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Effects of musical training and articulatory suppression on true and false associative memory.

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ABSTRACT

A number of studies propose a link between music training and the enhancement of cognitive abilities including verbal memory. This association has been attributed to the increased use of verbal rehearsal in musicians. This current study investigated this line of research and the interaction of verbal rehearsal on true and false memory recall. Twenty musical and twenty non-musical students who were recruited by opportunity sampling, participated independently in the DRM procedure, which involved memorising 12 computerised word-lists. During six of the lists, all participants were required to perform an articulatory suppression task. In line with the hypothesis, it was found that musical participants did recall more true memories. However, contrary to the hypothesis, articulatory suppression did not increase musical participants' recall of critical lures significantly more than non-musical participants. Together these results show that musical training does exert a benefit on true memory recall, however, the effect does not extend to false memory recall. Therefore, the effects of musical training are more general than the enhancement of verbal memory. Possible explanations for these results are discussed.

KEY WORDS:	MUSIC TRAINING	VERAL MEMORY	ARTICULATORY SUPPRESSION	TRUE MEMORY	FALSE MEMORY

Introduction

Overview

Previous research, comparing musical to non-musical participants, has concluded that musical training has influenced verbal memory. Brain scans have shown this to be attributable to changes to the brain structure in musical people, which has produced a superior working memory, allowing the use of an enhanced verbal rehearsal mechanism. Participants with a poor working memory have been found to produce more false memories, which has been exhibited through the DRM paradigm. This has led to the assumption that an enhanced verbal memory in musical subjects is less likely to lead to the recall of false critical cues. Therefore, this study aims to investigate the effect of musical training on true and false memories and proposes that musical participants should produce fewer false memories when recalling words, and the effect of this superior verbal memory will be eliminated through articulatory suppression.

Musical training and memory

Tierney and Nelson (2009) and Herholz and Zatore (2012) argue that there is an association between early experiences and the altering of brain structures which leads to enhanced cognitive functions. This is enabled due to brain plasticity which is more readily modified at a young age (Dawson, Ashman and Carver*,* 2000). This highlights the value of stimulating the brain with a variety of activities throughout childhood. This connection between neuroanatomical changes and experiences encountered has been largely investigated in relation to instrumental training, which is a multisensory motor experience (Lee and Noppeney, 2011; Wan and Schlaug 2010).

Review of Research

Schlaug, Norton and Overy (2005) suggests a broad range of skills are acquired through musical training such as rhythm and fine motor movements. However, other researchers have suggested that several non-musical abilities are also acquired, for example, Gaser and Schlaug (2003) and Hetland (2002) found superior spatial abilities in musical participants such as mental rotation of shapes and learning the layout of a new environment. These skills are important as they underlie many professions as well as every-day use. A different line of research found working memory is another highly specialised skill in musicians (Wallentin *et al.,* 2010) and specifically within this, verbal memory (VM) (Jakobson *et al.,* 2008; Ho *et al*., 2003). This was identified by results of higher recall scores in musical participants from tests such as the Hong Kong List Learning Test-form One (Ho, Cheung and Chan*,* 2003) which required participants to recall words which had been orally presented. However, although the participants were matched for age, education, socioeconomic background and musical ability, they only recruited male participants, which limits the generalisability of the study and cannot eliminate gender as a cause of the results. Brandler and Rammsayer (2003) implemented a different verbal memory test, the Berlin-Intelligence-Structure Test-form-4 (Jager, Suss and Beauducel*,* 1997), which involved participants memorising verbal information from a visually presented short story. They found a similar positive relationship between musical competence and enhanced verbal memory in their word recall trials and is a more reliable study as they recruited both males and females.

These studies demonstrate a strong association between musical training and verbal memory. However, this relationship was never measured over time therefore long-term memory effects cannot be assumed. In contradiction, a study by Helmbold, Rammsayer and Altenmuller (2005) into various mental abilities, including verbal memory, between musical and non-musical participants yielded no significant difference between the groups recall scores. Here, the participants were matched for age, sex and education, and they were required to reproduce memorised nouns. This conflict in findings highlights the necessity of additional research into the differences.

Investigating further the enhancement of this subdomain of the Working Memory (Baddeley and Hitch, 1974) through music training, an early study assessed 30 musical and 30 non-musical female participants on their verbal memory by recording the number of words recalled from a list (Chan, Ho and Cheung, 1998). They then tested their visual memory using the Benton visual retention test which involved drawing figures from memory. They concluded only the verbal memory test produced significantly enhanced results in the music training group, whereas visual memory did not. Their findings lead to the conclusion that there is a localised improvement of cognitive functions, which could be attributed to musicians repeatedly and frequently utilising specific regions. This localisation of function has been investigated through other procedures involving functional neuroimaging.

