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ABSTRACT

Although studies using recall tasks to measure memory typically report age-related declines in performance for older subjects, little is known about how these research results relate to performance in actual situations. A study was undertaken to determine whether years of experience in a domain of knowledge could compensate for age-related differences in performance on recall tasks, as well as to examine whether within that domain, areas that are better known would be more highly structured and richly recalled than less well-known areas. Telephone sales clerks (N=30) ranging in age from 23 to 69 years were recruited from three fastening companies, divided into three age groups, and asked to perform a sort-recall task of high (HF) and low (LF) frequency usage fastening items. The results revealed no age differences on sorting or recall for either the HF or the LF items. On a within-subject basis, all measures of recall were significantly higher for the HF items than for the LF items. HF items were found to have a different organizational relationship than LF items which supports the notion of a more cohesive and structured recall and a richer memory for well-known items. These findings suggest that work experience and frequent exposure to certain product items affects both qualitative and quantitative aspects of organization and recall of this knowledge domain. (NRB)

DOMAIN SPECIFIC KNOWLEDGE AND MEMORY PERFORMANCE IN THE WORK PLACE

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Domain Specific Knowledge and Memory Performance in the Work Place

The present study draws from two distinct areas of psychological research, (a) aging research dealing with memory changes in later years of life; and (b) the role of knowledge organization in recall. Specifically, I seek to investigate whether years of experience in a particular domain of knowledge can compensate for age - related differences in performance on recall tasks and to examine whether within this domain, areas that are better known will be more highly structured and more richly recalled than less well - known areas.

My interest in age differences in organization and recall of a naturally encountered domain of knowledge stems from the fact that age has been used traditionally in many studies to predict performance. Most studies, however, have been carried out within the artificial confines of the laboratory, with little effort to ensure the ecological salience of their results, or even the meaningfulness of the task. When these recall tasks are used to measure memory, laboratory studies typically report substantial age related declines in performance for older subjects (Poon et al.,1980; Salthouse, 1982).

Hultsch (1971), for example, studied organization and free recall for three age groups ranging up to 69 years using a sort-recall technique developed by Mandler and Pearlstone (1966). In this experiment, subjects sorted unrelated words until they achieved stable groupings over time. While the sorting behavior of all groups was the same (ie. all the subjects used approximately the same number of categories), age differences were found in the subsequent recall test. In other words, even though the older subjects sorted like the younger subjects, it did not help their recall.

The problem confronting Hultsch's study, is that nothing is known about how well the results of this experiment relate to the performance of older people in real-life settings. My concern here is with the ability of older people to retrieve pre-experimentally acquired knowledge, that is, knowledge that has been acquired during the day-to-day experience of working. There are a relatively small number of investigations that have examined memory of information not specifically acquired in the course of a laboratory task. For example studies such as those of Lachman and Lachman (1980) and Pearlmutter (1978) have found age related improvement in adult memory for factual knowledge such as current events, movies, sports and historical events. These suggest that age - related decrements in free recall may not be obtained for items that are members of a domain of naturally acquired knowledge.

The second area of research on which this study is based pertains to the effect of knowledge organization on recall. Recent work by Chi (1981) has emphasized the complex interaction of knowledge and cognitive strategies. According to Chi & Koeske (1983), the quality and quantity of recall is not a function solely of more efficient strategies in the developing child. As important is the growth in knowledge as a function of age and how that knowledge is represented. In an innovative study, Chi asked a 4 1/2 year old boy who was very knowledgeable about dinosaurs, to generate the names of 46 dinosaurs. Based on the frequency of generation and the frequency of mention in the texts read to the child, Chi was able to select 20 better known and 20 lesser known dinosaurs. Using frequency data and information on dinosaur properties, Chi mapped the child's representation of better known and lesser known dinosaurs. When dinosaurs names were subsequently presented in a free recall task, the child's recall for the better known set was twice as high as for the lesser known set. Chi concluded that since the subject was too young to have adequate strategies for remembering, only the structure of the child's knowledge base accounted for his differential memory performance.

