A Study on Forward Digit Span Test

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Contents

1 General Problem

In this practical, the general problem is to study on memory. Particularly we will study about the short term memory here, i.e. the capacity of a person for holding a small amount of information in mind in an active, readily available state for a short period of time.

2 Specific Problem

We are interested here to determine short-term memory span using customized Forward Digit Span Test of a few selected subjects on the basis of age, gender, educational qualifications etc.

3 Basic Concept

3.1 Multi-Store Model of Memory

Two American Psychologists- Atkinson and Shiffrin suggested a three store structural multi-store model for memory. The first, called the sensory memory, where the inputs from the sensory organs is stored for a very small time in it's preliminary form before it is passed on to the next part, called short-term memory or STM. STM was assumed to be a temporary storage system that holds material just long enough for it to be processed; the capacity of this temporary store is very small. Once processing in this first store is completed, the coded material would be transferred to a more permanent store called long-term memory, or LTM. This model explained many of the memory related data so successfully that is soon became the modal model.

3.1.1 Sensory Memory

During every moment of an organism's life, sensory information is being taken in by sensory receptors and processed by the nervous system. Sensory information is stored in sensory memory just long enough to be transferred to short-term memory. Humans have five traditional senses: sight, hearing, taste, smell, touch. Sensory memory (SM) allows individuals to retain impressions of sensory information after the original stimulus has ceased. A common demonstration of SM is a child's ability to write letters and make circles by twirling a sparkler at night. When the sparkler is spun fast enough, it appears to leave a trail which forms a continuous image. This 'light trail' is the image that is represented in the visual sensory store known as iconic memory. The other two types of SM that have been most extensively studied are echoic memory, and haptic memory.

It is the first stage of the Modal Model.The SM do not process the information carried by the stimulus, but rather detect and hold that information for use in STM. For this reason Atkinson and Shiffrin also called the registers 'buffers', as they prevent immense amounts of information from overwhelming higher-level cognitive processes. Information is only transferred to the STM when attention is given to it, otherwise it decays rapidly and is forgotten.

The short-term memory gives us access to information that is salient to our current situation, but is limited in its capacity. Therefore, we need to further rehearse information in the short-term memory to remember it for longer. This may involve merely recalling and thinking about a past event, or remembering a fact by rote - by thinking or writing about it repeatedly. Rehearsal then further promotes this significant information to the long-term memory store, where Atkinson and Shiffrin believed that it could survive for years, decades or even a lifetime.

Iconic Memory Iconic memory, which is associated with the visual system, is perhaps the most researched of the sensory registers.Iconic memory is only limited to field of vision. That is, as long as a stimulus has entered the field of vision there is no limit to the amount of visual information iconic memory can hold at any one time. As noted above, sensory registers do not allow for further processing of information, and as such iconic memory only holds information for visual stimuli such as shape, size, color and location (but not semantic meaning). As the higher-level processes are limited in their capacities, not all information from sensory memory can be conveyed. It has been argued that the momentary mental freezing of visual

input allows for the selection of specific aspects which should be passed on for further memory processing. The biggest limitation of iconic memory is the rapid decay of the information stored there; items in iconic memory decay after only 0.5-1.0 seconds.

Echoic Memory Echoic memory refers to information that is registered by the auditory system. As with iconic memory, echoic memory only holds superficial aspects of sound (e.g. pitch, tempo, or rhythm) and it has a nearly limitless capacity. Echoic memory is generally have a a duration of between 1.5 and 5 seconds depending on context but has been shown to last up to 20 seconds in the absence of competing information.

3.1.2 Short Term Memory

Short-Term Memory (STM) is the capacity for holding, but not manipulating, a small amount of information in mind in an active, readily available state for a short period of time. The purpose of the STM was to allow preliminary processing of information. Items held in the short-term memory decay rapidly over time; Atkinson and Shiffrin estimated that all trace of a word placed in STM will normally be lost within 30 seconds. For as long as an item resides in STM, however, there is a tendency to transfer it to the long-term memory(LTM); the longer an item is resident in STM, the greater the likelihood that a copy will be transferred to LTM. And once information is transferred to LTM, it is likely to be held there permanently.

