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The effects of unique encoding on the recall of numeric information

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Parker-Haney, Elizabeth, M.A.

San Jose State University, 1991

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THE EFFECTS OF UNIQUE ENCODING ON THE RECALL
OF NUMERIC INFORMATION

A Thesis

Presented to

the Faculty of the Department of Psychology
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by

Elizabeth Parker-Haney

May, 1991

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**The Effects of Unique Encoding on the Recall
of Numeric Information**

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Running head: UNIQUE ENCODING

Footnotes

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ABSTRACT

THE EFFECTS OF UNIQUE ENCODING ON THE RECALL
OF NUMERIC INFORMATION

by Elizabeth Parker-Haney

In order to determine the suitability of the digit-by-digit transmission of numeric data to pilots, the present experiment examined pilots' short term memory span by auditorily presenting air traffic control messages with one of two presentation formats: either the digit-by-digit transmission or the unique "chunked" transmission. Pilots were asked to repeat the message verbatim and then perform an alphabetizing distractor task. Recall was tested after various retention intervals. Recall was measured as the ability to write the numeric information accurately. Sixteen first officers between the ages of 27 and 50 participated as paid volunteers.

Data analysis revealed that there were no significant differences in recall between the digit-by-digit and the chunking conditions. However, analysis of message type and length of retention interval revealed significant main effects and interactions. The importance of errors found in recall and the error types are also discussed.

The Effects Of Unique Encoding On The Recall Of Numeric Information

The accurate recall of numeric information by pilots is a critical issue in dealing with the capabilities and limitations of human performance. Problems in air/ground communications have indicated that most of the communication problems originate with human error (Grayson & Billings, 1981). The human factor aspects found most often in association with information transfer problems have been those of distraction and forgetting (Billings & Cheaney, 1981; Lee & Lozito, 1989). The highly significant information (changes in weather, clearances, traffic avoidance data, etc.) is transferred almost entirely by means of simplex radio-telephone, a system in which only one message may be sent in either direction at one time. Hence, the pilot's task is to receive this advisory information, acknowledge instructions from the ground, and act upon them. Most of the information that is transferred is numeric and the accepted procedure in the air-traffic control system is to transmit all numeric information in a sequential, or digit-by-digit pattern, which may contribute to information transfer errors (Billings & Cheaney, 1981). Therefore, in order to minimize recall errors in pilots, the means of transmission of numeric information may have to be changed, and/or the way that the pilot encodes this information may have to be changed.

Three separate memory stores - sensory memory, working or short term memory, and secondary or long term memory - have been used to describe the human memory system (Ellis & Hunt, 1989). Sensory memory is considered to be a large capacity store from which information is lost rapidly unless attended to and transferred to working memory. Working, or short term memory, is a conceptual system that is believed to have a limited capacity from which information is lost within about fifteen to twenty seconds. Information selected for more permanent storage would then enter

secondary memory, which is speculated to have an unlimited capacity. Although this is one of many models of memory, this particular model will be used in this paper because it is widely regarded as one that describes information processing as a function of attention.

The transfer of information from the sensory register to the working, or short term memory is controlled by attention (Atkinson & Shiffrin, 1968). Once in working memory, the information is subject to control processes such as rehearsal, retrieval, coding, or decision making. The capacity of short-term memory is severely limited and incoming information from the sensory register to the short term memory is held in a phonetic code (Baddeley & Hitch, 1974). Short term memory is characterized by a brief trace, a small capacity, and an acoustic coding nature (Ellis & Hunt, 1989).

Short term span

Limitations. The capacity limitation in short term memory has been the focus of most models of information processing and most models attribute this limitation to a combination of short term memory and attention (Broadbent, 1958). Early theories, (e.g. Waugh and Norman, 1965), viewed short term memory as having a fixed number of "grooves" or "slots." Later studies argued for the term working memory (Baddeley & Hitch, 1974) and for its importance in processing and storage. Short term memory is a working memory in that it is an operative system in which information is accumulated and systematized prior to recall. It is the place where items are held while they are worked on, where they are rehearsed, reconciled or chunked. Retrieval is the process of accessing this information in memory and if the information cannot be retrieved, it is said to be forgotten. Forgetting is proposed to be the failure to retrieve, the fading of the memory trace, or interference produced from another memory trace.