The present study extends both Hultsch's and Chi & Koeske's work to adults in a naturalistic setting. Specifically, I investigated the attributes which differentiate better and lesser known subdomains of knowledge in the workplace and examined the implication of knowledge organization for memory function among older adults.

The setting chosen for my study consists of three companies who are major producers of industrial fastening items which are used in the electronic, aerospace and computer industries. The major fastening products which they manufacture and distribute are bolts, nuts, screws and washers. These products can be related to each other in many ways such as by material, diameter, thread series, length, shape, cost and use.

Subjects were recruited from telephone sales clerks in these three organizations. They had varied degrees of technical knowledge and experience in the industry acquired over a period of one to over thirty years. These employees started at different levels within the corporation, either in the clerical or expediting departments and were promoted to sales only after a lengthy apprenticeship. The knowledge required of sales clerks includes a technical understanding of engineering principles required in order to understand the needs of the customer when dealing with specifications of tensile requirements, diameter, gage fit, or various functions of the fastening items. Level of education is not a basis for hiring.

The nature of a sales clerk's work consists of (a) receiving orders from buyers, (b) checking inventory to fill these orders, (c) buying material from other manufacturing sources not found in stock and (d) pricing the items. This type of work often involves remembering lists of items as well as using and filing inventory cards used to check stock. The inventory consists of a manual card filing system. Figure 1 illustrates the way in which the items are organized within this system.

Insert Figure 1

Products are listed in the inventory hierachically according to the type of metal such as steel, brass, stainless steel, monel or plastic. For each type of metal the inventory is subdivided into categories of bolts, nuts, screws and washers. Further organization of the inventory becomes increasingly specific. For example under" screw" one will find machine screws, sheet metal screws or wood screws. These parts are then further broken down into diameter, thread series, lengths and head styles (eg. steel machine screw, 6-32 x 1/2 binding head).

Making use of Mandler's sort/recall proceedure, I decided to explore whether sales clerks organize and recall inventory materials differently depending on the frequency of their use. Both inter and intra - subject differences were examined. My three principal hypotheses were: First, on between- suject basis, that older workers would recall less than the younger groups in the low frequency subdomain but would have equivalent recall for products in the high frequency subdomain. The basis for this speculation is that, following Chi & Koeske (1983), I assumed that the knowledge base for the low frequency items would be less tightly organized, consequently recall of these items will need to be supported by deliberate memory strategies. Research has shown, however, that organization and such strategies may be deficient among older groups; second, on a within-subject basis, high frequency product items will have qualitatively different organizational relationships than low frequency products; and finally on a within-subject basis, recall will be better for high frequency products items than for low frequency products items.

Method

Subjects

Thirty telephone sales clerks from three medium sized fastening companies participated in this experiment. They were divided into three age groups ranging from 23 to 69 years. The first group consisted of ten subjects between 23 and 37 years (mean age 31.7 years), the second group consisted of ten middle aged subjects between 39 and 53 years (mean age 46.9) and the final group of 10 older subjects was between the age of 55 and 69 years (mean age 64.5 years). Subjects' formal education ranged from 10-17 years and their work experience from 1-32 years.

Stimulus Material

The experimental material consisted of two sets of 48 3 x 5 index cards. Each card listed the name and full description (eg. type, size, material) of a fastening item as it appears listed on the inventory card of the company. One set of cards consisted of high frequency usage items and one set consisted of low frequency usage items both drawn in equal number from four product categories of bolts, nuts, screws and washers. Frequency ratings were based on annual sales volume of these items and confirmed in interviews with management and employees.

Procedure

The procedure used was a modified sort-recall paradigm developed by Mandler & Pearlstone (1966) and also used by Hultsch. Each subject was asked to group fastening items that "fit together" to a criterion of two successive sorts. Subjects were required to make groups of two or more items and were permitted to view the array while sorting. Then the array was removed and subjects were requested to write down as many items as they could recall in any order. Stimulus material in one session consisted of frequently used items (HF items). Another session was devoted to products which are rarely used (LF items). The two experimental conditions were administered in a random order, in order to control for practice effects. After the recall task, subjects were interviewed on tape and asked to explain the basis of their sorting organization. It is important to note that sorting and recall are activities very similar to those these sales clerks engage in while performing their daily jobs.

