Working Memory Span in Sequential and Non Sequential Digital and Word Stimuli of Jordanian Students 4 through 20 Years Old

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Abstract: The study goal was investigating working memory span of students in Jordan from four to twenty years old, in digital and word sequential and non-sequential recalling tasks, and comparing them with the western working memory span criteria. A Sample of 510 participants, from kindergarten to college students participated in the current study. Two digital and word instruments were developed to assess the memory span, each of them has two versions; one for sequential, and the other for non-sequential recalling tasks. Memory span for each individual is defined when he/she cannot retrieve the digits, or the words written on a card. His /Her score represented by the last successful answer. Results indicated that means of the working memory span increases by age. Non sequential memory span was larger than sequential. Jordan students memory span, in general, were higher than the western working memory span, especially in adulthood. This result, perhaps, is due to culture factors which emphasize memorizing.

Introduction

Learning is defined by cognitive theorists as a change in a person's mental structures that creates a capacity to demonstrate different behaviors. This change happens when certain stimuli, which enters our memory systems, is selected and organized for storage and retrieval (Eggen & Kauchak, 2007). Memory, which is the retention of information over time, has a great effect on a person's life, because it is the storage of all his experiences and knowledge to a degree that it can be said, personality is nothing but memory storage.

Memory Storage

Memory storage involves three types of memory: Sensory, working, and long term memory. Although all memory types are important because they work in an integrated way, the current study focuses on working memory, or as it is also called, the short - term memory. Working memory is defined as the ability to manipulate and store material simultaneously (Gathercole, 1999). It is a store that holds information as a person processes it, consciously, with a deliberate thinking. That is, while anyone is not aware of the contents of either sensory or long term memory until they are pulled
into working memory for processing. Information in the working memory is retained for nearly thirty seconds, unless it is processed further. Its capacity, known as memory span, is limited in the range of 7±2 items (Gage & Berliner, 1998; Santrock, 2008; Woolfolk, 2005).

**Working Memory**

The standard working memory model comprises three components: The central executive, phonological loop, and the visuospatial sketchpad. The latter two specialized for processing of limited amounts of information within specific domains. The central executive is capable of performing a range of high - level functions, like coordination of tasks performance, switching retrieval plans, controlled attention and maintenance of activated information from long term memory (Cowan, 2008). In a study of working memory content and functions capacity–facets, Obrauer, Sub, Shulze, Whilhelm & Wittmann (2000) found that spatial working memory content was distinct from verbal and numerical content; and at the functional dimensions: storages, transformation and coordination could not be separated. Corbin, McElroy, & Black (2010) found that a wide working memory span enables deeper information processing, in a study on eighty six participants took risky – choice tasks.

**Studies Review**

Studies about working memory, found also, that working memory span increases during the age of 8 through 24 years in both verbal and visual tasks (Papalia & Feldman, 2000; Swanson, 1999; Towse, Hitch, Hamilton, & Pirre, 2008). In these studies, verbal tasks were auditory digit and semantic association, while visual tasks were a map of a street, and a matrix of dots. Another study found that memory span increased from two digits by the age of 2 years, to five by the age of 7, and between six and seven by the age of 12 years (Dempaster, 1981; Gathercole & Peckering, 2000).

In another study examined the effect of verbal and nonverbal stimuli on auditory sequential, results showed that verbal sequences were produced with more accuracy than were nonverbal sequences (Jutras, Ostroff, Roy, & Gagne, 2003). These results also supported by Speech (2008) who found that recalling words is better than digits, in dual-task performance.

Research showed that memory function can be affected by several factors. For example, Philipose, Alphs, Prabhakaran, & Hills (2007) demonstrated that left cortical stroke patients had a verbal working memory impairments, and right cortical stroke patients had both verbal and spatial working memory impairments. Working memory is also affected negatively by bad emotional feelings (Grays, 2001). Students can improve their working - memory efficiency, and writing rapidly if they ignore grammar and punctuation which elicit anxiety, and reduce cognitive load. Some strategies can be used to overcome the limitations of working memory, like chunking, which is a mental process that combines separate items into larger units (Woolfolk, 2005).