The STM was itself fed by a series of sensory registers from sensory memory. These registers acted as a system for selecting and collating sensory information ormation, which could be viewed as an essential component of perception. It reflect faculties of the human mind that can hold a limited amount of information in a very accessible state temporarily. One might relate short-term memory to a pattern of neural firing that represents a particular idea and one might consider the idea to be in short-term memory only when the firing pattern, or cell assembly, is active.

Duration As with sensory memory, the information that enters short-term memory decays and is lost, but the information in the short-term store has a longer duration, approximately 18 to 20 seconds when the information is not being actively rehearsed, though it is possible that this depends on modality and could be as long as 30 seconds. Fortunately, the information can be held in the short-term store for much longer through what Atkinson and Shiffrin called rehearsal. For auditory information rehearsal can be taken in a literal sense: continually repeating the items. However, the term can be applied for any information that is attended to, such as when a visual image is intentionally held in mind. Finally, information in the short-term store does not have to be of the same modality as its sensory input. For example, written text which enters visually can be held as auditory information, and likewise auditory input can be visualized. On this model, rehearsal of information allows for it to be stored more permanently in the long-term store. Atkinson and Shiffrin discussed this at length for auditory and visual information but did not give much attention to the rehearsal/storage of other modalities due to the experimental difficulties of studying those modalities.

Capacity There is a limit to the amount of information that can be held in the STM: 7 ± 2 chunks. These chunks, which were noted by Miller in his seminal paper The Magical Number Seven, Plus or Minus Two, are defined as independent items of information. It is important to note that some chunks are perceived as one unit though they could be broken down into multiple items, for example '1066' can be either the series of four digits '1, 0, 6, 6' or the semantically grouped item '1066' which is the year the Battle of Hastings was fought. Chunking allows for large amounts of information to be held in memory: 149283141066 is twelve individual items, well outside the limit of the STM, but it can be grouped semantically into the 3 chunks [1492][8314][1066]. Because short-term memory is limited in capacity, it severely limits the amount of information that can be attended to at any one time.

3.1.3 Long Term Memory

Long-Term Memory(LTM) is is the stage of the AtkinsonâShiffrin memory model in which informative knowledge is held indefinitely. It is defined in contrast to short-term and working memory, which persist for only about 18 to 30 seconds. Long-term memory is commonly labelled as explicit memory (declarative), as well as episodic memory, semantic memory, autobiographical memory, and implicit memory.

The LTM is concerned with storing information over extensive periods of time and fed by a STM that acted as a controller, feeding in new information and selecting particular processes for pulling information out of the LTM. It is a vast store of knowledge and a record of prior events, and it exists according to all theoretical views; it would be difficult to deny that each normal person has at his or her command a rich, although not flawless or complete, set of long-term memories.

Transfer from STM Information is postulated to enter the LTM store from the STM more or less automatically. As Atkinson and Shiffrin model it, transfer from the STM to the LTM is occurring for as long as the information is being attended to in the STM. In this way, varying amounts of attention result in varying amounts of time in STM. Ostensibly, the longer an item is held in STM, the stronger its memory trace will be in LTM. Repeated rote repetition enhances LTM. Forgetting increases for items which are studied fewer times. There are stronger encoding processes than simple rote rehearsal, namely relating the new information to information which has already made its way into the LTM.

Capacity and Duration In this model, as with most models of memory, LTM is assumed to be nearly limitless in its duration and capacity. It is most often the case that brain structures begin to deteriorate and fail before any limit of learning is reached. This is not to assume that any item which is stored in LTM is accessible at any point in the lifetime. Rather, it is noted that the connections, cues, or associations to the memory deteriorate; the memory remains intact but unreachable.