Results

In the interest of clarity, the scoring scheme and performance measures will be discussed together with the presentation of the results. I will turn to the sorting task first. Scoring for the sorting task was based on the number of trials, the number of groups, and the number of features. The feature analysis evolved from observing how workers performed in their daily tasks, ie. how they identified various characteristics of an item while taking telephone orders (eg. discussing material, length, diameter and thread series). Since the major categories (bolts, nuts, screws and washers) were already identified on the stimulus card, only the subcategory such as machine screw or flat washer was considered a property of the item and together with material, length, thread series, diameter and head type was counted as such. These properties I called features. Thus, features consisted of the number of characteristics or criteria the subject used to determine each grouping made. The followind is a typical sorting protocol which illustrates the analysis:

Insert Figure 2

For example, as illustrated in Figure 2, the first group shares the same sub-group, flat washer, and diameter sequence from small to large. The scoring of the sorting and recall data was not based on some arbitrary system but according to standard industry practice existing in the inventory which is the accepted system in these firms.

Both inter and intra - subject differences were examined. For inter - subject differences, my first analyses were concerned with age differences in sorting. A stepwise regression was carried out. Age was not a significant predictor for any of the sorting variables in either HF or LF knowledge domains. Older workers did not impose different organization on the LF items and thus my hypothesis was not born out. Interestingly, however, as shown in Table 1, education, namely years of schooling completed, was a significant predictor for two sorting variable for LF items: (a) number of groups formed, and (b) number of features used as sorting criteria for each group.

Insert Table 1

The next comparisons involve within subject differences across knowledge domains. The number of trials required to reach a criterion sort is an index of the relative difficulty of the sorting task. Forty three percent of the subjects did not reach a criterion of two identical sorts for the LF product items, therefore data from the 7th trial was analyzed wether or not this was the criterion trial. A comparison of the sorting means for HF and LF item domains of knowledge can be seen on Table 2.

Insert Table 2

Using t tests for repeated measures, two out of three sorting variables for the two subdomains of knowledge, the number of trials and the number of features, reached significance levels. Note , however, that there were no significant differences for the number of sorting groups.

Explanation offered by the subjects for their sorting patterns for the two stimulus conditions can be seen on Table 3.

Insert Table 3

Explanation of sorting was classified in five ways: **unrelated**, if the reasons did not contain a reference to any characteristic of the item. For example:" They are very expensive or they are a miscellaneous group or they are never in stock;" **idiosyncratic**, if the reasons were based on some unusual attribute of the item such as:" All these washers have an odd shape, or these screws have special heads;"

shallow, if classification was based solely on the four major taxanomical categories; **compound**, if classification was based on one common characteri-tic such as material or diameter; and finally **deep**, if classifica: n was based on two or more characteristics.

As can be seen on Table 3, 50% of the subjects classified according to standard industry practice for the HF stimulus items but only 3% for the LF stimulus items. Moreover, for the LF condition many subjects forced items into categories that made little sense. Forty seven percent of the sujects imposed some kind of personal organization on the items that was unrelated to the characteristic: of the product. For example, some collapsed categories and created new groups, or they classified according to price. Sixty six percent of the subjects changed the r criteria for sorting within sessions.

For the recall task, recall protocols were scored for the number of items recalled, the number of features recalled, the number of groups recalled. An **item** was counted as correctly recalled if it was identified by a sub-category (eg. wood screw; flat washer). Thus, listing "screw" or "washer" alone did not count. **Feature**, in recall differ from those of sorting only in sofar that they belong to individual items. Each frequency group of 48 items had a total of 112 features and therefore a maximum score of 220 for the number of features. A typical recall protocol is illustrated on Figure 3.

Insert Figure 3

Clustering was measured by the number of items recalled from the same input group using Blousefield's 1953 ratio of repetitions (RR) scoring. This measure is calculated by dividing the number of category repetitions (the number of items from the same input category) by the total number of items recalled minus one. This measure calculates the extent which recall is structured according to the individuals own groupings in the sorting task as is shown on Table 1.

