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The Effect of Musical Training on Working Memory

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Abstract

The use of PowerPoint technology to complement lecturing is a common teaching technique. This classroom technology requires students to process text, images, and spoken words in working memory; the temporary storage and active manipulation of information during everyday cognitive tasks. Previous research has shown that students are more adept at processing auditory and visual information versus printed text. The present experiment extended this work by investigating the role of musical training in the ability to process these modalities. Musical training gives rise to structural changes in the brain, particularly in areas associated with auditory and visual processing[1]. Thus, it is possible that musical training aids students' working memory ability in the classroom. This project tested the ability of musicians and non-musicians to hold text, images, and spoken words in working memory. Undergraduate students were recruited from first year seminar courses for science or music majors (n=67). Participants were asked to view PowerPoint slides containing groups of 5 images (black and white or color), 5 written words, or 5 spoken words followed by a slide containing a simple math problem, serving as a distracter. Each participant wrote the answer to the math problem and then the text, images, or spoken words in exact order. Correct recall was calculated for each participant. The results showed that all students recalled spoken words most accurately, regardless of musical training. Years of musical training were positively correlated to recall of written text but not images or spoken words. Professors of general education courses who lecture to students with a variety of educational backgrounds may benefit from gaining further insight into how students process information in working memory. The use of spoken words and text in Power Point presentations may be more valuable than the use of images for student understanding.

Keywords: Working Memory, Musical Training, Recall

1. Introduction

The inclusion of both printed text and images on PowerPoint slides requires students in the college classroom to simultaneously process text, images, and the spoken words of the professor in working memory; the temporary storage and manipulation of information during the process of language comprehension and learning[2]. According to Baddeley[2], working memory is thought to be mediated through two separate components each controlled by a central executive; a visual-spatial sketchpad, which manipulates visual images, and a phonological loop, which stores and rehearses speech. Working memory allows multiple pieces of information to be held in the mind simultaneously, before further processing can occur. While each of us utilizes working memory throughout our daily lives, there is evidence that individuals differ in the amount of information they can hold in working memory at once. The central executive of working memory processes one task at a time, limiting the ability of working memory to divide attention between multiple sources of information[3].

Working memory tests conducted by Goolkasian and Foos[4] indicate that college students as a whole show superior recall for spoken words followed by printed words and pictures. To determine whether Capital University students follow the same trend as those tested by Goolkasian[4], the experimental design used by Goolkasian[4] was replicated. Furthermore, the effect of musical training on students' working memory performance was studied. Work performed with musicians, children through adults, indicates that there may be substantial differences in working memory depending on one's exposure to musical training. Work by Ho[5], Kraus[6], and Strait[7,8] indicates that musical training improves verbal but NOT visual memory. These auditory differences were seen even when controlling for age, IQ, education and years of practice. Given that exposure to musical training may indeed influence auditory processing pathways in the brain it is possible that musically trained students may be exceedingly competent at holding spoken words rather than images or text in working memory. Thus, this project was also designed to correlate working memory scores by years of musical training. Deciphering such differences may become important because, beginning with the 2014-2015 academic year, all students on Capital University's campus have been required to take a laboratory based science class to fulfill a general education requirement. The percentage of non-majors enrolled in Biology 151 has increased from 21% (Fall 2013) to 50% (Fall 2016).

2. Methods

2.1 Participants

Permission was obtained from Capital University's IRB to recruit first year, undergraduate students from Capital University at the beginning of the Fall 2016 semester. Students were verbally recruited by the researchers, who presented a script, from a first year biology seminar and a weekly recital hour. Participants received no benefits and signed an informed consent form before participating.

Both vocalists and instrumentalists were classified as musicians and assigned a score based on the number of school years of musical involvement. The students who studied music beginning in elementary school years and continued as college students were considered highly trained, those who studied through high school (9^{th}-12^{th} grade) but not at the college level were moderately trained, those students who studied music before high school (grades K-8) but discontinued their musical training in high school were considered to be semi-trained. Those students with no musical background were classified as untrained.

2.2 Procedure

Participants were asked to view a total of 105 PowerPoint slides contained in groups of 5. Participants were presented with printed text, black and white images, or spoken words. Participants were also tested in a mixed modality condition with image plus spoken word, image plus text, or text plus spoken word. The images presented to students were taken from Snodgrass and Vanderwart's standardized set of pictures[9]. Each group of 5 slides was followed by a simple math problem, which served as a distracter. Students first solved the math problem by writing the answer on a data sheet. They then wrote the 5 items on the data sheet in exact order. Students were scored for accuracy in the ability to correctly list items in exact order. Items not listed in exact order were considered incorrect. The order of modalities presented to participants was randomized to avoid fatigue or training effects.

