be remediated.

Need for the Study

As mentioned above, the bulk of all the research into the development of long term memory of children pertains to acquisition, with little empirical work designed to measure retention processes. In addition, there are numerous methodological problems present in long term memory research. For example, the majority of researchers have used a small set number of study trials, not insuring that the material to be recalled has been deposited in long term memory, and thus not insuring that the process is retention at all. A growing body of literature now suggests that acquisition and retention are asymmetrical processes; therefore, conclusions derived from acquisition research cannot be simply applied to retention processes. Acquisition and retention processes are governed by different rules (Howe & Hunter, 1986). For example, it has been shown that multiple study trials at acquisition have a huge effect on acquisition learning, yet are unrelated to the amount of forgetting after a two week interval (Slameka & McElree, 1983).

Brainerd and Reyna (1988) recently noted that many fundamental questions about the normal development of retention have neither been posed nor answered. Their work has investigated normal children's performance fluctuations

across sequences of tests for previously studied material. They have specifically examined the long term retention variables of amnesia and hypermnesia, which pertain to changes in net recall, as well as forgetting and reminiscence, which pertain to the recall/non recall of individual words. In another related article, Brainerd, Kingma, Howe, & Reyna (1988) examined measurement of forgetting and relearning processes in long-term retention in normal children. From their results the authors concluded, that forgetting was more of a storage, rather than retrieval failure with these children. This was quite contrary to widely held belief that forgetting equals retrieval failure (Loftus & Loftus, 1980).

To date, no one has considered these specific long term retention variables with LD children, of whom teachers have often said, "He had that yesterday, but today it's gone." The absence of this information about how LD children remember as well as forget material over a significant time interval may mislead researchers in the field in serious ways. Thus, there are important theoretical as well as practical implications for understanding the long term retention abilities of LD children.

Purpose of the Study

The primary purpose of this study was to investigate

the development of several retention processes, in addition
to more common global measures in LD and Non-LD children.
The processes targeted were amnesia, hypermnesia,
reminiscence, forgetting, at both acquisition and retention,
and storage failure, retrieval, restorage, and retrieval
relearning, at long term retention. The experiment utilized
the repeated-recall paradigm with lists of categorized and
unrelated nouns. In this study it was also of interest to
examine age effects, as well as the taxonomic relatedness of
word lists with LD and Non-LD children.

<div align="center">Research Questions</div>

The following questions guided the study.

1. Are there differences between Learning Disabled and
   Non-LD children in long-term retention?

2. Is hypermnesia or amnesia the preeminent mode of
   intertest changes in net recall?

3. Is forgetting or reminiscence the preeminent mode
   of intertest change in individual item recall?

4. Is forgetting primarily a function of storage or
   retrieval failure?

5. How do these groups vary on other test-induced
   processes, such as their restorage ability
   and retrieval relearning?

6. What effect does taxonomic relatedness with test
   cues have on net recall and other retention

processes?

7. Are there ontogenetic shifts in these processes?

Definition of Terms

Learning Disabled children: The label Learning Disabled
refers to those children who met state and federal (PL
94-142) guidelines for the placement of children in
learning disability programs. The federal definition
of LD states, that it is a disorder in one or more of
the basic psychological processes involved in
understanding or in using language, spoken or written,
which may manifest itself in imperfect ability to
listen, think, speak, read, write, spell, or to do
mathematical calculation. The term does not include
children who have learning problems which are primarily
the result of visual, hearing, or motor handicaps,
mental retardation, of emotional disturbance or
environmental, cultural, or economic disadvantage
(Federal Register, 1977). In this study, LD students
with impairments primarily in reading process were
targeted.

Auditory-linguistic LD: As defined by Pirozzolo (1979),
this term refers to those LD or dyslexic children
having the following characteristics: at least 1 1/2 -
2 year delay in reading, phonological aspects of
language disordered, low verbal IQ (relative to

performance IQ), average or above-average performance
IQ, relatively intact visual-spatial abilities, and
developmentally-delayed language onset. Pirozzolo
contrasts this group with the visual-spatial LD
subtype.

long term retention: Originally studied by Ebbinghaus in
the 1890's, long term retention refers to the
measurement of recall of material studied after a
period of time, such as a few days to weeks, has
elapsed.

repeated recall paradigm: In this paradigm subjects are
administered multiple tests of their ability to recall
previously studied information. After subjects study a
set of items, they receive two or more recall tests for
those items without additional study opportunities.

taxonomic relatedness: This variable refers to the
relationship of items to each other on a given list.
The current study compared two list conditions which
varied on taxonomic relatedness. The categorized list
had high taxonomic relatedness, with its 16 words
falling into four categories. The unrelated list had
low taxonomic relatedness, with its words being drawn
from 16 different categories.

hypermnesia: This aggregate variable refers to an increase
in net recall from test to test without any more study

opportunities. Both hypermnesia and amnesia are concerned with comparing the unconditional probabilities of successful recall across different tests. In hypermnesia, $p(T1) < p(T2)$.

amnesia: This aggregate variable refers to an decrease in net recall from test to test. In amnesia, the pattern is $p(T1) > p(T2)$.

forgetting: This variable is concerned with how recall performance of individual items, rather than net recall, changes. There are four possible patterns of recall for individual items, namely, two errors, two successes, a success followed by an error, and an error followed by a success. Forgetting occurs if a success is followed by an error.

reminiscence: This variable refers to the individual pattern of a error followed by a success.

Limitations of the Study

A particular subtype of LD child (auditory linguistic) was targeted in subject selection. In doing so, some of the heterogeneity of LD children was reduced. Thus, the generalizability of findings to other subtypes of LD is not be warranted.

Another limitation was the nature of the experimental tasks themselves. Although the repeated recall paradigm is quite common in the experimental literature, its rote nature

may somewhat limit it applicability to school learning tasks.

Another caution in interpreting the lists effects of this study pertains to the low level of difficulty of the categorized list with cued recall. This fact may have resulted in ceiling / floor effects.

The limited age range of the sample (7 to 12 years), and subsequent division into younger (mean age = 8-3) and older (mean age = 10-8) groups, restricts the interpretation of age changes. Other studies have utilized more highly contrasted groups, for example, second versus sixth graders. As the mean age of younger and older subjects only differed by approximately two and a half years, age differences are logically smaller. There was not a large enough N to maintain statistical power with first and fourth quartiles, for example.

A final limitation of the present study was caused by the time constraints of the school situation. Subjects were required to make only one errorless pass, rather than the typical two passes through the list for the acquisition phase to end. This modification could have altered the parameter estimates of storage failure versus retrieval failure, favoring the storage failure.

Review of the Literature

This section begins with a general overview of the research concerning the development of long term memory in children with learning disabilities. Next, the literature concerning the effect of categorization or taxonomic relatedness on list learning will be considered. Finally, the development of long term retention and forgetting in normal and LD children will be discussed. Theoretical perspectives on retention processes will be discussed, particularly those of C. J. Brainerd.