3.2 Digit Span Test

3.2.1 Definition & Importance

A digit-span task is used to measure STM's number storage capacity. Participants see or hear a sequence of numerical digits and are tasked to recall the sequence correctly, with increasingly longer sequences being tested in each trial. The participant's span is the longest number of sequential digits that can accurately be remembered. Digit-span tasks can be given forwards or backwards, meaning that once the sequence is presented, the participant is asked to either recall the sequence in normal or reverse order. Digit-span tasks are the most commonly used test for memory span, partially because performance on a digit-span task cannot be affected by factors such as semantics, frequency of appearance in daily life, complexity, etc

Verbal working memory is involved in many everyday tasks, such as remembering a friend's telephone number while entering it into a phone and understanding long and difficult sentences. Verbal working memory is also thought to be one of the elements underlying intelligence (often referred to as 'IQ,' meaning 'intelligence quotient'); thus, the digit span task is a common component of many IQ tests, including the widely used Wechsler Adult Intelligence Scale (WAIS). Performance on the digit span task is also closely linked to language learning abilities; improving verbal memory capacities may therefore aid mastery of a new language.

One of the earliest measures of STM was digit span, the longest sequence of numbers that can be immediately repeated back in the correct order. People vary in their span, but it is usually around seven digits or five random letters.

3.2.2 Classification

Digit Span Test can be classified into two types :

- **Forward Digit Span:** Once the sequence is presented, the subject is asked to recall the sequence in given order.
- **Backward Digit Span:** Once the sequence is presented, the subject is asked to recall the sequence in reverse order.

In this project, we have worked on the Forward Digit Span only, which helps us in assessing a person's short-term memory capacity.

3.2.3 Advantages

- It is very simple test and doesn't require any special setup apart from a silent environment and test subject.
- It serves as a part of assessing the IQ of the subjects. Higher values indicate higher remembering capacity.
- It is an effective method in finding out the Short Term Memory capacity of subjects and the findings are reliable.
- Computer and mobile versions of the test eliminate examiner differences and increase the inter-rater reliability.
- The digit sequence shows a superiority effect when compared to any non-digit span, and the Digit Span test is a preferred method to measure one's cognitive functioning.

3.2.4 Disadvantages

- It is criticised for being artificial in nature.
- This experiment is not the representative for the kinds of STM we do in everyday life.
- It is an effective method in finding out the Short Term Memory capacity of subjects and the findings are reliable.
- It lacks temporal validity i.e. findings may not generalize to modern times as it was devised almost a century ago.

4 Preliminaries

4.1 Subject Characteristics

We have collected information from the subjects regarding Age, Sex, Educational level, Profession, Academic Performance, Mathematical Background, Musical Background and Current Surroundings. These are necessary for further studies on Digit Span. We have used snowball sampling (or, Chain-referral Sampling) to collect data from 20 individuals, which is defined to be a non-probability sampling procedure in which the samples have traits or characteristics that are necessary for research purposes. Here a summary of the information which were collected from the subjects:
(1) Age: The average age of the subjects was found out to be approximately 22.4. The range of ages was 19 years - 51 years.
(2) Sex: Among the 36 subjects, it was observed that 31 were males, and the rest (5 in number) of the subjects were females.
(3) Educational level: We have categorized the educational qualifications of the subjects in the following manner:
• School and 12th Grade
• Pursuing Bachelors(or last completed degree is Bachelors)
• Pursuing Masters or PhD(or last completed degree is Masters or PhD)
(4) Professional Background: The following categorization is made:
• Working in Academia
• Working in Industry, Business, etc
(5) Mathematical Background: The following categorization is made:
• Mathematics Oriented
• Non-Mathematics Oriented
(6) Musical Background: The following categorization is made:
• Music Oriented: Plays musical instrument.
• Non-Music Oriented: Does not play musical intrument.