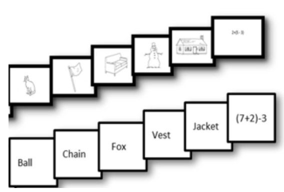

Figure 1. Examples of slides used to test text and image modalities

A total of 67 participants were tested (22 male and 45 female). To eliminate potential confounding variables, each participant was asked to complete an extensive questionnaire including questions related to class standing, gender, high school ACT composite score, concussion history, whether English is their primary language, dyslexia diagnosis and a detailed description of musical experience. ACT scores ranged from 15 to 35. Participants for whom English is not their native language and participants with a history of one or more concussions or a diagnosis of dyslexia were eliminated from the study. Two students could not remember their high school ACT composite score resulting in a sample size of 65 for ACT composite scores.

3. Results

3.1 Ability To Hold Spoken Words, Text And Images In Working Memory

Participants (n=67) held spoken words in working memory (M=84.2%) better than either text (M=72.4%) or images (M=68.7%) (Table 1). A one-way ANOVA was used to compare the ability of college students to report with complete accuracy spoken words, images, or printed words in working memory. One-way ANOVA reached significance, F (2, 66) = 17.36, p<0.001. Bonferroni Post Hoc test indicated that the spoken word modality differed from text (p<0.001) and images (p<0.001) but images and printed word modalities did not differ from each other (p= 0.469) (Table 1).

Table 1. The ability of college students (n=67) to hold spoken words, text, or images in working memory.

Modality	Accuracy Score (M ± SEM)
Spoken words	84.2% ± 2.1*
Text	72.4% ± 2.7
Images	68.7% ± 2.8

*Spoken word modality is statistically different from text and image modalities (p<0.01).

3. 2 Correlation Between Musical Training And Working Memory:

The ability to hold both text (Person's r (67) = 0.260, p=0.034) and images (Person's r (67) = 0.279, p=0.022) in working memory was positively correlated with level of musical training, suggesting that musical training may improve the ability to hold text and images in working memory. The ability to hold spoken words in working memory showed no correlation with level of musical training, Person's r (67) = 0.207, p=0.093 (Table 2). The correlation between musical training and working memory does not appear to be confounded by ACT composite scores because there was no correlation between the level of musical training and ACT composite score (Person's r (65) = 0.063, p=0.620). There was also no correlation between ACT composite score and the ability to hold either text (Person's r (65) = 0.141, p=0.262) or images (Person's r (65) = 0.163, p=0.194) in working memory, although there was a positive correlation between ACT score and the ability to hold spoken words in working memory (Person's r (65) = 0.251, p=0.044).

Table 2. The relationship between the ability to hold text, spoken words, and images in working memory as a function of musical training and ACT composite score.

Pearson's *r* values	Spoken Words	Text	Images	Musical Training
Musical Training	0.207	0.260*	0.279*	--------
ACT score	0.251*	0.262	0.163	0.063

* Correlation is significant at the 0.05 level (2-tailed)

3.3 The Role of Musical Training in Holding Combined Modalities in Working Memory:

Subjects were also tested on the ability to hold with complete accuracy combined modalities (images and spoken word, images and text, text and spoken word) in working memory. Participants (n=67) held text plus spoken words in working memory (M=82.8%) better than either images plus spoken words (M=78.9%) or images plus text (M=70.7%) (Table 3). One-way ANOVA reached significance, F (2, 67) = 9.10, p<0.001. Bonferroni Post Hoc test showed that the images plus spoken word modality differed from images plus text (p=0.039) and images plus text modality differed from text plus spoken word modality (p<0.001) but images plus spoken word and text plus spoken word modalities did not differ from each other (p= 0.469) (Table 3).

Musical training was positively correlated with the ability to hold images plus text (Person's r (67) = 0.291, p=0.017) and text plus spoken words (Person's r (67) = 0.277, p=0.023) but not images plus spoken words (Person's r (65) = 0.218, p=0.076) in working memory (Table 4). ACT composite score did not appear to be a confounding variable because there was no correlation between ACT score and the ability to hold images plus text (Person's r (65) = 0.176, p=0.161) and text plus spoken words (Person's r (65) = 0.189, p=0.132) or images plus spoken words (Person's r (65) = 0.159, p=0.206) in working memory. Furthermore, there was no correlation between ACT score and musical training (Person's r (65) = 0.063, p=0.620) (Table 4).

Table 3. The ability of college students (n=67) to hold mixed modalities in working memory.

Modality	Accuracy Score (M ± SEM)
Text/Spoken words	82.8% ± 2.4
Image/ Spoken words	78.9% ± 2.8
Image/Text	70.7% ± 3.2

Table 4. The relationships between musical training and ACT score on working memory accuracy.

Pearson's r values	Image/Spoken Words	Image/Text	Text/Spoken words	Musical Training
Musical Training	0.218	0.291*	0.277*	-------
ACT score	0.159	0.176	0.189	0.063

* Correlation is significant at the 0.05 level (2-tailed)

4. Discussion of Results

When students are in a classroom they must utilize working memory to manipulate auditory and visual information as they experience a lecture with PowerPoint slides, but the visual information includes both pictures and text. To test how many pictures, printed words, and spoken words college students could hold in working memory, Goolkasian and Foos[4], measured recall for pictures, text, and spoken words and discovered that college students demonstrate superior recall for spoken words over pictures and text. The current study supports the work of Goolkasian and Foos[4] as Capital University students performed significantly better on the recall of spoken words compared to text or images.