While the majority of work on memory processes in LD children has traditionally pertained to short term memory, there is a growing body of literature concerning long term memory (LTM). Certainly the two systems of short and long term memory are very closely integrated in operation; however, their processes have generally been considered separately in different types of experiments. This separation results from evidence that a number of memory tasks appear to have two components which behave in quite different ways. Examples include research with brain-damaged subjects, as well as the recency effect in free recall, which has many components (rate of presentation, familiarity of the words, etc.) affecting long term memory but not short term memory (Baddeley, 1982). Psychologists who study short term memory typically utilize methods such as rote memory tasks, using sequences of forms and paired

associates, as well as span tests, such as digit span.

Those who study long term memory commonly utilize list learning procedures, which may include free recall, cued recall, paired-associate memorizing, and serial learning. Generally, there are safeguards for insuring that the responses are not based on short term memory, such as having buffer activities between study and test trials in cued and free recall experiments. These activities, such as counting backwards or number shadowing, are designed to "dump" the short term memory by insuring that a competing cognitive process is engaged in. The studies reported here presently concern the acquisition phase of LTM with LD children.

Ceci, Lea, & Ringstrom (1980) utilized auditory and visual modalities with free and cued recall, and found LD students to have deficits in recall. These recall deficits have been documented by many others in free and cued recall of unrelated and categorized word lists (e.g., Torgesen, 1977b; Bauer, 1977; Howe, Brainerd, & Kingma, 1985); elaborative rehearsal strategies (Bauserman & Obrzut, 1981); and purposive semantic processing (Ceci,1984). Across a variety of tasks with both words and pictures, LD children perform more poorly than matched control children.

Brainerd, Kingma, & Howe (1986) concluded that LD children were poorer at learning how to retrieve, both before and after a trace has been stored. In contrast,

poststorage retrieval performance (heuristic retrieval) did
not consistantly separate the groups.

In a free recall experiment using lists of unrelated
concrete nouns and line drawings of these same objects,
Howe, Brainerd, & Kingma (1985) found that memorization was
easiest with pictures and by older and Non-LD groups.
Differences between the LD and Non-LD children were not
global, however, as LD children were deficient in both
storage abilities and in the ability to acquire algorithmic
retrieval operations. They were not deficient in retaining
traces once they had been stored, or in heuristic retrieval
between the time a trace was stored and the time retrieval
learning was complete. Ability differences at storage
remained developmentally invariant, whereas ability
differences in algorithmic retrieval increased with age.

Taxonomic relatedness / Cuing

The issue of how the taxonomic relatedness of a
particular list effects recall, with or without the cuing of
categories, has been investigated by a number of
researchers. In particular, the organizational strategies
of LD students have been studied. Wiig and Semel (1984)
note that LD children often have problems in abstracting
either similarities or differences in word meaning or both.
They may have difficulty classifying words and concepts by
meaning features, particularly semantic classes or

subclasses. They also note that specific retrieval cues,
particularly those that name the semantic category to which
the word belongs, may help restore word recall and retrieval
to an optimum level (Wiig & Semel, 1980).

They agree with Tulving's theory (1974) that forgetting
or the inability to recall and retrieve information is a
cue-dependent phenomenon. Tulving believes that forgetting
occurs because the cues for retrieval are no longer
available, and the person cannot retrieve perfectly intact
information. Wiig & Semel (1980) advocate the use of cues
in intervention to help children retrieve words accurately
and quickly. They contend, "Strengthening a child's ability
to classify words by semantic category should improve his
long-term memory storage, and thus help him recall and
retrieve specific words" (Wiig & Semel, 1980, p. 349).

Wong (1978) investigated whether or not directive cues
would facilitate recall and clustering of verbal materials
in good and poor readers (LD). Subjects in this study were
only able to view the words for 90 or 180 seconds, depending
on the condition. Good readers recalled significantly more
items, regardless of cuing and time allotted. She
postulates a performance deficit interpretation, rather than
a conceptualization deficit. The LD children rehearsed the
items significantly less, but despite lower recall, they
showed the same degree of clustering or organization of

memory as good readers. Wong believes that the failure LD children experience on certain memory tasks may be due to their failure to use appropriate or efficient strategies. Here, she agrees with Torgeson's (1977b) notion of these children as inactive learners, demonstrating performance, rather than ability deficits.

Suiter and Potter (1978) found that LD students were able to remember more words when they were presented in groups of four pictures by category, compared with LD students presented the same pictures in groups of four usually unrelated words. The task required only short term memory, since recall was immediately after the presentation of the four pictures. They neglected to make this distinction from the more typical study of LTM. Torgeson (1977a) also found that the recall of pictures by LD readers was inferior to that of good readers until both groups received instructions to cluster pictures by category.

Brainerd et. al. (1986) found the largest LD/Non-LD differences with categorized lists, both cued and free recall, compared with unrelated lists. They concluded that LD and Non-LD children are equally likely to use organizational strategies when they are available, but that LD children are less likely to possess them. The cuing of the categories did not make a difference in their acquisition of the 16 word list.

One recent research study (Moe & Harris, 1983) used only categorizable pictures and manipulated presentation for encoding and recall conditions. Here they made a one minute simultaneous presentation of 36 picture cards. The pictures were positioned either randomly or blocked, by arranging those pictures of the same category in the same row, manner. The cards were presented three times, with a 30 second buffer and recall test trial in between. The first two test trials were free recall for all groups. In the third trial, however, there were three recall conditions: free recall, cued recall, and constrained cued recall. In the cued recall condition children were briefly shown the stack of six category cue cards and told they could look at them if it would help them remember. In the constrained cue recall condition, the number of items in each category was stated and recall of that category solicited, before moving along to the next category. Thus, there were two encoding conditions and three recall conditions.

Results indicated superior recall overall by the normal children. Constrained cued recall was superior to free, and to a lesser extent, cued recall. On the cued recall, however, LD and normal children did not differ. These results supported their hypothesis, that LD children suffer from a production deficiency for spontaneous use of

retrieval strategies in a free recall situation, while not differing from normal children in amount recalled in a cued recall situation. In addition they concluded that both encoding and retrieval factors influence recall. "That is, even when categorical organization is very salient during encoding, cues which foster retrieval of items by categories have an additional facilitating effect on recall" (p. 243).

Similar work was conducted by Swanson (1987a), where subjects were directed to encode information in a semantic or a nonsemantic (phonemic) fashion. During the directive encoding, subjects were instructed to sort the picture cards according to category (semantic or phonemic) and to study the items for two minutes. Children engaged in a one minute distractor (buffer) task before they had five minutes of free recall. A five minute distractor task followed this directed encoding phase. Next the children had two nondirected encoding trials, one with unrelated items and one with stimulus items that could easily be categorized into two semantic and two phonemic categories. Results indicated that both groups responded more favorably to the semantically than the nonsemantically organized items. Semantic encoding instructions did not eliminate recall differences between ability groups. There was an ability difference on the unrelated item lists, but only with the younger children.

Criticism of the research

Brainerd et. al. (1986) are critical of the strategy deficit position because of its vagueness about the specific LTM loci of normal/LD differences. They contend that this position depends on the spontaneous use of mnemonic strategies, when the evidence does not favor this assumption with children, only adults. They note that LTM performance deficits are observed at age levels where, apparently, children almost never use strategies. Their major criticism of hypotheses concerning LD/normal differences is, that theories have come before the empirical documentation of just where these processes of memorization break down.