In another experiment, participants were presented with a matrix of twelve letters for a very brief period of time. They were asked to remember only the top, middle, or bottom lines of the matrix. Results showed that participants were only capable of recalling three or four numbers (Sperling, as cited in, Salkind & Rasmussen, 2008).

Improving working memory was demonstrated in two experiments, on 59 and 119 college students, when their recall for peripheral and central details was enhanced with repeated retrieval, by using negative valence slides (Hauer, Wessel, Merckelbach, Roefs, & Dalgleish, 2007).
Testing verbal memory can tell about some brain diseases, and provides early detection, as in the case of Alzheimer's disease. This was supported by a Meta-analysis of 31 studies that included 1144 patients with Alzheimer's disease and 6046 healthy participants. Wechsler Adult Intelligence Scale (WAIS) was used to assess digit span (Boules & Zakzanis, 2002). Javid (2000) found in a study on 19 school-age children with language impairment and matched normal peers, that as working memory span increased, reticence decreased, and both likeability and pro-social skills increased.

Reviewing the previous studies shows that there is scarcity in non-sequential and cross-cultural studies in the memory field. This study aimed at comparing the results of working memory span of Jordanian students, with corresponding results of western culture studies in the same field. The non-sequential task depends on a general educational principle that an answer is right, or partially right, when the answer or response contains all or most of its elements, without considering their sequence. This principle is considered in the light of the assessment objectives, and what is happening in real life – situations.

The Study Questions
The purpose of the current study was to answer the following questions:

1. What are the means of working memory span of participants of ages 4 to 20 years old, on digital and word sequence and non-sequence recalling tasks?
2. Are there significant differences between the means of working memory span on digital and word sequence and non-sequence recalling tasks of participants two groups (4 – 11 and 12 – 20) years old?
3. Are there significant differences among means of working memory span across ages 4 to 20 years, on digital and words sequence and non-sequence recalling tasks?
4. Are there significant differences between Jordanian sample means of working memory span and their western corresponding means in both digital and words sequence recalling tasks?

Methodology
Participants
Participants in the current study were (510) individuals, distributed in subgroups aged 4 through 20 years, thirty for each year old, with equal number of males and Females, chosen from kindergartens, elementary and secondary schools, and the Hashemite University, in Zarqa city of Jordan.

Procedure
Three classes of senior university students participated in data collecting, as a field team. A number of (162) senior counseling students, and (58) child care students, were enrolled in a course of research methods in education and psychology. In this course, students were trained to choose a suitable problem for each kind of research method, write a short proposal, develop tools, such as: questionnaires, check-lists, interview schedules; as well as, research ethics.

Research method references in psychology and education, such as, Kerlinger, 1973; Goodwin, 2008; and Coolican, 2009, do not mention any limited number for data-collectors. They only emphasize on their training and research ethics.

Data-collecting training
A special training for data collectors was given. Each of the course instructors did as a model, by applying the tool, on two volunteer students, and recording the data, before the students in the laboratory,
to show them the testing procedure.

Then as a practicum exercise, each class was divided into groups of (3) students. Each student in the group tested the other (2) respectively, and shared in recording the responses. They worked as a team in their training, and corrected each other when there was a necessity. They repeated their training till they got 80% inter-observer reliability as a minimum level, which is an accepted level of agreement, compared with 76.6% of Halliday’s and Lesile’s study in 1986 (cited in Coolican, 2009).

By this procedure, the field team had the experience as data collectors, and participant subjects. Each one of them applied the experiment on two to three available subjects of a certain age. All these activities, and field data collecting, were done under the course instructors'/researchers’ supervision, who were part of the current study team researchers, to achieve the ethical research principles: fidelity, integrity, and competence (American Psychological Association, 2010).

Instruments

Working memory is typically tested by varying sequence length of words, numbers, visual objects, etc., all embedded within processing episodes. This yields working memory span, the number of items remembered when completing some mental operations (Papalia & Feldman, 2000; Speech, 2008; Towse, Hitch, Hamilton, & Pirre, 2008).

For the purpose of the current study two instruments; word and numeric were developed.

Word Instrument - The first instrument consisted of words, collected by a pilot study on 100 participants of age 4-20 years old and not from the sample of the current study. They were asked to give five names of usual things. A list of three hundred and twenty words was generated and ordered from first to last, according to their frequency.