Rates of forgetting are different for each memory store and the causes may also be different (Kintsch, 1970). The control processes regulate what information is selected from sensory memory, what gets rehearsed, and what gets stored in memory. Sensory memory is at the outermost region of processing; it is one of the first stages through which information passes. It is in working memory that we first have conscious control over the processing of information and it is at this point that mental strategies start playing a major role in the processing. If we selectively attend to the material, such as rehearse it, we can encode material for long term storage in long term memory.

The primary substantiation for limited capacity in short term memory comes from experiments on immediate memory span (Miller, 1956). In 1905, Wundt observed that the capacity of short term memory was restricted to around six items when the learning material consisted of items taken in isolation, such as numbers or letters. However, if these elements were grouped into larger units, many more elements could be retained in working memory (cited in Kintsch, 1970). Later, in 1956, Miller found that the number of units, or "chunks" determine the rate of forgetting, rather than the number of physical elements within an item. Miller found that the memory span for binary digits could be dramatically increased by a recoding technique he termed "chunking." Miller's model of chunking states that it is the process of combining information so that it takes up as little as possible of the limited space in short term memory. A unit of short term memory's capacity would therefore correspond to a chunk and would be a rather variable structure, containing more or less information as conditions allow. Chunking is believed to occur as the material enters short term memory and is accelerated to the degree that the to-be-chunked items have some intrinsic relationship that permits them to form a unit. This method of unique encoding, or chunking, is found to greatly expand the capacity of working memory.

Miller originally argued that these chunks are stored in both short term and long term memory, but the chunks of short term memory are the result of very superficial perceptual processing, while the units of long term memory are based on higher-level analyses and require more time and effort (Miller, 1956). Miller postulated that a list of seven, plus or minus two items, was the capacity of the short term memory. Later, Simon (1974) postulated that this capacity remained constant over time. Although there is a reasonable degree of constancy in an individual's memory span, there is some variation. As a result, the memory span is defined as a statistical average whereby the number of items that have a probability of being correctly reproduced is at .50. Using this definition, the average adult would be able to recall about seven digits or letters accurately about fifty percent of the time (Hall, 1971).

Measuring Retention. The major source of information about retention in short term memory is through a set of recall tasks, such as distractor tasks, probed recall tasks, free recall and serial recall tasks (Glanzer, 1982). Brown (1958) provided the first systematic study of retention time in short term memory recall and devised an experimental procedure for the study of single items. The Brown-Peterson, or Peterson-Peterson (Brown, 1958; Peterson & Peterson, 1959) distractor tasks are a famous distractor paradigm for measuring short term retention. In the Brown-Peterson paradigm, a subject is presented with a sequence of to-be-remembered items, followed by a distractor task which is continued for varying periods of time. Distractor tasks are normally seen as minimizing but not completely abolishing, the possibility for rehearsal. Their findings indicate that short term retention is a function of the length of the recall interval (Hall, 1971).

The distinction between working and long term memory is that they are influenced differentially by experimental variables. The recall of items involves a search and

retrieval process, the efficacy of which depends on how well the learning material has been organized in memory (Kintsch, 1970). Presentation rate and word frequency largely affect the probability of long term store, but have no effect upon the recall of the most recently presented items. Therefore, retention should be nearly perfect for an immediate test, but should decrease as a function of lag to an asymptotic value, the long term memory component (Glanzer, 1982). For probability measures, recall is distinguished as the number or percentage of responses correct, or the number or percentage of errors that are used as basic data (Hall, 1971).

The utilization of various distractor tasks to minimize rehearsal is a common paradigm in memory experiments. In order to affect short term store, visual or acoustic tasks are commonly used in conjunction with various retention intervals, in order to measure recall.