Another major criticism of the literature concerns stages of learning confounds. Fixed trials or exposure designs like those described (e.g., Moe & Harris, 1983; Wong, 1978) do not ensure that a subject's learning has been completed at the end of the testing session. What happens with this design is, that treatment effects and completeness of learning are confounded. For example, with items on easier lists like categorized, subjects have completed more of the acquisition stages than items on harder lists. Completeness of learning is confounded in developmental studies where older children learn lists faster, and therefore have completed more of the acquisition process.

This factor is particularly critical in research about long term retention/forgetting, which will be described in the next section.

Correcting for these methodological problems, both the type of list (categorized or unrelated) and the type of recall (free or cued recall) were manipulated in work of Brainerd et. al. (1986) in an effort to identify the loci of these LTM differences. The experiments they presented concern these list and recall factors, as well as age effects. They found both LD and normal children equally likely to use organizational strategies when they were available, but disabled children less likely to possess them. They found ability differences greater on categorized lists than on unrelated lists. Ability differences for categorized lists were the same when the categories were cued and when they were not cued.

In another recent study, Howe, O'Sullivan, Brainerd, & Kingma (1988) concluded that while the effects of categorical structure were, at best, only slightly positive for learning disabled students, there were strong effects for the normally achieving students. The use of category cues on test trials had large effects across age and ability, again with normal children and older children benefitting more.

Long term retention

The research reported thus far has concerned the acquisition phase of long term memory. As previously noted, acquisition and retention processes are governed by different rules (e.g., Howe and Hunter, 1986; Slamecka & McElree, 1983), yet only one study concerning the long term retention abilities of LD children was found in the literature. Unfortunately, this study by Hall, Humphreys, and Wilson (1983) had a number of the methodological problems illustrated above. They utilized a fixed number of study and trials (3), and, according to their data, none of the groups ever mastered the list of 10 words. Consequently what they discuss is LD children's retention processes of partially learned material. Retention was tested after two minutes and 24 hours. The LD group reflected poorer recall at both retention intervals, yet the researchers concluded, that there was no evidence of more rapid long term forgetting by the LD children. This finding was due to some of the measurement and methodological problems already alluded to. Consequently, this research did not answer the questions it sought to answer.

A picture of the development of long term retention and forgetting in normal children has begun to emerge from the literature. Recent articles by Brainerd, Kingma, & Howe (1985b); Brainerd, Kingma, Howe, & Reyna (1988); and Brainerd & Reyna (1988) have brought these processes into

focus with normal children. These articles further develop the Markov / stochastic models, which they earlier proposed for acquisition processes. Details of these memory models for retention are provided in the above articles. A general overview is provided here.

Forgetting model. According to Brainerd et. al. (1988), the memory variables that control performance on the retention tests can be partitioned into two broad classes: those that are operative in the gap between acquisition and retention, which they term true forgetting processes, and those that are specific to the retention tests, which they term test-induced processes. They contend that the segregation of the contributions of forgetting and test-induced factors are essential to a theretical interpretation. They are described within the context of long term retention designs with repeated recall tests.

Two components of the forgetting process are storage failure ($\underline{S}$), also known as decay or substitive encoding, and retrieval failure ($\underline{R}$), which concerns whether a trace is retrievable. Thus, with storage failure, the item is unavailable for recall. Storage failure is an unconditional probability, that the item is unavailable for recall on the first memory test following the forgetting interval and remains so.

With retrieval failure, the trace is still available in

memory but unable to be retrieved. Retrieval failure is
stated as a conditional probability, that is, given an item
is still available for recall after the forgetting interval,
it is the probability that it will no longer be accessible
on a retention test. Thus, $\underline{R}$, is the probability of making
a recall error on the first test if the item is available
for recall.

Two test-induced processes are also measured by the
model, restorage ($\underline{a}$) and relearning of retrieval operations,
with the latter being divided into relearning that follows
successful recalls ($\underline{r}$), and relearning that follows errors
($\underline{f}$). All are conditional probabilities estimating the
subject's ability to retrieve an available item following
various patterns of errors and successes on prior retention
tests.

These parameters of the forgetting model are associated
with the theoretical work of Brainerd et.al. (1988), in what
is referred to as the disintegration/redintegration
hypothesis. This hypothesis assumes that the degree of
trace integration, the strength of the relationships that
bind features together to form traces, is the key variable
in forgetting; the greater the integration, the greater the
retention. Both storage failure and retrieval failure are
thought to be consequences of a single process-- namely,
featural disintegration during the forgetting interval.

Forgetting in this model, then, is a progressive dilution of the "glue" that holds features together, a type of unavailability process, rather than feature decay or trace substitution. Thus, storage failure occurs when a trace has disintegrated to the point that it is no longer a distinct memory structure, and therefore virtually impossible to retrieve. Relearning is seen as a product of the complementary process of redintegration, a mechanism where the activation of some of a trace's features spreads rapidly to other features and increases the level of featural integration.

This series of experiments in the article made the following conclusions. Variation in forgetting rates always contributed more to development than variations in test-induced processes. Declines in performance across the forgetting interval were more a matter of storage failure than retrieval, regardless of age or list condition. These storage failures were not permanent, however. Even though the lists were not restudied, there was considerable restorage. Brainerd and Reyna proposed featural disintegration as the potential mechanism, suggesting that the bonds that unite features to form a trace gradually weaken during the retention interval. With this, the trace fades out as a discriminable unit, relative to more well-integrated traces. When no longer discriminable against the

background of more well-integrated traces, recall is impossible. This phenomenon is what the model calls storage failure. This theory and mathematical framework were also the basis for the present study.

Amnesia, hypermnesia, forgetting, and reminiscence. These variables are the constituents of retention, according to Brainerd and Reyna (1988). They have already been defined in the "Definition of Terms" section. These variables are also considered under the auspices of the disintegration/redintegration hypothesis with normal subjects. From the experiments described in that article, the following conclusions were drawn. Hypermnesia was increased with categorized materials, as the taxonomic information bound features together, which facilitated featural integration and prevented featural disintegration. While hypermnesia was the exception at acquisition, it was commonplace after a two week interval. As it occurred with young children, the authors considered it unlikely that hypermnesia was rooted in processes that develop later in childhood or adolescence, such as the spontaneous use of sophisticated mnemonic strategies.

Forgetting rates in these experiments were larger than reminiscence at acquisition, but again the situation was reversed at retention. These results were again consistent in terms of the disintegration/ redintegration hypothesis.

The fact that reminiscence predominated over forgetting on the delayed test was explained by concept, that featural redintegration of a previously well-formed trace (the process that produces reminiscence) was predominant over featural disintegration (the process that produces forgetting).

In summary, this section has provided the theoretical and empirical framework for the present study. Long term retention is the least investigated aspect of memory work with children. This is particularly true with LD children, whose long term retention abilities we know virtually nothing about. This topic is of particular importance to educational and school psychologists, who are concerned with learning and educational outcomes for this population.