For the inter-subject differences in recall, my predictions were not born out. Age is not a significant predictor for any of the recall measures. As was shown on Table 2 experience, was a significant predictor for three recall variables, ie. the number of features for the HF items, the number of features for the LF items, and the amount of clustering for the LF items. As expected intra-subject differences for all measures of recall were significantly higher for the HF stimulus items. As can be seen on Table 2, the strongest findings were obtained for the number of features recalled and the number of groups recalled. These results support and extend Chi & Koeske's notion of not only a more cohesive and structured recall but also a richer memory for the HF stimulous items.

Discussion

I will discuss my findings based on the three principal hypotheses raised earlier in this paper.

First, with respect to age differences in recall, the most important and unexpected finding was the fact that there were no age differences on recall for either the HF or the LF product items. These results are interesting for two reasons: First, they contradict Hultsch's finding who used a similar procedure, and although he found no age differences for the sorting task, he did find subsequent recall deficits for the older group compared to the two younger groups; and second, more important, in view of the substantial research evidence portraying pervasive memory decrements among older individuals. These telephone clerks, however, have spent thousands of hours working with this specialized knowledge. Two possibilities exist. One is that there is no age dicline in the recall of these items; the other that this experience compensates for the age decrements so often discussed in the aging literature.

Contrary to my predictions, these findings also suggest, because of their many years of experince, that older workers in their specific domains of expertise, can maintain high levels of recall performance, even for the less frequently encountered areas of that domain. It is important to note that the tasks had more relevance for these workers than school related tests so often administered in the laboratory. These results suggest that experience was the best predictor of recall for these items, regardless of age and education. Future work must investigate whether these age related memory findings for older people generalize to other naturally encountered domains of knowledge.

Second, on a within-subject basis, it was anticipated that high frequency product items will have a different organizational relationship than low frequency products. As expected, all measures were significantly higher for the HF product items. The concern, here was not for the quantity of knowledge but rather how that knowledge was represented and structured in memory. My data support and extend Chi and Koeske's findings and the notion that the interconnectedness and structure of the knowledge base fascilitates both taxanomic, more exhaustive and qualitatively different organization than the less familiar product items. According to Mandler & Pearlstone (1966), sorting to criterion implies achievement of a stable organization. Almost half the subjects did not achieve a criterion of two identical sorts for the LF items even after 7 trials. This provides evidence for an inability to achieve a stable organization and a less structured knowledge base for the less familiar product items. Consistent with these findings, criteria for sorting performance for these LF items proved to be less stable and more idiosyncratic. Further evidence for a qualitative difference of the two sorting patterns was revealed in the subjects' explanation for their sorting pattern. Interestingly, for the LF items there was an especially strong relationship between sorting and education. These findings suggest that this task may also access school related abilities for these workers. It is difficult, however to explain why this finding did not hold true for the HF product items.

Finally, on a within -subject basis, it was predicted that recall will be better for high frequency product items than for low frequency product items and as expected all measures of recall were significantly higher for the HF product items. The strongest findings were obtained for the number of features recalled demonstrating a richer and more elaborate memory for these product items. The significant results for the clustering measure provide evidence of a greater relationship between input and output organization and more structured recall for the HF items.

In sum. this research suggests that work experience and frequent exposure to these product items affects the qualitative and quantitative aspects of organization and recall of this knowledge domain. Items were classified and recalled on the basis of their many properties. These findings have implication for theories of memory and aging and should be confirmed and extended to other naturally acquired knowledge domains.