Pilot/Controller Communications. The above characteristics of short term memory have a direct impact on the performance of both air traffic controllers and pilots. The fact that most of a pilot's tasks are related to recalling numeric information makes this a critical issue. The type of error most common in pilot/controller communications is the error of transposition, or number reversals (Grayson & Billings, 1981).

The four types of errors found in conjunction with recalling numbers are those of transposition, omission, intrusion, and substitution. If given the stimuli of "4237" and the response at recall is "4273," an error of transposition has transpired. If a response of "42--" is given, it is considered an omission. Or, if the response is "42377" is given, the additional digit would be considered an intrusion. Finally, if the response "4248" was given, the error would be considered a substitution. Since pilots generally

know that a certain message contains a certain amount of numbers, omissions and intrusions may be less likely to occur under recall conditions.

Transposition refers to the transfer that apparently results from learning to respond to patterns or relations among stimuli rather than to stimulus elements. The literal meaning of transposition is a change in spatial location, and responses of this nature are controlled by the stimulus relations and patterns, not by the absolute properties of the stimulus (Reese, 1968). Transposition errors appear to increase as stimulus similarity increases (Gundlach & Herington, 1933). In human subjects, delay has also been found to increase transposition (Reese, 1968). In the case of pilots, it may be suggested that transposition occurs because of a failure to notice a change in stimuli, or type of message.

Surprisingly, not much has been done to study the forgetting of numeric information other than Loftus' (1979) study, which emphasized the amount of information given to a subject at a given time and the retention interval between the time the information is transmitted and the time it is acted upon by the subject. Actual pilots were not used in the Loftus' study but the subjects were well-practiced in the types of numeric messages given to pilots.

The current study examines the basic issue of forgetting numeric information that is presented auditorily to pilots. It examines the retention of chunking versus digit-by-digit transmission of numeric data over time. This experiment is designed to simulate the pilot's memory task in a controlled, laboratory setting within the context of the Brown-Peterson paradigm. The importance of presentation format and various retention intervals is assessed for a range of relevant pilot/controller communication tasks by examining the nature and number of errors.

Hypothesis 1: A main effect for presentation format was expected in that uniquely encoded, or chunked, numeric information would lead to significantly reduced rates of forgetting, i.e., there would be significantly fewer performance errors at all retention intervals. This hypothesis was based on generalizations from studies that have shown that chunking information can offset the capacity limitations in short term memory (Miller, 1956; Simon, 1974; Loftus, 1979).

Hypothesis 2: A main effect was also expected for retention intervals along with a significant linear trend. It was expected that the memory for numeric information would be greatest at the shortest retention interval of the recall task, with an immediate test, for both the chunking and digit-by-digit conditions. The proportion of correct recalls as a function of delay was expected to show a regular decline to some asymptotic level as found in previous retention studies by Glanzer (1982).

Hypothesis 3: It was expected that there would be an interaction between the variables of presentation (chunked vs. digit-by-digit) with regard to their effects on retention levels (0 vs. 5 vs. 10 vs. 15 seconds).

Method

Subjects

Sixteen commercial airline pilots (first officers), between the ages of 27 and 50, served as paid volunteers (see Appendix B). Demographic information was collected and verbal instructions (see Appendix C) were given to each subject. Each subject was provided with four training trials. The trials included examples of distractor tasks and both chunked and digit-by-digit conditions.

An Apple Macintosh II CX computer with a color 13-inch monitor screen was used in the experiment. A recording device and presentation software known as a

MacRecorder was used as the oral presenter of the stimulus information and used in conjunction with a programming application called Hypercard.

Design

A 2 presentation type (chunked vs. digit-by-digit) in counterbalanced order, X 4 retention delay (0 vs. 5 vs. 10 vs. 15 seconds) X 5 message type (radio frequency, heading, altitude in feet, flight level, and transponder code) X 2 (replication) repeated measures design was used. This design was chosen because it is more sensitive and requires fewer subjects than a corresponding completely randomized between-subjects design. Subjects received all of the required treatment conditions within a single retention interval (see Figure 1). In order to remove practice effects, a digram-balanced Latin square matrix was arranged. The purpose was to balance any practice effects equally over the treatment conditions. Testing position therefore reflected treatment combinations.