CHAPTER 2

METHODOLOGY

This chapter presents the methodology used in
conducting the research. The subject population of Learning
Disabled (LD) and Non-LD students is described in terms of
how they were selected and their characteristics. The
materials and word lists used in the study are described.
The experimental procedure followed is described, as are the
data analyses.

Method

Subjects

Fifty LD students and 56 Non-LD students aged 7-12
participated in the study. All were students in one Arizona
public school district of approximately 6,000 students, and
drawn from four elementary schools. These students came
from homes of all socio-economic groups, with the majority
of students from lower income homes. They were
predominantly Anglo and Hispanic children. Ninety two
percent of the students were right handed, as determined by
the Edinburgh Handedness Inventory (Oldfield, 1971).
Approximately equal numbers of each gender participated in
the study (54 males and 52 females). Students were divided
into two age groups at the median age for the purpose of
conducting a developmental analysis. Those between 7 years

0 months and 9 years 4 months were classified in the Younger

group (mean age = 8-3). Those between 9 years 5 months and

12 years 6 months were included in the Older group (mean age

= 10-8). After school board and individual approval was

obtained, the parent's written consent and student's assent

were also obtained. All children were examined individually

by a female graduate student.

Learning disabled students were selected in the

following manner. The school district's special education

files were reviewed for all students aged 7-12 who were

currently enrolled in learning disability programs. All

students had been identified through formal psychological

and educational assessment and had been placed in LD special

education classes according to state and federal guidelines

(see Definition of Terms section of Chapter I).

In order to identify auditory-linguistic LD children

from the total LD population whose files were reviewed, a

particular profile of scores was targeted. The student was

of at least average intelligence, as determined by an

individually administered intelligence test, such as the

Weschler Intelligence Scale for Children-Revised (WISC-R) or

Stanford-Binet Intelligence Scale. Of those who had been

administered one of the Weschler scales (WISC-R or WIPPSI),

preferred subjects were those whose Performance IQ was at

least ten points higher than Verbal IQ. The Full Scale IQ

scores for the LD group ranged from 80 to 123 (mean Full
Scale IQ = 95, SD=10). It is well documented that the lack
of reading ability can depress a student's Verbal IQ, thus
reducing the Full Scale IQ as well.

Targeted subjects were those who demonstrated a
significant discrepancy of 20 scaled score points between IQ
and reading ability, but not mathematical ability, which
were measured by an individually administered test such as
the Woodcock-Johnson Psycho-educational Battery (WJ).
Subtest scores on the Cognitive section of the WJ were also
noted. Consistent with the profile of auditory-linguistic
LD, it was expected, that scores on the oral language and
verbal ability clusters of the WJ would be depressed.

In order that reading ability be the major contrasting
factor between the experimental and control groups,
classroom teachers nominated good readers (Non-LD) for
inclusion in the study. Consequently, this was a group with
strong verbal abilities, contrasted with a group (LD) with
relatively weak verbal abilities. The Non-LD subjects were
matched to the LD group according to age (within 6 months)
and gender. Six more Non-LD than LD students returned their
permissions and were included in the study.

As the study was conducted in a public school setting,
it was impossible to give a similar battery of tests to what
the LD students received. Consequently, in order to screen

for at least average intelligence, these Non-LD students
were administered the Peabody Picture Vocabulary Test-
Revised (Dunn & Dunn, 1981). Although only a measure of
receptive vocabulary, PPVT-R scores are often used as an
estimation of verbal intelligence. The Non-LD group had
standard scores which ranged from 93 to 135 (mean Vocabulary
Quotient = 115, SD=10). Given the nature of the test, and
that good readers had been targeted, it was not unexpected
that they scored one standard deviation above the mean.

Materials

All subjects memorized one of two 16 item lists of
concrete nouns, varying on taxonomic relatedness. Both
lists were compiled from the 24 item lists utilized by
Brainerd and Reyna (1988) and Brainerd, Kingma, & Howe
(1986). These lists were originally derived from Battig and
Montague's (1969) categorized word norms.

The first list, "categorized," consisted of four of the
most typical exemplars from each of four Battig & Montague
categories, for a total of 16 words. These categories and
their words were animals (cat, dog, lion, tiger); fruit
(apple, orange, grape, banana); furniture (chair, bed, desk,
table); and clothing (shirt, socks, pants, dress). The
second list condition, "unrelated," consisted of 16 words
drawn from the most typical exemplars of 16 different
categories. These words were apartment, drum, foot,

general, head, iron, lawyer, pearl, plane, pot, red, river,
sister, soccer, sword, and wool.

Procedures

All subjects were randomly assigned to list condition
with one exception. Pilot testing indicated that the
unrelated list was too difficult and frustrating for first
graders, so consequently only the categorized list was
assigned to all the first graders. Pilot testing had also
indicated that the 24 item list originally planned was also
too long for the time constraints of the schools.

The examiner met with all of the children to administer
the Edinburgh Handedness Inventory and, with the Non-LD
students, the PPVT-R prior to the actual experiment. The
experiment consisted of two sessions two weeks apart. A
general Ebbinghaus retention design with repeated recall
tests was utilized. The basic design consisted of two
phases - acquisition and long term retention. During the
initial acquisition phase, subjects individually memorized a
word list to the criterion of one errorless recall test.
The long term retention phase occurred two weeks after the
initial acquisition phase. At this phase the subjects had
five additional test cycles on the target list without any
further opportunities to see or study the list. Subjects
were randomly assigned to one of two conditions, an
unrelated list with free recall or a categorized list with

cued recall. The procedure common for both conditions is described below.

Initially each subject received a single study trial (S) with the examiner on the list of 16 nouns (either unrelated or categorized). The study trial consisted of words, which were professionally printed on laminated 3 x 5 inch cards, presented at the rate of one word every five seconds. As subjects significantly differed in their reading ability, the experimenter pronounced each word aloud as it was displayed to the subject. After the last word, the subject performed a buffer activity (B) to eliminate short-term memory effects. This activity consisted of the subject counting backwards from 10 aloud. Next, in the first recall test (T1), the subject was asked to recall as many of the words as he or she could remember. Depending on the list condition, this recall was either free or cued by category. The recall test was terminated when all words had been recalled or 10 seconds had elapsed without the emission of a word. The child then counted backwards again and was asked to recall as many words as he or she could (T2). This additional recall test was required by the mathematical model which later analyzed the data.

Word cards were reshuffled for randomization and presented at the five second rate as before (S). Again, a buffer activity (B) and recall test (T3) followed the study

trial. This sequence of study trial, buffer activity, and recall test was repeated until the subject was able to name all 16 words in a single test trial (criterion). With S denoting a study trial, B a buffer activity, and T a recall test, the acquisition procedure was as follows: S B T1 B T2; S B T3; S B T4; S B T5; .... to 100% criterion.

The unique features of the two list/recall conditions are summarized below.

1. Unrelated/free recall. Subjects in this condition memorized a list of 16 unrelated words as described above. After random presentation of the 16 words and buffer activity, subjects were simply asked, "Tell me all the words that you can remember." Their responses were noted on a coding sheet as to the order in which the words were recalled and any incorrect insertions of other words.

