A Behavioral Experimental Study on Verbal Working Memory Capacity Differences Induced by Positive and Negative Emotions

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Abstract. The purpose of this study is: Firstly, to explore the influences of different emotion states on verbal working memory capacity by experiment. Secondly, to put forward advices for classroom education and student learning basing on the experiment results, so as to improve the efficiencies of students in learning and teachers in teaching. This study experimentally investigated the working memory capacity differences of 90 college students under positive, negative, and neutral emotion states based on two parts: emotional arousal and verbal working memory capacity test. Firstly, the positive, neutral, and negative emotions of the subjects were aroused by watching three videos. Then operation-word span test was performed on the subjects using a program compiled by E-prime2.0 to measure the verbal working memory span of the subjects. In accordance with the number of words recalled by the subjects, the verbal working memory capacities of the subjects were assessed. The experimental results suggested that: the subjects in emotion state of joy presented significantly higher verbal working memory span than those in calmness; the subjects in emotion state of calmness showed significantly higher verbal working memory span than those in sadness; the subjects in emotion state of joy showed significantly higher verbal working memory span than those in sadness. The innovation of this research is mainly reflected in its research direction, namely, a specific aspect of working memory.

Introduction

Significances

Working memory acts as an indispensably important link in working and learning. In recent years, as the deepening of research on working memory, people are beginning to realize the correlations of student’s academic record differences with knowledge level and working memory [1]. Verbal working memory, mainly referring to the processing and storage of the information related to written and oral language, exerts significant impacts on the reading and understanding of words and sentences etc.. The processing of environmental information is always accompanied with emotion, while emotion is intertwined and interacted with cognition constantly [2]. Since emotion exerts great influences on people's behavior and cognitive activities, exploration on the influences of emotion on verbal working memory is of great significances to improve life and learning efficiencies.

Purposes

Firstly, to explore the influences of different emotion states on verbal working memory capacity by experiment. Secondly, to put forward advices for classroom education and student learning basing on the experiment results, so as to improve the efficiencies of students in learning and teachers in teaching.

Concepts

The Span of Verbal Working Memory Capacity. In 1950s, Miller experimentally found that short-term memory was spanned by 7±2 chunks. Although working memory is a kind of short-term memory, it is far from short-term memory in capacity due to the tasks it takes: the storage and
processing of information. In a study named by “Recognition on mental storage capability: the magic number 4”, Cowan argued that Miller exaggerated human’s working memory span and pointed out that the span should be 4 in average [3].

**Emotion.** Emotion, the subjective experiences to external stimulus, has direct influences on human behavior. In the 3D theory of emotion proposed by Wundt, emotion is considered to be constituted by three dimensions, including pleasure vs. displeasure, excitement vs. calmness, and tension vs. relaxation. Moreover, emotions distribute on different points of the three dimensions according to their composition and intensity differences. In this study, three emotions (joy, calmness, and sadness) from the pleasure vs. displeasure dimension were used to represent positive, neutral, and negative emotions respectively. Based on this, cognition test was performed on the subjects.

The Arousal and Measurement of Emotion
(1) Emotion arousal
Emotion arousal aims at evoking the emotions required by experiment, based on which, the following experiment can be conducted. The materials used mainly include picture, music, and video. The video therein shows the best effect than the other two since it is a combination of them. Therefore, the emotions of the subjects are evoked by videos in the experiment.

(2) Emotion measurement
Emotion measurement is consisted of physiological measurement, expression measurement, and subjective emotion measurement.

In this study, subject emotion measurement is employed.

**Hypotheses**
Based on previous studies, the following hypotheses are proposed:

Hypothesis 1: subjects present significantly higher verbal working memory span in positive emotion than in neutral emotion;

Hypothesis 2: subjects present significantly higher verbal working memory span in neutral emotion than in negative emotion;

Hypothesis 3: subjects present significantly higher verbal working memory span in positive emotion than in negative emotion.

**Methods and Process**

**Subject**
Ninety college students, comprising 45 males and 45 females, participated in the experiment. These subjects were aged in 20-22 and normal in intelligence and vision.