An individual with previous air traffic control experience was used to record the stimulus information with the MacRecorder. The recording was performed at the normal rate of conversation, or 150-180 words per minute. The computer was programmed to present 80 trials and 80 distractor tasks alternately and to generate the stimulus information according to the separate conditions. The screen presentation first consisted of a visual command to listen during which the verbal message was given. This was followed by a visual "recall" instruction in the immediate interval or a distractor task of variable length followed by recall. This pattern was continued throughout the experiment.

Procedure

Each subject was asked to fill out a short demographic questionnaire. Subjects were then given verbal instructions that explained the nature of the intent of the

Figure 1. Distribution of conditions among 80 trials in an experimental session.

experiment and then given four training trials. Responses were recorded by the subject by writing them down on the response sheet provided. Subjects were seated in front of the computer for the duration of the experiment.

Subjects heard a series of 80 codes, each consisting of a condition phrase and a numeric code. Each was followed by a variable retention interval. Several variables were manipulated over trials. Each trial consisted of:

1. A screen prompt to "listen", followed by the presentation of a condition phrase and a numerical message, presented at approximately 150-180 words per minute; i.e. "Squawk 3-1-6-2."
2. A screen prompt to "repeat out loud," whereby the subject would repeat the message verbatim in order to control for variation in encoding. Repeating the message as given is normal procedure in ATC communications.
3. A variable retention interval began during which the subject was required to alphabetize aloud ten non-aviation, non-numeric words presented on the screen.
4. A recall signal was flashed on the screen.
5. A 10 second free-recall period began during which the subject was required to write the previously presented information on the response sheet provided (see Figure 2).

The retention interval consisted of an immediate test (0 sec), or a five, ten, or fifteen second period in which the subject may have been required to perform a distractor task. This task involved alphabetizing aloud a group of ten categorically related words that were presented in randomly determined positions on the screen. Different groups of words were used for each trial (see Appendix D).

The stimulus information, or the to-be-remembered material, consisted of five different types of data: a five-digit radio frequency, a four-digit transponder code, a

Figure 2. Sequence of events of the experimental session.

five-digit altitude in feet number, a three-digit flight level number or a three-digit heading number. The five numerical conditions are as follows:

Radio frequencies. All radio frequencies chosen were between 118.00 to 136.05 to conform to actual flight operations. The five-digit code used had three digits to the left of the decimal and two digits to the right. The numbers to the right of the decimal included .25, .35, .55 or .65 only. Acoustically similar numbers were not be used, nor were ascending or descending numerical sequences (e.g. 123.45). Numbers higher than one were not used in third digit to the left of the decimal. All radio frequency identifications began with "Contact" and were followed with one of three real-world air traffic control facilities (Salt Lake Center, Denver Center, or Cleveland Center). Eight numbers were chosen at random to be used for the trials: 131.55; 133.65; 122.65; 130.55; 120.35; 131.35; 122.25; 133.55.

Transponder codes. All transponder codes are four digits and the identifier of this code is the word "Squawk." The individual numbers range from 0 to 7. In this experiment, the entire code ranged from 1064 to 6132. Again, all ascending and descending number orders were avoided. Eight numbers were chosen at random to be used for the trials: 4257, 3163, 3647, 1126, 2463, 1064, 5263, 6132.

Heading Instructions. All heading instructions are three digits. In this experiment, no number higher than three was used in the second digit. The third digit in all cases ended in zero or five. The identifying word for this condition was "Fly Heading." Heading instructions did not begin with a zero, nor was there an ascending or descending number series. Eight numbers were chosen at random to be used for the trials: 120, 135, 105, 210, 110, 125, 220, 130.

Flight Level. A flight level is a three digit code which denotes altitudes above 18,000 feet and the boundaries are from 18,000-45,000 feet. Flight levels are stated

without the use of the word "thousand" and are stated as a three-number sequence (180-450). Flight levels are identified by the phrase "Climb and maintain" or "Descend and maintain." Again, an ascending or descending number series was avoided. All numbers end in zeros. Again, eight numbers were chosen at random for use in the trials: 270, 180, 310, 390, 350, 380, 130, 240.