2. Categorized/cued recall. Subjects in this condition memorized a list of 16 words which belonged to four categories: fruit, animals, furniture, and clothing. As with the unrelated list, words were presented in random order. However, at no time were these categorizes stated or words grouped into categories during the presentation/study trials. They were not told that it was a categorized list. After study trial and buffer activity, subjects were asked to recall the words in each category. The order of the categories that were cued was randomized.

For example, the examiner said, "Tell me all the fruit that you can remember," followed by requests for the items in each of the other three categories.

Two weeks after the initial acquisition session, the subject's long term retention of the memorized list was evaluated. Five recall tests were administered with all subjects. There were buffer activities between each of the recall tests, but no further opportunities to see or study the word list. As in the acquisition phase, the recall was either free or cued by category. This long term retention phase for all subjects was T1 B T2 B T3 B T4 B T5.

Data summary and analyses

These data were coded in the following manner. The experimenter used a grid-like coding sheet to make note of the order that each word was recalled by the subject in each test trial at acquisition and the five test trials at retention. Any intrusions of words not on the list were also noted. These coding sheets contained the necessary data for global measures, such as analyses of variance (ANOVA), as well as for measurement of amnesia, hypermnesia, reminiscence, and forgetting, and in addition at retention, the model based parameters for forgetting. The statistical significance level was set at p. $< .05$.

Acquisition. These data were summarized by three measures. For each word, it was noted how many errors were

made before the list was mastered. These errors were summed

for the whole list and divided by the number of words (16).

This number was called "total-errors." This statistic

reflects the difficulty of the list for the child. In

addition, it was noted on which trial the last error was

made for each word. A mean was computed for each child of

"trial-of-last-error." This statistic is more sensitive to

patterns of partial learning, that is when a child recalls

it and then does not and then recalls it, etc. These

results were employed in the ANOVAs, which analyzed the

data.

As a measure of forgetting/reminiscence, recall

performance on trials 1A and 1B was also coded. These first

two trials were after only one study trial, and just had a

buffer activity between them. The children's performance

was either Correct, Correct (CC); Correct, Error (CE);

Error, Correct (EC); or Error, Error (EE). Conditional and

unconditional probabilities were calculated. The

significance of within group differences was analyzed using

binomial tests. Further analysis was completed with exact

probability tests, described in Brainerd & Kingma (1985).

Retention. The number of words recalled on each of

the five trials were recorded, in the same manner as at

acquisition. These data were utilized in the "retention

trials" repeated measures ANOVAs. In addition, the number

of different words recalled over the course of the recall
tests was recorded. Sometimes this number was higher than
the number recalled on any one trial. These data were used
in the "total words" ANOVA. As with the acquisition data,
reminiscence/forgetting was measured between adjacent test
trials. Specifically, counts were made and compared for CC,
CE, EC, EE, for Trial 1-2; Trial 2-3; Trial 3-4; and Trial
4-5. Changes in net recall (amnesia and hypermnesia) as
well as the reminiscence/forgetting probability estimates
were tested for significance with using binomial tests.

This chapter described the methodology and data
analyses utilized in investigating the research questions
defined in Chapter 1. One hundred six LD and Non-LD
subjects between the ages of 7 and 12 participated in this
repeated recall long term retention experiment. They were
randomly assigned to learn a 16 word list of either
unrelated words, with free recall, or of categorized words.
with cued recall. ANOVAs, probability estimates, binomial
tests, and forgetting model-based analyses were utilized on
the data.

CHAPTER 3

RESULTS

This chapter presents the results of the data analyses on acquisition and long term retention variables. The acquisition data is presented in two sections--global measures, which was analyzed by use of analyses of variance (ANOVA); and the amnesia, hypermnesia, reminiscence, and forgetting data, which was analyzed using binomial tests. The long term retention data is presented in three sections- the global measures, also analyzed by ANOVAs; and the amnesia, hypermnesia, reminiscence, and forgetting data, analyzed by binomial tests; and the model based analyses, which were employed to isolate the significant conponent processes in forgetting. All ANOVAs were computed using the computer program BMDP 2V (UCLA, 1987). The computations of the results for amnesia, hypermnesia, forgetting and reminiscence, as well as other memory processes measured by the forgetting model, are described in detail in Brainerd, Kingma, Howe, & Reyna (1988) and Brainerd and Reyna (1988).

Acquisition

Global measures

The means and standard deviations of the acquisition data are shown in Table 1. It was expected that there would

Table 1

Summary Statistics for the Acquisition Data

Condition	Total-Errors		Trial-of-Last-Error	
	$\underline{M}$	$\underline{SD}$	$\underline{M}$	$\underline{SD}$
Categorized list				
Younger LD	1.27	0.61	1.41	0.77
Older LD	0.88	0.37	1.06	0.56
Younger Non-LD	1.07	0.78	1.20	1.03
Older Non-LD	0.56	0.27	0.57	0.27
Unrelated List				
Younger LD	4.61	1.54	7.31	2.70
Older LD	4.04	2.21	6.41	3.96
Younger Non-LD	3.70	1.11	5.73	2.75
Older Non-LD	2.80	0.88	3.97	1.15

be group differences in the number of trials (per word) that it took students to learn the list and the last trial that an error was made. These acquisition data were analyzed by employing two analyses of variance (ANOVA). Both ANOVAs were 2 (Age: younger, older) x 2 (Group: LD, Non-LD) x 2 (List: categorized, unrelated) designs, one using the total-errors to criterion as the raw data and the second using trial-of-last-error. Because the data indicated a bimodal distribution for list condition, additional ANOVAs were computed separately for each list condition.

The ANOVA computed on total-errors revealed significant main effects for age, $F(1,97) = 6.93$, $p. < .01$; group, $F(1,97) = 8.90$, $p. < .01$; and list, $F(1,97) = 161.40$, $p. < .001$. There were no interactions. On the categorized list, there was a main effect for age, $F(1,57) = 8.83$. $p. < .01$, but no main effect for group, $F(1,97) = 3.07$, n.s. On the unrelated list, there was only a main effect for group, $F(1,40) = 4.64$, $p. < .04$, but no main effect for age, $F(1,40) = 2.18$, n.s.

On the trial-of-last-error measure, significant main effects were revealed for age, $F(1,97) = 5.21$, $p. < .05$; group, $F(1,97) = 8.67$, $p. < .001$; and list, $F(1,97) = 143.39$, $p. < .001$. There was a significant List x Group interaction, $F(1,97) = 4.32$, $p. < .04$. On the categorized list, there was a main effect for age, $F(1,57) = 6.51$, $p. <$

.02, but no main effect for group, $F(1,57) = 3.22$, n.s. On
the unrelated list, there was a main effect for group,
$F(1,40) = 4.63$, $p. < .04$, but no main effect for age,
$F(1,40) = 2.04$, n.s.

The main effects found on both acquisition measures
revealed that older children made fewer errors and required
fewer trials than younger children, and the Non-LD children
learned the list with fewer errors and trials. The
categorized list with cued recall was learned with fewer
errors and trials than the unrelated list with free recall.
Further analyses within list condition revealed that the LD
and Non-LD groups were significantly different on the
unrelated list only. The younger and older children were
significantly different on the categorized list only.