**Experimental Materials**

**Emotion Materials.** Stimuli: positive emotions are stimulated by a film clip of “Mr. Bean” of 4 minutes and 45 seconds long, which has been used to stimulate positive emotions in the research of Jia Jing et al. in 2006 [4]; neutral emotion stimulus is a movie clip of “March of the penguins” in length of 5 minutes and 23 seconds, which has been used to evoke neutral emotions in the study of Meng Zhaolan et al. in 1993[5]; negative emotion stimulus is a movie clip of “Black sun”, which has been used to evoke negative emotions in the study of Li Fang et al. in 2008 [6].

Emotion self-assessment scale: it is designed to grade emotion intensity. According to the video type watched, emotions are divided into joy, calmness, and sadness. Basing on the intensity, they are further graded into five levels that increased from 1 to 5 in sequence. This scale is made in reference with the scale designed by Liu Xiaoming et al. in the research in 2013 [7].

**Measurement Material of Working Memory Span.** Operation-word span test: operation-word span test, created by Turner et al. in 1989, is composed of a series of operators formed by formulas and single words, i.e. 2*4-3=3 language. In this test, subjects are required to remember the single
word behind the formula as they make judgments on simple calculations with right and wrong answers in half separately. The number of the single word remembered by a subject is the working memory span of this subject. The test is applicable to test verbal working memory span owing to its requirements on numerical calculation and remembering of single words.

**Experimental Design and Process**

**Experimental Design.** The experiment was designed using intragroup two-factor method. The 90 subjects were averagely grouped into three according to their emotion states, with 15 males and 15 females in each group, as shown in Table 2. Dependent variables include emotion state and gender. Intra-group design effectively reduced exercise effect, fatigue effect, and experimental error, while enhanced the reliability of the experiment.

<table>
<thead>
<tr>
<th>Table 2-1. Experimental design.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joy</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
</tbody>
</table>

**Experimental Process.** To avoid disturbances of subjects in experiment, subjects were tested on computers in turn. Since the experiment is an inter-subject experiment, training and sequence errors were ignored. In the experiment, subjects were required to complete experimental operations individually in turn to reduce interactive interferences. The specific procedure is indicated as follows:

**Step one: emotion arousal**

The film clip of “Mr. Bean” was played to the subjects of the first group to evoke positive emotions and then the subjects filled the self-assessment scale.

The film clip of “March of the penguins” was played to the subjects of the second group to evoke neutral emotion and then the subjects completed the self-assessment scale.

The film clip of “Black sun” was played to the subjects of the third group to induce neutral emotion and then the subjects completed the self-assessment scale.

**Step two: measurement of verbal working memory span**

Computer screen shows an instruction as follows: you will see an operator constituted by a formula and a word, i.e. 2*4-5=2 forest. Making judgment on the result of the formula is right or wrong in five seconds. If the result is right, pressing the “R”; if it is wrong, pressing “F”. Then remembering the word behind the formula. The operator will disappear and replaced by a new one in five seconds. Continuing your judgments until the screen shows “???” and trying best to write down the words you recalled in sequence. Before the experiment, subjects were required to read the instruction carefully. In case of unclear points, they needed to read the instruction again. Then they were given two operators for exercise to ensure that they had comprehended the experiment procedure and could complete the procedure in formal experiment smoothly. Finally, they were inquired whether they were familiar with the experiment procedure or not. Formal experiment was performed as all subjects had understood the experiment procedure. Figure 2-1 exhibits the procedure:

**Results and Analysis**

The data obtained from the experiment were conducted with one-way variance analysis using SPSS Statistics17.0.
Analysis on the Verbal Working Memory Span Differences In Different Emotion States

Table 3-1 shows the descriptive data of the verbal working memory spans of subjects in three emotion states (joy, calmness, and sadness)

![Experimental procedures](image)

Figure 2-1 Experimental procedures.

Table 3-1. The descriptive data of the verbal working memory spans of subjects in different emotion states.