Altitude in feet. The altitudes in feet boundaries are from 10,000 to 17,500 feet. The word "thousand" is verbalized. The same identifiers ("Climb and maintain"; "Descend and maintain") were used as in flight levels because both denote altitude. Eight numbers were chosen at random to be used for the trials: 10,000; 13,500; 16,500; 12,500; 11,500; 12,000; 13,000; 11,000.

Presentation format

The presentation format consisted of two conditions: a digit-by-digit condition or a chunked condition. All information was presented alternately. Chunked digits were presented as a pair of two-digit numbers. For example, "4273" was presented as "42," a short pause, "73." On a trial involving sequential presentation, or digit-by-digit presentation, this same transponder code was presented as "4-2-7-3."

The order of presentation was sequenced according to the balanced Latin square matrix. Each subject was given equal numbers of each of the five conditions per sequence; such as four transponder codes, four heading codes, four radio frequency codes, four flight level altitude codes and four altitude by feet codes. Of these four, two were presented chunked and two were presented digit-by-digit. Therefore, each subject heard twenty numerical codes per condition, ten of which were presented in a chunked fashion, and ten of the same which were presented in the digit-by-digit fashion (see Figure 1). The Latin square was replicated for the second half of the subject pool; in other words, half of the subjects heard the sequences in a given order and half heard the same

information in reverse order (a chunked condition before a digit-by-digit condition versus the digit-by-digit before the chunked condition). Responses given by the subject were considered correct if all the components of the numerical information were correct. That is, all digits had to be correct and in the correct order.

The recall period was carried out as follows. During the recall period of each trial, the subjects were asked to fill in the answer exactly as remembered on a response sheet. Subjects were also given a 10-minute break period during the course of the experiment in order to reduce the possibility of differential carry-over effects. The total length of the experiment was approximately 30 minutes. Therefore, the total time required for each subject was approximately 50 minutes. This included the 10 minutes required to obtain demographic information, provide verbal instructions and train subjects on four training trials.

Results

Table 1 presents the number of errors per cell as a function of retention interval, presentation type, and information type. As can be seen, overall retention of information was very good. Although analysis of variance has been used on binary (0,1) or trinary (0,1,2) data, the data set did not match the conditions for a single three-way analysis of variance to be appropriate, due to limited observations and near-ceiling performance in two cells. Therefore, three two-way analyses of variance (ANOVAS) constituted the primary statistical analyses. The number correct for each subject (0-2) for each presentation type (chunked versus digit-by-digit) at each interval (0,5,10,15s) and for each information type (radio frequency, transponder code, etc.) comprised the independent variables. The data were combined across one of the independent variables and the percent correct was calculated to provide the dependent variable for the ANOVA employing the two other independent variables. Thus,

Table 1

Number of errors per presentation type, information type and retention interval

	Chunked				Digit-by-Digit			
	Retention interval (sec)				Retention interval (sec)			
	0	5	10	15	0	5	10	15
Flight level	0	0	0	1	1	0	2	0
Heading	0	1	2	3	0	1	3	5
Altitude in feet	0	1	2	3	0	1	5	7
Transponder code	0	5	1	7	0	4	3	4
Radio frequency	0	5	10	6	3	5	8	6

the three ANOVAS were presentation type by retention interval, presentation type by information type, and retention interval by information type.

The two analyses that addressed Hypothesis 1, the effect of presentation type, were the presentation type by interval and the presentation type by information type ANOVAS. For the presentation type by interval ANOVA, neither the main effect for presentation type nor the interaction with interval was significant, $F(1,15)=2.046$, $p > .10$, and $F(3,45)=0.825$, $p > .10$, respectively (see Figure 3). Again, for the presentation type by information type ANOVA, neither the main effect nor interaction proved significant with $F(1,15)=2.05$, $p > .10$ and $F(4,60)=.505$, $p > .10$, respectively (see Figure 4). Therefore, contrary to Hypothesis 1 and previous research, no effect of presentation type was observed.