Amnesia and hypermnesia

The unconditional probability estimates of successful
recall for Test Trials 1A and 1B are presented for each list
by age / group combinations and are found in the first two
columns of Table 2. Unconditional probabilities for the
categorized list ranged from .56 to .77. Unconditional
probabilities for the unrelated list ranged from .30 to .39.
The pattern of intertest change was classified amnesia if
$p(TA) > p(TB)$, and hypermnesia if the reverse was true. On
the categorized list, the pattern of intertest change was
hypermnesia (increase in net recall) with both Non-LD groups

Table 2

Conditional and Unconditional Probabilities of Correct

Recall at Acquisition Trials 1A-1B

Condition	Statistic			
	p(T1A)	p(T1B)	p($\overline{T}$1B/T1A) forgetting	p(T1B/$\overline{T}$1A) reminiscence
Categorized list	·			
Younger LD	.58	.60	.05	.12
Older LD	.62	.69	.04	.25
Younger Non-LD	.56	.61	.10	.11
Older Non-LD	.69	.77	.00	.28
Unrelated list				
Younger LD	.32	.31	.19	.08
Older LD	.35	.35	.03	.02
Younger Non-LD	.30	.32	.03	.02
Older Non-LD	.38	.39	.11	.09

and the older LD group. Rates were stable with the younger

LD subjects.

On the unrelated list, unconditional probabilities are

stable, indicating neither hypermnesia, nor amnesia.

Forgetting and reminiscence

The third and fourth columns of Table 2 provide the

conditional probabilities rates for forgetting and

reminiscence, respectively for both lists by age / group

combination. Forgetting probabilities ranged from .00 to

.19. Reminiscence probabilities ranged from .11 to .25.

The pertinent statistical analyses is described elsewhere

(Brainerd & Kingma, 1985).

An examination of these data indicates that on the

categorized list, the probability for reminiscence is higher

than the probability for forgetting in all groups except

the younger-LD subjects, where they are equivalent. Older

subjects displayed more reminiscence than younger subjects.

younger Non-LD children had a higher probability of

forgetting than all other groups. There was no significant

age difference on forgetting with the LD children.

However, on the unrelated list, the results were

mixed. The probabilities for reminiscence and forgetting

were equivalent, for all but the younger LD subjects, who

demonstrated higher forgetting probability (.19) than

reminiscence (.08). The older Non-LD children demonstrated

both higher forgetting and reminiscence probabilities than the younger Non-LD and older LD subjects. Reminiscence did not vary as a function of group (LD / Non-LD). Reminiscence was stronger on the categorized list than the unrelated list.

Retention

Global measures

Table 3 presents the means and standard deviations of the retention global measure of total-words. It was expected, that there would be group differences in the retention measures similar to those at acquisition. ANOVAs were computed to test these hypotheses. As with the acquisition data, the design for the total-words measure was a 2 (Age: younger, older) x 2 (Group: LD, Non-LD) x 2 (List: categorized, unrelated). Retention was also measured by a test-trials ANOVA, consisting of a 2 (Age: younger, older) x 2 (Group: LD, Non-LD) x 2 (List: categorized, unrelated) x 5 (test trials: 1-5) with repeated measures on the last factor.

The total-words ANOVA yielded main effects for group, $F(1,98) = 18.57$, $p. < .001$ and list, $F(1,98) = 304.32$, $p. < .001$. There was no main effect for age, $F(1,98) = 3.21$, n.s. However, there was a significant Group x List interaction, $F(1,98) = 5.94$, $p. < .02$. Non-LD children remembered more words than LD children. More words were remembered on the

Table 3

Summary Statistics for the Retention Data

Condition	Total-Words	
	$\underline{M}$	$\underline{SD}$
Categorized list		
Younger LD	13.81	1.64
Older LD	14.20	1.26
Younger Non-LD	14.17	1.47
Older Non-LD	15.25	0.87
Unrelated List		
Younger LD	6.17	2.32
Older LD	6.92	2.56
Younger Non-LD	8.84	1.63
Older Non-LD	9.31	2.69

categorized list. As with the acquisition data, a bimodal
distribution indicated the need for within list ANOVAs. On
the categorized list, there was a main effect for age,
$F(1,57) = 4.28$, $p. < .05$, and group, $F(1,57) = 3.90$, $p. <$
.05. On the unrelated list, there was a main effect for
$F(1,41) = 11.8$, $p. < .001$, but no main effect for age,
$F(1,41) = .68$, n.s.

The Test-Trials repeated measures ANOVA revealed main
effects for group, $F(1,98) = 24.98$, $p. < .001$, list,
$F(1,98) = 438.17$, $p, < .001.$, and test trials, $F(4,392) =$
36.46, $p. < .001$. Again, age was not significant, $F(1,98) =$
3.09, n.s. Similar to the findings for total-words, a
significant List x Group interaction was present, $F(1,98) =$
4.61, $p. < .03$. On the categorized list, there were main
effects for age, $F(1,57) = 4.57$, $p. < .04$; group, $F(1,57) =$
6.9, $p. < .01$; and trials, $F(4,228) = 27.82$, $p. < .001$. On
the unrelated list, there were main effects for group,
$F(1,41) = 15.55$, $p. < .001$, and trials, $F(4,164) = 12.55$, $p.$
< .001, but no main effect for age, $F(1,41) = .43$, n.s.

In summary, these retention data indicate that children
retained the categorized list better than the unrelated
list. The Non-LD group remembered more words than the LD
group did after the two week interval in both list
conditions. Although there were significant group
differences on both lists, the largest differences

continued to be on the unrelated list. The retention
performance of all groups of children improved over the five
test trials. Age was not a significant overall factor at
retention, although there were significant age differences
within the categorized list.

Amnesia and hypermnesia

The unconditional probabilities of correct recall in
each of the five test trials for younger and older LD and
Non-LD groups is presented in Table 4 for the categorized
list and in Table 5 for the unrelated list. Hypermnesia, an
increase in net recall over trials, was predominant over a
decrease in net recall, amnesia, for all groups. This
hypermnesia effect was not present between all adjacent
trials, but was instead evident over the course of the five
test trials. There was no amnesia on any adjacent test
trial comparisons.