<table>
<thead>
<tr>
<th>Emotion state</th>
<th>N</th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>Standard error</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joy</td>
<td>30</td>
<td>5.067</td>
<td>0.888</td>
<td>0.162</td>
<td>4.735</td>
<td>5.398</td>
<td>2.5</td>
</tr>
<tr>
<td>Calmness</td>
<td>30</td>
<td>3.617</td>
<td>0.552</td>
<td>0.100</td>
<td>3.410</td>
<td>3.823</td>
<td>2.5</td>
</tr>
<tr>
<td>Sadness</td>
<td>30</td>
<td>2.750</td>
<td>0.716</td>
<td>0.130</td>
<td>2.483</td>
<td>3.017</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>3.811</td>
<td>1.202</td>
<td>0.126</td>
<td>3.559</td>
<td>4.063</td>
<td>2</td>
</tr>
</tbody>
</table>

As shown in this table, the verbal working memory span of the subjects in emotion state of joy is averaged by 5.067. In the confidence interval of 95%, the upper and lower limits lie in 4.725-5.398; the verbal working memory span of the subjects in emotion state of calmness is 3.617 in average. In the confidence interval of 95%, the upper and lower limits are ranged by 3.41-3.823; the verbal working memory span of the subjects in emotion state of sadness is averaged by 2.75. In the confidence interval of 95%, the upper and lower limits are in a range of 2.483-3.559. The total average of verbal working memory span is 3.811, which is close to the verbal working memory of 4 concluded by Cowan and the average verbal working memory span of the subjects in calmness.

In the following, detailed analysis was given to the differences of the verbal working memory span of the subjects in the three emotion states.

Table 3-2 displays the variance analysis results of the verbal working memory spans of the subjects in different emotion states.

Table 3-2. The variance analysis results of the verbal working memory spans of the subjects in different emotion states.

<table>
<thead>
<tr>
<th></th>
<th>Quadratic sum</th>
<th>Degree of freedom</th>
<th>Mean square</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intergroup</td>
<td>82.206</td>
<td>2</td>
<td>41.103</td>
<td>76.764</td>
<td>0.000*</td>
</tr>
<tr>
<td>Intragroup</td>
<td>46.583</td>
<td>87</td>
<td>0.535</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>128.789</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*. The significance level of mean difference is 0.05
As suggested, variance test yields an F value of 76.764 and significance probability p of 0.000<0.05, indicating that the verbal working memory spans of the subjects are significantly different on the level of α=0.05 in the three emotion states. Unfortunately, it is unclear of the differences are merely available between arbitrary two emotion states or extensively available among every two emotion states, namely, joy and sadness, joy and calmness, or calmness and sadness. To determine the specific differences among the three groups, multiple comparisons are necessary.

Table 3-3 displays the results of multiple comparisons on the verbal working memory span variances of the subjects in different emotion states.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard</th>
<th>Significance</th>
<th>Lower limit</th>
<th>Upper limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joy-calmness</td>
<td>1.450</td>
<td>0.190</td>
<td>0.000*</td>
<td>0.978</td>
<td>1.922</td>
</tr>
<tr>
<td>Sadness</td>
<td>2.316</td>
<td>0.208</td>
<td>0.000*</td>
<td>1.804</td>
<td>2.829</td>
</tr>
<tr>
<td>Calmness-joy</td>
<td>-1.450</td>
<td>0.190</td>
<td>0.000*</td>
<td>-1.922</td>
<td>-0.978</td>
</tr>
<tr>
<td>Sadness</td>
<td>0.866</td>
<td>0.165</td>
<td>0.000*</td>
<td>0.460</td>
<td>1.273</td>
</tr>
<tr>
<td>Sadness-joy</td>
<td>-2.316</td>
<td>0.208</td>
<td>0.000*</td>
<td>-2.829</td>
<td>-1.804</td>
</tr>
<tr>
<td>Calmness</td>
<td>-0.866</td>
<td>0.165</td>
<td>0.000*</td>
<td>-1.273</td>
<td>-0.460</td>
</tr>
</tbody>
</table>

*. 0.05 The significance level of mean difference is 0.05

In Tamhane, p is lower than 0.05 in emotion states of joy-sadness, calmness-sadness, and joy-sadness. Thus it can be concluded that the verbal working memory span of the subjects in joy is significantly different with that in calmness; the verbal working memory span of the subjects in calmness is significantly different with that in sadness; the verbal working memory span of the subjects in joy is significantly different with that in sadness.