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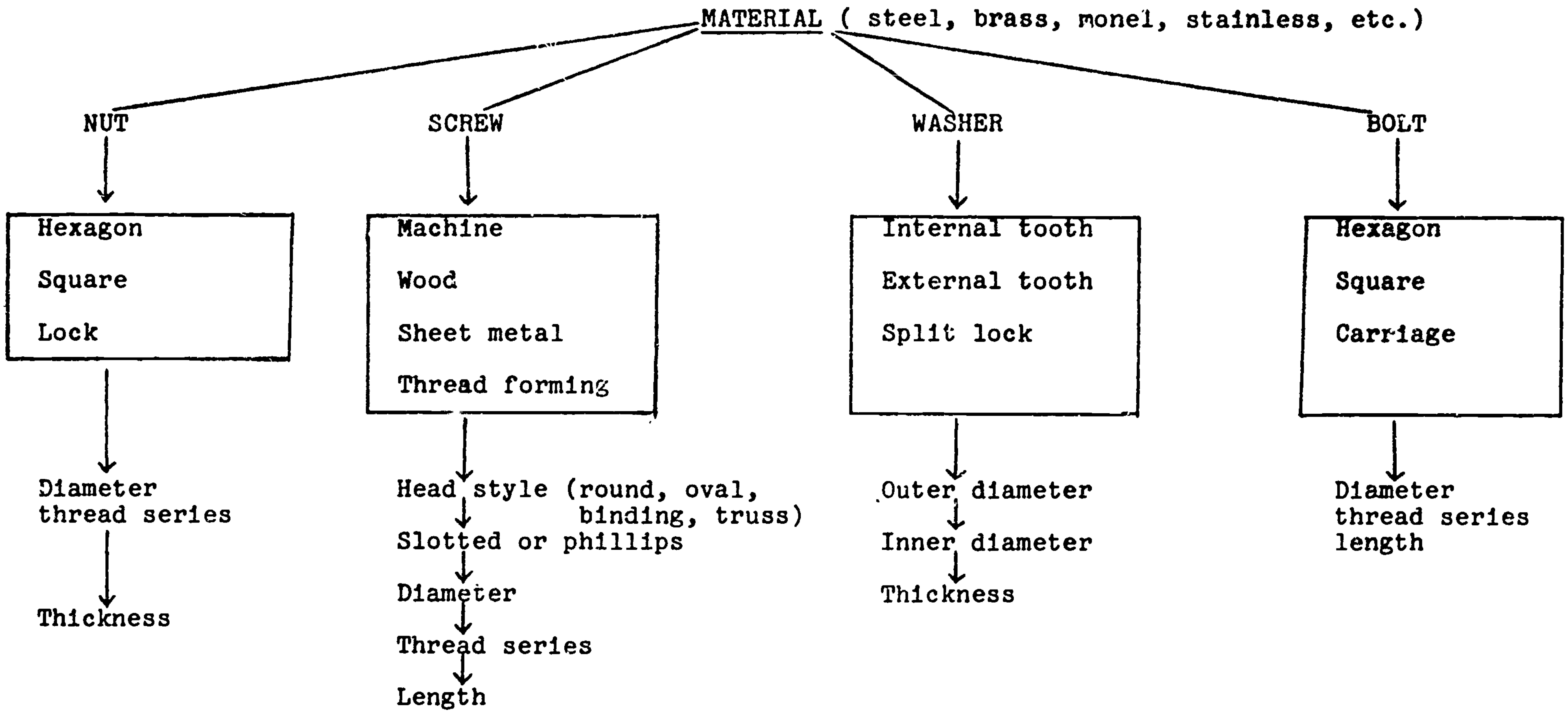