(5) Current Surrounding: The following categorization is made:
• Silent or Normal surrounding
• Noisy or very Noisy surrounding
(6) Academic Performance: The following categorization is made:
• Poor Performance
• Neutral Performmance
• Good Performance

4.2 Customized Digit Span Test

We have used R code to generate random numbers for the test. We have followed some specific rules for the Digit Span Test, unlike the general Digit Span Test, which are mentioned later.

5 Test

5.1 Description

In the experiment, independent variable is the 2 sets of Digit Span tests, and the dependent variable is memory span. The digits of each number (i.e. the whole number itself) were generated randomly to reduce bias, following all the rules of Customized Digit Span Test. We have used the "sample" function in R for the task of generation of the random numbers with lengths in strictly increasing order.

5.2 Rules for Construction

- In a number, consecutive digits should be different.
- In a number, consecutive gaps between two digits must be different.
- First digit of a number will not come at end of the previous number.
- We have to generate random numbers of lengths in strictly increasing order.

5.3 Scoring

- Once the test is started, the numbers will begin to appear on the screen. Each number shown on the screen is wiped out after exactly 1.5 seconds of displaying. The first number can be considered as a trial.
- If the subject guesses the correct number, then he/she is shown the next number with a digit more than the previous one.
- If the subject makes a wrong guess, the test is still continued. However, as soon as the second mistake is made in the same round, the test is stopped there. The number of digits of the last correctly guessed number is noted automatically by the R program.
- Each subject is tested twice with the help of the R Program. The Digit Span of the subject, i.e. the average the outputs of the 2 tests, is returned as the output of the program.

6 Procedure

6.1 Data Collection

In order to increase variability in the data, we have collected data from various age ranges, mathematical, musical, professional backgrounds, different educational levels and from both males and females.