The first fifty words were chosen to be the bank from which words for the eighteen cards were chosen randomly. The words are:


The first card started with two words chosen randomly from the list of the fifty words. The second card consisted of three words, and the other cards consisted of words from four to eighteen. Two versions of the word instrument; A and B, were created for the sequence, and non-sequence tasks.

Digital Instrument - The numeric instrument consisted of numbers from one – nine, randomly chosen for the eighteen cards. Card no.1 holds two digits; card no.2 holds three digits, and so on. Two versions of the digital instrument; A and B, were created for the sequence and the non-sequence tasks.

Validity - Face validity for the words and digital instruments was done by a jury of eight faculty members at the college of educational sciences in the Hashemite University.

Reliability - A retest after fifteen days was administered on a sample of twenty college students and twenty high school students. Pearson's correlation was computed between first and second scores application. The correlation coefficients were: 0.85 for the word instrument, and 0.82 for the digital instrument, on the non-sequence tasks, and 0.81 for the word instrument, and 0.80 for the digit instrument, on the sequence task.

Instruments Administration - Each data collector administered the
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instruments on two – three participants individually, defined for him/her according to age and gender, in an empty class-room. Cards were read for children participants from age 4 – 8 years old. The other participants read the cards themselves, and then asked to recall their contents as follows:

1. Recalling without sequence.
   The first card from version A of the digital instrument was presented to the participant for three seconds, and then he/she was asked to recall the content. The answer was considered right if he/she recall the numbers, even without sequence. Then, the second card was presented, and if the recall was right, the third card would be presented, until the participant failed to recall the content correctly. At this point the trial was ended, and the administrator recorded the last successful trial as a short term memory span. For version A of the word instrument, the same procedure was applied.

2. Recalling with sequence:
   The administrators applied the above procedure for version B digital and word instrument, except that if a participants recalled the card content with wrong sequence, his/her answer was considered wrong.

Results

To answer the first research question “What are the means of working memory span of participants of ages 4 to 20 years old, on digital and word sequence and non-sequence recalling tasks?” means and standard deviations were computed. Means increase, and reveal a developmental trend across different ages. At age 4 the means of working memory span were: four in recalling digits without sequence; two in digits with sequence; six in words without sequence; and two in words with sequence. Means become fifteen at the age of 20 in recalling digits with non-sequence; eleven in recalling digits with sequence; sixteen in words non sequential recall, and nine in words sequential recall.

To answer the second research question, “Are there significant differences between the means of working memory span on digital and word sequence and non-sequence recalling tasks of participants two groups (4 – 11 and 12 – 20) years old?”, one-way ANOVA was performed. (See Table 2 show significant differences across ages in both digits and words sequence and non-sequence recall).

To answer the third research, “Are there significant differences among means of working memory span on digital and word sequence and non-sequence recalling tasks of participants two groups (4 – 11, and 12-20 years old)?” one-sample t-test statistics was performed. (See Table 3 shows statistical differences between means of working memory span of digits and words in sequential recall for both groups: 4-11, and 12-20 years old). The differences appear in table 3 indicate that recalling in sequence is in favor of the digits for all age groups.

To answer question four, “Are there significant differences between Jordanian sample means of working memory span and their western corresponding means in both digital and words sequence recalling tasks?” one-Sample t-test was performed. Table 4 shows significant mean differences between Jordanian students’ working memory at the age (4-12), and the western criterion mean of 5, in favor of the former. The result in word sequence recalling is different; it is in favor of the western criterion. Means differences in both digital and words sequence recalling of the youth group (13-20) were in favor of Jordanian students, as compared with the western criterion.

Discussion

Results of the current study confirmed that working memory span increases as the human being grows from
early childhood to adulthood (Broadly, McDonald, & Buckley, 1995; Santrock, 2008; Swanson, 1999). This development is a result of the interaction between maturation and environment. The developmental cognitive theories, like Piaget confirms this fact, with a growing ability to do more complicated information processing. Results also confirmed that recalling of any content, digital or words, from short term memory, without a condition of retrieving content in sequence, makes the memory span wider. This kind of evaluation depends on an educational logic, which considers the answer right, if it contains all the basic elements of the examined subject, and in some cases, even if the basic elements are not mentioned completely.