Fig. 1. Hierarchical Ordering of Fastening Products as found in the Inventory

Figure 2

Typical Sorting Protocol

Sort Groups	Features	Score=
#10 Flat washer, silicon bronze	sb.	1
# 8 Flat washer, nylon	diam.	1
# 5 Flat washer, mica material		
		2
1/4-20 x 1 Drilled fillister M/S, silicon bronze	sb.	1
4/40 x 5/16 Drilled fillister M/S, steel	t.	1
		2
10/32 x 1/2 Cross slotted, truss head M/S	m.	1
8/32 x 1 Pyramid Head M/S, steel	sb.	1
8/32 x 3/4 Slotted oval undercut head M/S, steel	diam.	1
6/32 x 3/16 Slotted flat M/S, steel		
		3
1/2-13 Flex-loc hex nut steel	m.	1
5/16-18 Cap nut, steel	sb.	1
8/36 Flex-loc nut, steel	diam.	1
8/32 Pal nut, steel		
		3
1/2-13 Kep nut, steel	sb.	1
6/32 Kep nut, steel	m.	1
		2
3/4-10 x 5 T head bolt, steel	m.	1
3/4-10 x 2 Elevator bolt, steel		
1/2-20 x 2 Carriage bolt, steel		
1/2-20 x 1/2 Wing screw, steel		
1/2-13 x 3 Countersink square neck bolt, steel		
1/2-13 x 3 stripper bolt, steel		
3/8-16 x 2 Drilled hex head bolt, steel		
5/16-18 x 2 Round head ribbed neck bolt, steel		
1/2-20 x 4 Step bolt, steel		
1/4-20 x 2 1/2 Plow bolt, steel		
		16 Features

sb. = sub category
m. = material
diam. = diameter
t. = type
l. = length
hd. = head type
[illegible] = thread series

Figure 3

Typical Recall Protocol

Groups Recalled	Features	Score=
1) 6 x 1/2 Slotted Round W/S, brass	diam.; l.; t.; hd.; sb.; m.	6
8 x 1 Slotted Flat W/S, brass	"	6
2) 2-56 Hex nuts, stainless	diam.; thr.; m.; sb.	4
4-40 Hex nuts, stainless	"	4
6-32 hex nuts, stainless	"	4
3) 8-32 Hex nuts, steel	diam.; thr.; m.; sb.	4
10-32 Hex M/S nuts steel	"	4
1/4-20 Hex nuts, steel	"	4
1/2-13 Hex nuts, steel	"	4
4) #4 Lite split L/W, steel	diam.; t.; m.; sb.	4
#4 Internal L/W, steel	"	4
#6 Lite split L/W, steel	"	4
10 Lite split L/W, steel	"	4
5) 1/2-13 x 2 Hex head bolts	diam.; thr.; l.	3
1/4-20 x 2 Hex tap bolts	"	3
3/8-16 x 2 Carriage bolts	"	3
6) #4 Flat washers, steel	diam.; m.; sb.	3
#6 Flat washers, steel	"	3
7) #4 Flat washers, brass	diam.; m.; sb.;	3
#5 Fla' washers, brass	"	3
8) #10 x 1 Pan head SMS A	diam.; l.; hd.; t.; sb.	5
#4 x 1/2 Pan head SMS B	"	5
		87 features

l.	= length
diam.	= diameter
m	= material
thr.	= thread series
t.	= type
hd.	= head type
sb.	= sub category

Table 1

Significant Dependent Variables in Multiple Regression Analysis of Inter-Subject Differences

Dependent Variable	Predictor Variable	F Ratio (df = 28)
	Sorting	
LF # of Groups	Education	4.68^{*}
LF # of Features	Education	10.34^{**}
	Recall	
HF # of Features	Experience	9.82^{**}
LF # of Features	Experience	5.95^{*}
LF # of Ratio of Repetition (RR)	Experience	6.10^{*}

* $p < .05$
** $p < .01$

Table 2

Comparison of the Means for HF and LF Item Domains for all Subjects

	Sorting		
Variable	HF condition	LF Condition	Significance
No. of Trials	3.67	5.37	***
No. of Groups	10.33	10.70	n.s.
No. of Features	18.10	12.10	**
	Recall		
No. of Items Recalled	16.70	14.10	*
No. of Features Recalled	47.30	27.70	***
No. of Groups Recalled	3.47	1.90	***
No. of Items in Groups	11.00	7.00	*
Ratio of Repetitions (RR)	0.39	0.28	*

*** $p<.001$
** $p<.01$
* $p<.05$

Table 3

Different Sorting Patterns for the Frequently Used HF and Rarely Used LF Items

Sorting Pattern	HF Items	LF Items
Idiosyncratic	3%	38%
Unrelated	3%	47%
Shallow	20%	30%
Compound	27%	20%
Deep	50%	3%