The possible effects of delay upon recall performance was addressed in Hypothesis 2. The interval by information type ANOVA is one of two analyses that evaluates this hypothesis. The main effect of interval was found to be significant with $F(3,45)=9.619$, $p < .001$ (see Figure 5). The main effect of information type was also found to be significant with $F(4,60)=8.659$, $p < .001$ (see Figure 6). The presentation type by interval ANOVA is the other analysis which evaluates the hypothesis. Again, there was a significant main effect for interval, $F(3,45)=9.619$, $p < .001$, and as described above, neither the interaction nor the main effect for presentation type was significant. Additionally, a trend analyses showed significant linear $F(1, 76)=549.16$, $p < .05$ and quadratic $F(1,76)=26.66$, $p < .05$ trends.

Hypothesis 3 predicted a significant interaction between the variables of presentation type and retention interval. The analysis did not reveal a significant two-way interaction but a significant interaction was found between message type and interval, $F(12,180)=2.415$, $p < .05$ (see Figure 7). Further exploratory analyses

Figure 3. Percent of digits recalled correctly as a function of retention interval for two presentation types.

Key:
FR= Radio Frequency FT= Altitude in Feet
TR= Transponder Code HDG= Heading
FL= Flight Level

Figure 4. Percentage of correctly recalled responses with digit vs. chunk presentation by information type.

Figure 5. Effect of retention interval on recall.

Figure 6. Effect of information type on recall.

Figure 7. Percent of digits recalled correctly as a function of information type and retention interval.

were conducted on information type because of the interaction found. The message types were ordered by the number of possible responses within the range known by professional pilots. For flight level there were 19 possible responses (11 responses presuming increments of 1,000 feet between 180-290; and 8 responses presuming increments of 2,000 feet between 290-450), and the percent correct was .98. For headings there were 72 possible responses (presuming 5 degree increments) and the percent correct was .94. For altitude in feet there were 72 possible responses (presuming 100 foot increments) and the percent correct for this message type was .93. For transponder code there were 2,401 possible responses and the percent correct was .91. Finally, for radio frequencies there were 358 possible responses (presuming .05 increments) and the percent correct was .83. As can be seen, the ordering of information types by the number of possible responses for a knowledgeable subject corresponds exactly to the ordering of information types by percent correct, except for radio frequencies. For radio frequencies, the number 1 was always the first digit and the number 5 was always the last digit. Therefore, no new information was transmitted by these digits. If primacy or recency effects operate in memory of multi-digit numbers they would not help for radio frequencies because the beginning and end were non-informative. The results show that the recall of the interior three numbers, however, have the highest incidence of errors.

Additionally, two chi-square analyses were conducted to test whether some types of errors were more common with some message types than others, and to test if some were more common with longer retention intervals than others. Four error types were predicted, namely omission, substitution, transposition, and intrusion. Only two, substitution and omission, had high enough frequencies of occurrence to be examined statistically. However, neither chi square for error type by information type nor error

type by interval were significant, $\chi^2(4, N=16)=5.74$, $p > .2$, and $\chi^2(3, N=16)=4.92$, $p > .10$ respectively. Therefore, substitution and omission were randomly distributed over interval and message type.

Discussion

Previous research in the area of short term memory has shown that chunking increases the amount of information that can be retained. Loftus (1979) has demonstrated that the retention of numerical information, such as clearance information, can be improved by chunking techniques. This study investigated pilots' retention of critical air traffic control messages such as radio frequencies, transponder codes, headings, flight levels, and altitudes in feet, to test whether recall could be facilitated using chunking techniques.

In Hypothesis 1, a main effect for presentation format was expected because the uniquely encoded, or chunked, numeric information would lead to significantly reduced rates of forgetting. This prediction was based on previous findings by Miller (1956), Simon (1974) and Loftus (1979). Neither of the two analyses testing Hypothesis 1 supported Hypothesis 1. Nor did presentation type participate in a significant interaction that might help explain the failure to support Hypothesis 1. The reasons this study failed to find the expected chunking effects might be attributed to a ceiling effect, a small sample size, or that the distractor task was not a good model for cockpit distractions. Overtraining by pilots on the digit-by-digit mode of transmission may also be a major contributing factor.