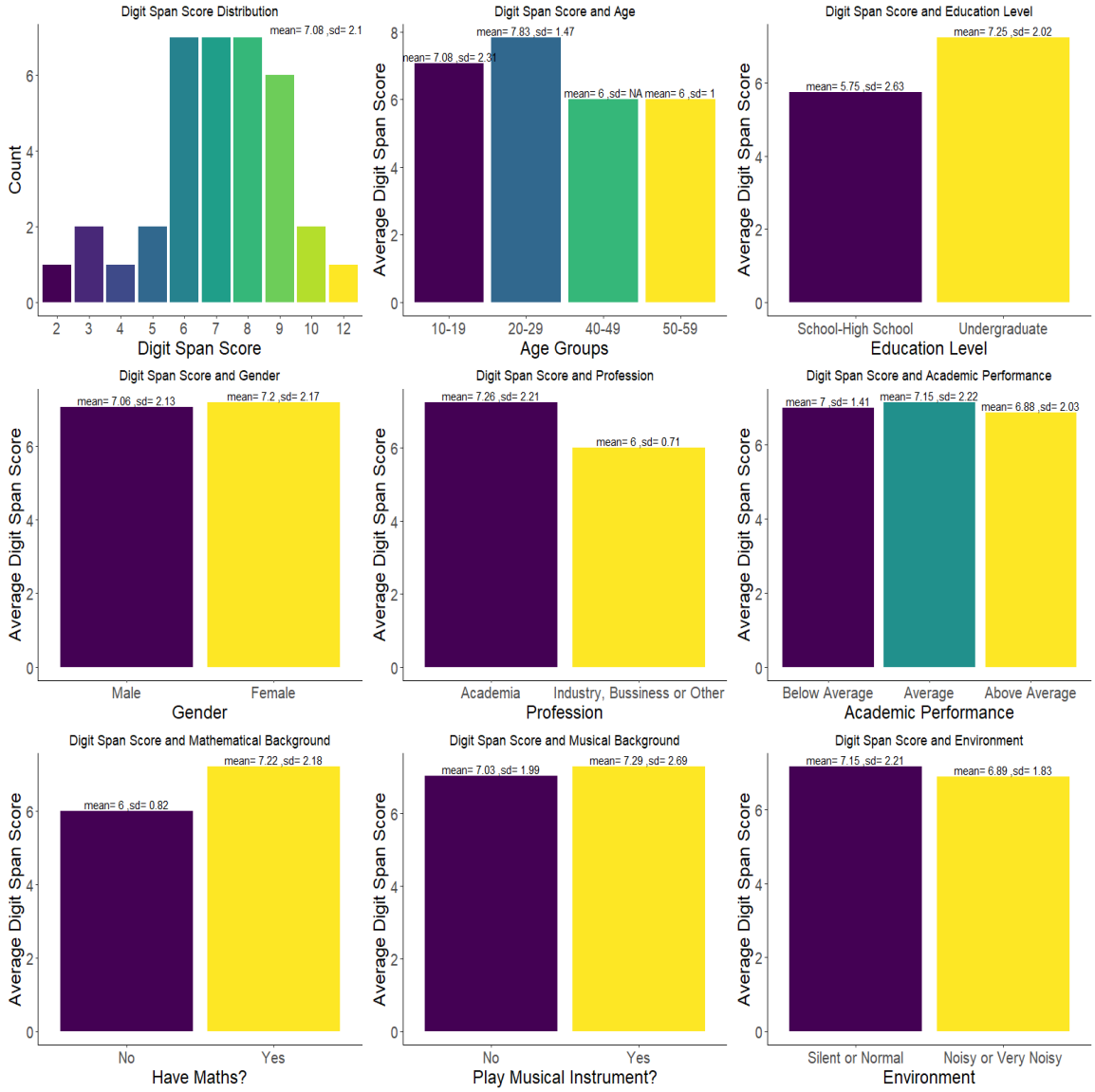
6.2 Statistical Analysis

We have used descriptive statistics like central tendency, and variability statistics like measures of dispersion (e.g. Standard Deviation, Variance etc.) to study the average digit spans of the subjects and their variations. The average digit spans were determined with differences in age, sex, and educational level, mathematical background, academic performance, etc..