Forgetting and reminiscence. Forgetting and
reminiscence data between each pair of recall tests (1-2, 2-
3, 3-4, 4-5) is also displayed in Tables 4 and 5.
Forgetting rates on the categorized list were minute,
ranging from .00 to .04. There was far more variation on
the unrelated list where rates varied from .00 to .19. The
most forgetting occurred between the first and second test
trials for both of the younger groups (.19 for the LD and
.09 for the Non-LD). For the older LD group, the most

Table 4

Forgetting and Reminiscence Probabilities at Long Term
Retention with Categorized Lists

Measure	Condition			
	Younger LD	Older LD	Younger NON-LD	Older NON-LD
Unconditional probabilities:				
$p(T1)$	.76	.81	.82	.89
$p(T2)$	.79	.81	.83	.93
$p(T3)$	.83	.83	.83	.93
$p(T4)$	.84	.85	.87	.95
$p(T5)$	.85	.88	.87	.95
Forgetting:				
$p(\overline{T}2/T1)$	.03	.04	.03	.01
$p(\overline{T}3/T2)$	.00	.00	.00	.00
$p(\overline{T}4/T3)$	.01	.00	.01	.00
$p(\overline{T}5/T4)$	.00	.00	.00	.00
Reminiscence:				
$p(T2/\overline{T}1)$	.22	.16	.21	.43
$p(T3/\overline{T}2)$	.22	.19	.07	.14
$p(T4/\overline{T}3)$	.07	.17	.02	.20
$p(T5/\overline{T}4)$	.14	.16	.10	.13

Table 5

Forgetting and Reminiscence Probabilities at Long Term

Retention with Unrelated Lists

Measure	Condition			
	Younger LD	Older LD	Younger NON-LD	Older NON-LD
Unconditional probabilities:				
$p(T1)$	.29	.31	.44	.45
$p(T2)$	.29	.36	.47	.48
$p(T3)$	.29	.35	.49	.52
$p(T4)$	.33	.37	.49	.51
$p(T5)$	.36	.39	.51	.51
Forgetting:				
$p(\overline{T}2/T1)$	.19	.05	.09	.07
$p(\overline{T}3/T2)$	.08	.13	.03	.05
$p(\overline{T}4/T3)$	.03	.07	.07	.07
$p(\overline{T}5/T4)$	.00	.07	.04	.05
Reminiscence:				
$p(T2/\overline{T}1)$	.06	.09	.13	.14
$p(T3/\overline{T}2)$	.05	.06	.08	.13
$p(T4/\overline{T}3)$	.05	.06	.08	.06
$p(T5/\overline{T}4)$	.05	.06	.08	.12

forgetting occurred between the second and the third trials
(.13). For the older Non-LD group, forgetting probabilities
were the same (.07) from the first to second and third to
fourth.

The highest rates of reminiscence occurred with the
categorized list, where the Non-LD subjects had their
highest rates between the first and second trials (.21
younger and .43 older). This older Non-LD group also had
the most reminiscence (.28) at acquisition. This group
also displayed a higher rate of reminiscence, as indicated
by an average probability of .23. The younger LD group
demonstrated their highest reminiscence between trials 1 and
2 and between trials 2 and 3 (.22). The older LD group had
similar reminiscence probabilities across trial comparisons
(.16 to .19).

On the unrelated list, reminiscence probabilities were
lower than on the categorized list. The Non-LD subjects
demonstrated more reminiscence than the LD group. The
highest probability of reminiscence for all groups was
between the first and second trials.

Model-based analyses

In an attempt to define and factor the respective
contributions of the two forgetting processes of storage
failure and retrieval failure, as well as the other test
induced processes, restorage and retrieval relearning,

Brainerd et. al.'s (1988) forgetting model was utilized.

These variables are defined in Table 6. Table 7 provides

the parameter estimates for these variables, as calculated

by Brainerd's mathematical model of forgetting and

relearning processes (Brainerd, Kingma, Howe, & Reyna,

1988). According to these estimates, across age, group,

and list, the major action in children's forgetting was

storage failure, rather than a retrieval failure. The

differences between these parameters was very large with

the unrelated list, and smaller, yet still significant,

with the categorized list. There were significant

differences between categorized and unrelated lists on

storage failure (S), retrieval failure (R), both of which

had significantly larger probabilities with the unrelated

lists, and restorage (a), where unrelated list parameters

were smaller. Finally, there were no reliable age

differences on either of these three measures.

Most important to the study were the group differences

in these retention processes. The largest differences were

again found on the unrelated list, but only on storage

failure. LD children had significantly more storage failure

than Non-LD children. There was still a significant group

difference with storage failure on the categorized list, but

it was not as pronounced. In general, the LD group had two

to three times the amount of storage failure than retrieval

Table 6

Memory Processes Measured by the Forgetting Model

Parameter	Process Definition

Forgetting:

S The probability that storage fails during the retention interval.

R For traces that remain in storage, the probability that retrieval fails during the retention interval.

Test induced:

a For traces that do not remain in storage, the probability restorage occurs on any test trial.

$r1$ The probability that a stored trace is retrieved following successful recall on the immediately preceding test trial.

$r2$ The probability that a stored trace is retrieved following successful recalls on the two immediately preceding test trials.

$r3$ The probability that a stored trace is retrieved following successful recalls on the three immediately preceding test trials.

$f1$ The probability that a stored trace is retrieved following an error on the immediately preceding

test trial.

$\underline{f}2$ The probability that a stored trace is retrieved following errors on the two immediately preceding test trials.

$\underline{f}3$ The probability that a stored trace is retrieved following errors on the three immediately preceding test trials.

Table 7

Parameter Estimates by Condition

Condition	Parameter								
	S	R	a	r1	r2	r3	f1	f2	f3
Categorized list									
Young LD	.16	.09	.12	.97	.99	.98	.56	.79	1.0
Old LD	.17	.04	.06	.97	1.0	1.0	.48	.26	.27
Young Non-LD	.08	.18	.06	.97	1.0	1.0	.80	.95	.90
Old Non-LD	.06	.06	.09	.99	1.0	1.0	.30	.96	.64
Unrelated list									
Young LD	.61	.24	0	.86	.93	.95	.55	.74	.43
Old LD	.63	.18	.03	.95	.88	.94	.36	.63	.72
Young Non-LD	.49	.17	.02	.93	.96	.92	.35	.70	.63
Old Non-LD	.44	.24	.01	.94	.95	.91	.40	.31	.96

failure. Their retrieval failure, restorage, and retrieval learning rates were also similar to the Non-LD group. Thus, the forgetting model has isolated the process where LD children's retention breaks down to be storage failure, with the most dramatic effects found on the unrelated list.

In summary, there were significant differences between LD and Non-LD children on all global measures of acquisition and long term retention. Consistently, the largest group differences on all global measures were found on the unrelated list. On that list, the LD children took longer to memorize lists and recalled fewer words in total, as well as across test trials. The most storage failure obtained by any group and list was found with the LD children on the unrelated list. The LD children also had significantly more storage failure than the Non-LD on the categorized list, although differences were not as large. However, LD and Non-LD children were not different on any of the test-induced processes of restorage and retrieval relearning.

Hypermnesia was preeminent over amnesia in net recall at long term retention. When there was significant change between adjacent recall tests trials (for individual items), reminiscence was the preeminent mode. Forgetting was primarily a function of storage failure for all

groups, and most strongly for the LD children.

Although age was a significant factor on the acquisition measures, age changes were not evident on either of the global retention measures. On the categorized list, there was more reminiscence found with the older children. There were no age differences on the model-based analyses of forgetting.

CHAPTER 4

DISCUSSION

This chapter will discuss the theoretical and
practical implications of this study of acquisition and
retention processes in Learning Disabled (LD) and Non-LD
children. The research looked at the effect that the
taxonomic relatedness of the list, with its cuing condition,
had on recall performance, as well as issues concerning
developmental change in acquisition and long term retention
processes among these children. Asymmetries concerning
these acquisition and retention variables will also be
discussed.

In addition to these global measures of acquisition and
retention, specific processes were investigated. These
variables included amnesia, hypermnesia, forgetting,
reminiscence, storage failure, retrieval failure, restorage,
and retrieval relearning.