Discussion

The Verbal Working Memory Span Differences of the Subjects in Different Emotion States.

As analyzed above, p is lower than 0.05 in the confidence interval of 95%. That is to say, the groups present obviously different working memory spans in the three emotion states, with an average of 5.067 in joy, 3.617 in calmness, and 2.75 in sadness. The verbal working memory span of the subjects in positive emotion state significantly surpasses that of the subjects in neutral emotion state; the verbal working memory span of the subjects in neutral emotion state is significantly higher than that of the subjects in negative emotion state; the verbal working memory span of subjects in positive emotion state significantly exceeds that of the subjects in negative emotion state. The results above are interpretable by the asymmetry of brain in function. The left hemisphere of brain controls the verbal function and processes the positive emotions it received simultaneously. By possible interactions of the two functions, verbal information is processed by positive emotions, leading to the improvement of verbal working memory span.

According to the theory of processing effectiveness, working memory owns a certain amount of cognitive resources while limited capacity. The capacity of working memory is inversely proportional to the number of resource-occupying tasks and task difficulty. The more the resource-occupying tasks, the less the cognitive resources allocated to each task; the more difficult the task,
the more cognitive resources needed. As a result, the cognitive resources distributed to other tasks are reduced, or the time spent on solving the task is increased. In addition, negative emotions, such as anxiety, sadness, and fear, take up a certain amount of cognitive resources. The cognitive activities under negative emotion state also occupy cognitive resources. Therefore, the cognitive resources allocated to the cognitive activities under negative emotion state are less than those under positive emotion state, resulting in the time increase of completing cognitive activities under negative emotion state. This theory explains the interferences of negative emotions on working memory span from the perspective of cognitive resource allocation and clarifies the principle of the experimental results.

At present, researchers have put forward multiple theories and viewpoints on the explanation of positive emotion selectively affecting working memory system, such as cognitive resources and motivation theory, as well as competition and promotion viewpoint [8]. Isen et al pointed out that positive emotion might lead to task-independent and extensive verbal activation, which would promote the verbal working memory tasks related to verbal processing to some extent [9]. On one hand, individuals show high motivations to complete tasks in positive emotion states. According to the Yerks Dodson law, high completing motivations are conductive to the accomplishment of simple activities in experiment. On the other hand, the generation of positive emotions, as well as the activation and working of speech functions, are all controlled by the left hemisphere of brain. Therefore, the processing of homolateral hemisphere on verbal information may be also initiated as positive emotions are evoked. In this context, the tasks concerning verbal working memory span test will be more effective in the case of that cognitive resources are free of the occupation of other tasks and relevant verbal function is activated simultaneously. This is the explanation for positive emotions promoting verbal working memory.

Conclusions
The subjects in emotion state of joy present significantly higher verbal working memory span than those in calmness; the subjects in emotion state of calmness show significantly higher verbal working memory span than those in sadness; the subjects in emotion state of joy present significantly higher verbal working memory span than those in sadness. It is enlighten from the results that a relaxed and enjoyable learning and teaching atmosphere is necessary to help students maintain a joyful emotion in the learning. Moreover, such atmosphere is conducive to the physical and mental health of students and the flourishing of the sound personality of students. Video materials, as a powerful emotion arousal tool, are encouraged to be used in class as the carrier of knowledge. Besides, students should be good at adjusting their emotions and keep a good emotion and attitude in learning to achieve more effective results.

Innovations
The innovation of this research is mainly reflected in its research direction, namely, a specific aspect of working memory. Currently, researchers mainly focus on the span of the whole working memory or the comparisons between verbal working memory and spatial working memory. Unfortunately, little attention has been paid to a specific aspect of working memory. This study investigated the span of verbal working memory and the influences of different emotions (joy, calmness, sadness) on verbal working memory span. The results obtained provide clear references for the research on this aspect.

Shortcomings
This study has three shortcomings: limited subject number. If conditions permit, the number of subjects should be increased to improve the reliability of experimental results; short videos length. The videos used in the experiment are 4-6 minutes long. If the length can be prolonged, the arousal effect to emotion would be optimized; limited subject range. The subjects are all selected from colleges and random subject selection from society would be more desirable.
References