The results also indicated that there is a tendency of retrieving words better than digital numbers in non-sequential retrieving. The cause of this result may be due to the fact that words contain meaning, as well as, this meaning, makes it easier to chunk words into sequences, which leads to a more successful recall (Eggen, &Kauchak, 2007). But the result was different in words sequence retrieving. This results, perhaps due to an easier chunking with digital numbers. This result needs more investigation.

Another result in the current study is the wider working memory span among Jordanian students, in general, than that of western studies results. If we take the mean of the working memory span in the current study for the ages 16-20, it refers to 10±2 in word recall, and 9± in digital recall. These means are higher than what the references cite, which is 7± 2. This can be attributed to the culture of Jordan, which requires developing greater skills in encoding oral information, perhaps more than the western cultures do, as what Ross and Millson found in their study, in which they compared Ghanian and American college students’ memory (cited in Huffman, 2007).

**Recommendations**

It can be recommended that in related future research, a compound and complex stimuli have to be investigated, with non-sequential approach, and accepting some subtraction and addition in recalling answers. A cross-cultural comparison in all functions of the three memory storages can be done, to reveal the effect of culture.

**References**


Table 1:
Means and Standard Deviations of Working Memory Span across Ages from 4 – 20 Years old in Retrieving Digits and Words in Sequence and Non-Sequence Tasks

<table>
<thead>
<tr>
<th>Age</th>
<th>Digits-1 M</th>
<th>Digits-1 SD</th>
<th>Digits-2 M</th>
<th>Digits-2 SD</th>
<th>Word-1 M</th>
<th>Word-1 SD</th>
<th>Word-2 M</th>
<th>Word-2 SD</th>
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<td>1.64</td>
<td>9.10</td>
<td>1.52</td>
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Note: M= Mean, SD= Standard Deviation, no. 1=sequence, no. 2=non-sequence
Table 2.
One-Way ANOVA: Testing Differences across Ages in Digital and Words Sequence and Non-Sequence Recalling

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sources of variance</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F value</th>
<th>Sig.</th>
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<td></td>
<td>Within Groups</td>
<td>1346.767</td>
<td>493</td>
<td>2.732</td>
<td></td>
<td></td>
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<tr>
<td>number2</td>
<td>Between Groups</td>
<td>2966.541</td>
<td>16</td>
<td>185.409</td>
<td>6.633</td>
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<td>word1</td>
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Table 3.
One-Sample T-Test: Testing Differences between Means of Working Memory Span of Digits and Words for Age Groups (4-11 and 12-20) Years Old

<table>
<thead>
<tr>
<th>Group</th>
<th>Variables</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Test Value</th>
<th>t value</th>
<th>Sig.</th>
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<tbody>
<tr>
<td>4-11</td>
<td>Digital</td>
<td>270</td>
<td>5.38</td>
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<td></td>
<td>Words</td>
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<td>2.01</td>
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<td>12-20</td>
<td>Digital</td>
<td>240</td>
<td>9.15</td>
<td>1.77</td>
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<td>18.79</td>
<td>0.000</td>
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<td></td>
<td>Words</td>
<td>240</td>
<td>8.06</td>
<td>1.76</td>
<td>7</td>
<td>9.31</td>
<td>0.000</td>
</tr>
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</table>

Table 4.
One-Sample T-Test: Testing Differences between Jordanian Students’ Working Memory Span and Western Criterion Working Memory Span

<table>
<thead>
<tr>
<th>Age</th>
<th>Variables</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>T value</th>
<th>Sig.</th>
</tr>
</thead>
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<td>5.38</td>
<td>2.39</td>
<td>2.597</td>
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<td></td>
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<td>1.76</td>
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</table>

Note: (1)-Children means compared with 5; Youth means compared with 7.(2)- N= number of cases; M= mean, SD= standard deviation.
Figure 1: Shows the relationship between age and recalling digits with non-sequence.

Figure 2: Shows the relationship between age and recalling digits with sequence.
Figure 3 - Shows The Relationship Between Age And Recalling Words With Non-Sequence.

Figure 4 - Shows The Relationship Between Age And Recalling Words With Sequence.