The implications of the current work to educating
children with Learning Disabilities will be considered.
Finally, recommendations for future research will be
proposed.

Taxonomic relatedness

Discussion will concern itself with the issue of

taxonomic relatedness. Although overall Non-LD children were superior in acquiring and remembering lists, the relative difficulties of LD children were most severe on the unrelated list. At acquisition, the LD children were only less proficient than the Non-LD children on the unrelated list. At retention, however, they were less proficient than on both unrelated and categorized lists.

These findings are in contrast with earlier work at acquisition by Brainerd, Kingma, & Howe (1986), who found that LD children's difficulties, compared to Non-LD children, were most severe on categorized lists. However, their study used a 16 word categorized list of only two categories, with both free and cued recall. Consequently, the list was more difficult than the four category list used in the present study, and direct comparison is not possible. In their study, the group differences for the categorized lists were the same when the categories were cued, and when they were not cued. They proposed that the two ability levels were equally likely to use organizational strategies when they were available, but that disabled children were less likely to possess them.

Using list and recall conditions more similar to the present study, Howe, O'Sullivan, Brainerd, & Kingma (1988) utilized 16 word lists in investigating differences between LD and Non-LD children at acquisition. They utilized an

unrelated list (with free recall), a two category list (with free and cued recall), and a four category list (with free and cued recall). In contrast to the present study, they found that while all students benefited from categorizing a list, the Non-LD students benefited most. Again, it was found that it was the categorized list, more so than the unrelated list, which illustrated the recall difficulties of the LD children, in comparison to the Non-LD children.

In support of the present findings, other researchers, however, like Torgeson (1977) and Moe and Harris (1983), have found LD and Non-LD children did not differ on cued recall of categorized pictures. Neither study had other list or recall conditions, however.

At the acquisition phase, the present study reached opposite conclusions to Brainerd et al. (1986) and Howe et al. (1988). Group effects were found for only the unrelated list at acquisition, and for both unrelated and categorized lists at retention, with larger effects for the unrelated list. Past research has not provided information regarding the retention phase. There is the possibility that ceiling and floor effects on the categorized lists were responsible for the finding that the LD children were not worse than the Non-LD children at learning the list. The list was so easy that acquisition was quick, regardless of group (LD, Non-LD). After a forgetting interval of two

weeks, however, the Non-LD children remembered significantly more words than the LD children on both lists. No ceiling effects were evident at this retention phase.

On the unrelated list, recall could not be aided by any semantic organizer, such as taxonomic relatedness and the cuing of categories. This list was far more difficult than the categorized list. The LD children were much slower in both learning the unrelated list at acquisition, and subsequently remembering it at retention. Since there were no group differences on the categorized list at acquisition, the finding of group differences at retention was another demonstration of asymmetries present in these processes.

Developmental Change

This study found overall age differences, with the older children learning the lists with fewer errors and trials at acquisition. Closer examination within each list, however, reveals that the older children were only faster learners on the categorized list, and not the unrelated list. Overall, age differences were not present at retention. Within list analyses again revealed that, older children remembered more words after two weeks than the younger children did only on the categorized list, and not the unrelated list.

Although the present study failed to find general improvement in acquisition and retention performance as the

children got older, this finding was not unexpected due to the limited age range of the sample, seven to twelve years old. This was particularly true when these findings are compared to research where groups were separated by four years, such as in Howe et al. (1988), where second graders were less proficient than sixth graders. Other literature has demonstrated that recall improvements with development are largely a function of the type of list and cuing, as well as subject population (e.g., Howe et al., 1985; Howe et al., 1988; Brainerd et al., 1986 & 1988). The fact that older children were more proficient at acquisition, but not at retention is another example of the asymmetries between acquisition and retention processes.

Amnesia, Hypermnesia, Forgetting, and Reminiscence

The variability of recall across trials has been of interest to researchers since Ebbinghaus (1964/1885), according to a recent review of hypermnesia and reminiscence (Payne, 1987). The present study found that there was more variation in these variables between the categorized and unrelated lists than between the two groups. More hypermnesia and reminiscence occurred with the categorized than the unrelated list. This was consistent with Brainerd and Reyna's (1988) findings with normal children, where the tendency toward hypermnesia increased with age and with the categorization of the list, when it was cued. Age effects

were not found in the current study, which again could be
due to the limited age span.

Storage Failure

The present study found that forgetting in LD and Non-
LD children, and especially in LDs, was due more to storage
failure than retrieval failure. This finding is consistent
with what Brainerd et al. (1988) found with normal children.
It is contrary, however, to both popular belief, which views
forgetting as retrieval failure (Loftus & Loftus, 1980) and
the general notion in the literature (e.g., Baggeley, 1982)
which presents long term memory as a permanent store, with
retrieval that sometimes fails to access it. However, like
the results of the Brainerd et al. (1988) study, storage
failure was not permanent. The data showed that memory
traces could be restored on retention tests, even though
subjects were not permitted to restudy the list. Memory
traces were still present in some sense after storage
failure because they were able to be regenerated by the
subject. These phenomenon of storage failure and relearning
are consistent with Brainerd et al.'s (1988) notion of
featural disintegration, which was applied in the present
study to LD children.

An eight year old boy in the study was more aware of
his storage failure than the experts have been so far.
Frustrated, he told the examiner, "The brain burglar has

gotten in and stole those words from my bank...my memory."
Later, he provided an example of perceived retrieval failure
when he tried to coax out what he knew was there saying,
"Come on out, come on out!"

Practical Implications

The fact that LD children forget more will come as no
surprise to parents and teachers who have worked with them.
The fact that this is such a new research area is quite
surprising. It is clear that academic achievement is
largely dependent on the acquisition and long term retention
of material which is taught and learned. Unless children
retain information, they can not build an adequate
foundation for further learning, whether the subject is
reading, written language, spelling, or whatever.

It is important to know that LD students forget more
material than their peers, even when they have reached a
100% criterion, which had required more trials and errors to
mastery. It did appear that the children's categorizing the
list tended to glue the elements of each semantic class
together for better retention. It could be said that the
categorization had a benefit of inoculating the memory
traces against their failing. LD children did remember more
words on the categorized list, but their performance was
still much poorer than the performance of the Non-LD
children. Retention performances were closest on the

categorized list. Consequently, it may be helpful for LD children to organize material in such a manner, when appropriate.

It is also important for teachers to remember that if a child has only one opportunity to give an answer on a test and is incorrect, it is still quite possible that he or she knows it. On both lists and with both groups, students' recall improved across the five test trials (hypermnesia). In addition there was considerable relearning across trials. Students should be given more opportunities for recall.

Recommendations for Future Research

As the present study was the first of its kind with LD students, it is evident that much more work is required to understand these retention and forgetting processes. Because the only categorized list was also cued by category, it was impossible to separate the effects of the taxonomic relatedness of the list from the effects of cuing. This is an important question. Future work should again use the criterion of two errorless trials, to be certain that the effect of storage failure is as powerful as it now appears. It would also be important to equalize the list difficulty, so no possible confounding occurs.

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