Other work performed with musicians, children through adult, indicates that there may be substantial differences in working memory depending on one's exposure to musical training. Work by Ho[5], Kraus[6] and Straight[7,8]indicate that musical training improves verbal but not visual memory. These auditory differences were seen even when controlled for age, IQ, education and years of practice[5]. The results of the current study show a weak but positive correlation between the degree of formal musical training in kindergarten through college and the ability of students to hold text and images but not spoken words in working memory. Because Capital University's conservatory includes both vocal and instrumental programs, both vocalists and instrumentalists were included in this study. Confounding variables were reduced by eliminating non-English speakers, students who have ever reported a concussion and students with dyslexia. The ACT, the most popular college admission standardized test in the United States, is used by many colleges to gauge college readiness and success, particularly in the sciences. Students with higher ACT composite scores are more likely to do well in their first year of college than students with lower ACT scores[10], thus, it was important to recruit students with a wide range of ACT scores and to determine whether ACT score could act as a confounding variable. Neither level of musical training, nor the ability to hold image or text in working memory correlated with ACT composite score, thus it is unlikely that the positive correlation of musical training and working memory can be explained by the random recruitment of music students with high ACT scores.

This work with musicians is a novel mechanism to study verbal working memory especially since musicians translate visual symbols into auditory output. The effects on working memory may even induce permanent, structural changes in the brain, since brain structural differences have been discovered between musicians and non-musicians[1]. Gray matter volume differences in motor, auditory, and visual-spatial brain regions have been noted in professional musicians when compared to matched groups of amateur musicians and non-musicians[1]. Franklin et al.[11] provided further evidence for a link between musical training and improved verbal memory. They also suggested that these differences may be due to enhanced development brain structures such as the auditory cortex[11]. Klein et al.[12] found evidence of a neurophysiological fingerprint in musicians via EEG and fMRI that was detectable when musicians were at rest, and not being tested with any sort of task. They found that long-term musical training resulted in increased inter-hemispheric connectivity in the planum temporale and Broca's area[12]. Research has also shown a relationship between musical lessons and significant improvements in student IQ. Students engaged in music lessons improved their IQ score by several points, in contrast with students engaged in drama lessons or no lessons at all[11].

A dual coding hypothesis for working memory was proposed by Mayer and Sims[13] when they discovered that college students performed better on cognitive tests of mechanical devices when both visual and auditory instructions were given compared to visual or auditory instructions only. Like Baddeley[2], Mayer and Sims[13] argued that there are two parallel channels, visual and auditory, that process information in working memory. Optimal learning is thought to occur when a subject is able to organize visual and phonological information to make connections between different pieces of information[14]. Mayer and Moreno[14] found a split-attention affect when testing students' working memory, findings that students learned more effectively when pictorial and auditory information were paired rather than pictorial and verbal information. The current study demonstrated a positive correlation between musical training and the ability to hold text combined with either spoken words or images in working memory. Why musical training did not correlate with the ability to hold images and spoken words in working memory is not clear, however, the lack of correlation with ACT composite score strengthens the argument that musical training and not test taking abilities accounts for the correlations seen.

These findings with musicians have important implications for their outcomes in the classroom, as well as with their musicianship. This topic is especially important to the teaching of introductory science courses at Capital University because 14-16% of the total undergraduate population is enrolled in the Conservatory of Music. All students at Capital University are required to take a laboratory based science class. Therefore, it is important to know what students are capable of holding in working memory across different disciplines. The science classroom often relies heavily on PowerPoint lectures containing images, printed words, and spoken words, thus challenging students' working memory and learning abilities. The study of working memory is important for both musically and non-musically trained students in order to understand optimal functioning in the classroom.

4.1 Limitations

In order to create a study of manageable length and to recruit as many students as possible, participants were tested with only one type of working memory task. Ideally, working memory should be tested with as many types of tasks as possible. In addition, this study included twice as many females (n=45) as males (n=22), which is not representative of the college population in general, as almost 50% of the student body is male.

5. Conclusion

Our findings that working memory capacity improved with years of musical training are consistent with previous research in this field. Strait and Kraus[7] found that students with past musical experience had increased auditory comprehension and hypothesized that musical training during childhood may have profound impacts of neurosensory function that last into adulthood. Another study using fMRI to measure brain activity found that musicians had significant advantages in attention, auditory working memory, and verbal working memory[15]. This study supports previous evidence that musical training can help improve students' working memory in and out of the classroom. Professors at Capital University who teach general education science courses may expect music students to adjust well to the demands placed on working memory in the science classroom.

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