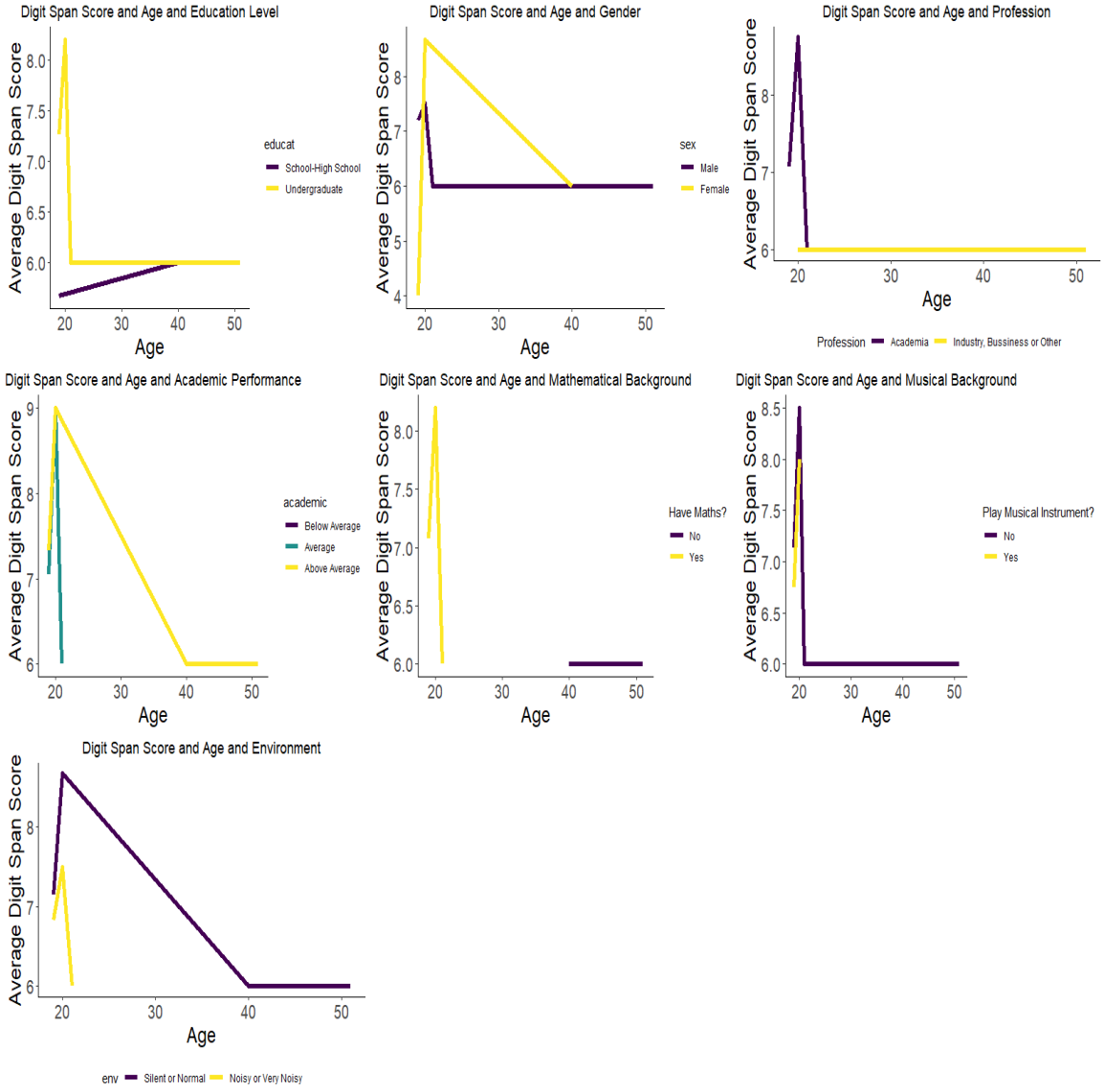
6.3 Control

- There must not be any noise during the test.
- In case of any anxiety or discomfort of the subject, the researcher may try to reduce the subject's tension or anxiety by proper verbal communication, else should not continue the test.
- Students may be used as subjects, as they are expected to have a greater short-term memory capacity.
- People with psychological disorders (e.g. ADHD) and mentally challenged people should not be used as subjects.

7 Results & Interpretation



- We observe the digit span score is centered at 7 approx. with a standard deviation of 2 approx.
- The Digit Span Score is observed to decrease with increase in age
- Digit Span Score is observed to increase with Education Level and Academic Performance.
- Females are observed to have slightly higher digit span score than males
- People with Mathematical Background or Musical Background have higher Digit Span Scores
- People who took the test in a silent environment performed better.



- Similar observations as the above ones in seen from the above graphs as well.

8 Conclusion

Considering the current situation, the provision of collecting data (i.e. implementing the experiment) from different subjects was quite difficult. So the number of subjects who participated in the test is 36, which is a quite small sample to work with. We may summarize our whole experiment by saying that our age, education, gender, mathematical or musical background and academic performance, etc. influence our memory span, and hence they are some controlling factors of our short-term memory capacity. From our analysis, it seems that as age increases, digit span decreases ; as our more formal education implies better short-term memory ; and females have possibly better short-term memory than males.

9 References

- Wikipidea Page - Short Term Memory
- Wikipedia Page - Long Term Memory

- Wikipedia Page - Memory Span
- Book - Essentials of Human Memory(Psychology Press) Alan D. Baddeley
- Book - Human Learning and Memory(Cambridge University Press) David A. Lieberman

10 R Codes Used & Data Collected

10.1 R Codes for the Experiment

Visit My Repo for R Codes and Instructions.
Also kindly consider taking the test on the test portal I developed at Digit Span Test and using the freely available and collected data in your analysis with proper citing.

10.2 Collected Data

The following 4 files contains all the possible aspects of data collected from the individuals.

- Basic Information of the Subjects
- The Digit Sequence shown