Hypothesis 2 predicted a main effect for retention intervals along with a significant linear trend. Hypothesis 2 was supported in that the interval had an effect and had a linear component to it. Just as expected, the longer the retention interval, the more the material is forgotten. The likelihood that intervals in the cockpit could cause

substantial forgetting is greatest at about 10 seconds. Material is best remembered if acted upon immediately. The fact that a ceiling effect, small sample size or an inefficient distractor task did not affect Hypothesis 2 show that, again, overtraining by pilots on the digit-by-digit mode of transmission may be the major contributing factor for the lack of a chunking effect as predicted in Hypothesis 1.

According to Hypothesis 3 an interaction was expected between presentation format and retention intervals. This interaction was not supported by the analyses. The same set of arguments applied in Hypothesis 1 also apply to Hypothesis 3.

The error analyses showed that only two kinds of errors occurred in recall and both were randomly distributed. These error types were substitution and omission. It was predicted that the error of transposition would be evident because the chunking effect was predicted to be significant. However, the error type expected from the chunking effect did not occur because no such effect was found.

The pattern of results found did fit into the broader framework of information theory, however, in that memory is best at the shortest retention interval and is better for items with less information content. The lack of difference found between the chunking and digit-by-digit modes of transmission may be attributed to the fact that average people can remember 5-7 digits of information whether this information is chunked or not. The more digits that are used, the more chunking may help. Conceivably, it is possible that not enough digits were present in order for chunking to significantly aid recall.

An evaluation of the strengths and weaknesses found in this approach indicate that information given to experienced pilots is recalled with the same accuracy whether transmitted digit-by-digit or chunked. Experienced pilots are used to the digit-by-digit transmission so the failure to get an advantage in favor of chunked transmission may be a

consequence of habits the pilot brings into the experiment. The advantages of chunking certain numeric information may be found in the training of beginning pilots, as long as phonetic confusions are eliminated.

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Appendix A

APPROVED BY THE MASTER'S THESIS COMMITTEE

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APPROVED BY THE DESIGN AND ANALYSIS COMMITTEE

Appendix B

Mean demographics

Subjects (n=16)		
	Mean	SD
Age	37	6.460
Total Flight Hours	6,618.75	2,980.20

Appendix C

Verbal Instructions

You will be participating in a memory experiment in which you will be asked to listen and to repeat aloud various air-traffic control messages. The computer will show you a screen message and give instructions. Your task is to listen to the message and repeat it exactly as presented. For some trials you will be asked to verbally put a list of words presented on the screen in alphabetical order. Then you will be asked to recall the entire message you heard earlier and to write it on the response sheet provided. It is important that you repeat aloud both the message and the alphabetizing tasks each time. The first session will last about fifteen minutes, and then you will be given a ten minute break. Upon your return, you will receive another session similar to the first.

Appendix D

Distractor Tasks Examples

1. garter asp cobra viper python rattler moccasin sidewinder coral seasnake
2. orange apple melon grape pear kiwi pineapple raisin date strawberry
3. heel pump sneaker sandal boot thong moccasin slipper rubber snowshoe
4. America Columbia Africa Canada England Asia Australia Mexico Greenland Iceland
5. Bogata Miami London Paris Berlin Brisbane Madrid Winnipeg Columbus Seattle
6. Washington Adams Roosevelt Jefferson Nixon Bush Reagan Truman Carter Kennedy
7. rhesus gorilla chimpanzee orangutan squirrel ape langur spider baboon macaque
8. Betty Carla Maureen Candy Mabel Sandra Elizabeth Donna Anne Carolyne
9. shepherd hound beagle terrier setter daschund huskie rottweiler collie greyhound
10. manx persian calico tom stray tabby siamese burmese himilayan balinese