Neuroscientific evidence

In relation to the above conjecture, there is support from a wide range of evidence indicating commonalities between the regions and structures of the brain involved in verbal processing, memory and those implicated in musical training. Providing a link between the left hemisphere and musicality, Schlaug (1995) also found left planum temporale asymmetry in musicians, which Bever and Chiarello (1974) and Elbert *et al.* (1995) attribute to cortical reorganisation and Ellis *et al*. (2013) found was strengthened with the duration of musical training. This reinforces the link between music and verbal memory as this region is known to play an important functional role in language processing. Also supporting this, Schneider *et al.* (2002) suggested that the association between music training and the enhancement of specific non-musical abilities such as language processing (Hallam, 2010) is as a result of shared processing systems in brain regions such as the multi-functioning planum temporale. Investigating the role of other brain regions, Ohnishi *et al.* (2001) used an fMRI scan on musically trained individuals during a listening task and found left dorsal lateral prefrontal cortex activation. This is a major functional brain region responsible for higher cognitive functions such as working memory, which reinforces the link between musicality and verbal memory. However, the complex neuroanatomy underpinning musical activities may not be the only factor involved in the improvement of memory, as personality could also play a role. Franklin *et al.* (2008) suggested musicians' motivation to begin and pursue learning an instrument could be linked.

Verbal memory and Verbal rehearsal

Due to its significance in this line of research, Baddeley and Hitch's (1974) Working Memory Model has been further investigated. In this model, memory is described as multimodal, consisting of three main subsystems with different roles within the memory process. The central executive controls the flow of information to the slave systems, the visuospatial sketchpad is responsible for virtual information such as visualisation and the phonological loop represents a brief memory store. The phonological loop component also processes verbal memory, which is responsible for encoding and storing verbal information and has the capacity for the manipulation of information using storage subsystems.

Verbal rehearsal enhances various aspects of memory, using mechanism such as repetition and rehearsal to provide advanced verbal memory through extensive use of the memory systems and stores (Craik, 1973; Longoni, Richardson and Aiello, 1993). Baddeley (1986) believed this to be an automatic process, however the extent to which an individual utilises it varies. Musical ability has been found to correlate with an enhanced use for verbal rehearsal (Franklin *et al.,* 2008). The use of verbal rehearsal to aid the storage of memories can be tested by manipulating participants' ability to rehearse the material by implementing articulatory suppression (AS) (Baddeley, Thompson and Buchanan, 1975). For example, the repeated use of a neutral word such as 'the', limits phonological rehearsal thus reducing overall performance (Murray, 1968), but more importantly in this case, eliminates the rehearsal mechanisms as the contributing factor for enhanced memory. This is supported by Franklin *et al.* (2008) who found preventing rehearsal, eliminated musical participants' superior performance in a verbal memory test when comparing their performance to non-musical participants. The rehearsal of verbal information relies on speech production processes and articulation, which provides further support for articulatory suppression reducing the effectiveness of verbal memory (Miyake and Shah, 1999). This has been investigated in relation to brain structure.

Neuroscientific evidence

Aiming to identify the brain areas involved with verbal memory, Smith and Jonides (1999) found it to be functionally associated with the left hemisphere of the brain. Specifically, Frisk and Milner (1990) found from the memory tests results of brain damaged patients that the left hippocampal region primarily mediates verbal memory. Those with extensive removal from the hippocampal area exhibited the slowest performance when memorising a short story compared to control subjects. This is one cause of brain structural differences, leading to functional neuroanatomical variation between individuals (Satterthwaite and Davatzikos, 2015), which may explain differences in memory abilities. Furthermore, an fMRI scan showed planum temporale and left dorsal lateral prefrontal cortex asymmetry in those who performed better in memory tests (Ohnishi *et al.,* 2001), which are brain areas better developed in musical people (Rauscher *et al.,* 1997). This therefore proposes an explanation that memory enhancement in musical participants is due to an altered brain structure which could explain the increased use of the verbal rehearsal mechanism.

False memories

A line of research emerging from verbal memory is false memories (FM), which are the subjective recollection of past experiences that are mistakenly thought to be authentic, but did not occur (Arndt, 2012). These are experienced in everyday life when recalling details, and also experimentally by the recall of word lists. A range of explanations have been proposed to explain both their occurrence and their relationships between factors, such as a poor working memory predicting the production of FM (Peters *et al.*, 2007). However, no research has investigated the effects of musicianship on the creation of FM.

Inducing False Memory

The Deese-Roediger-McDermott paradigm (DRM) (Deese, 1959; Roediger and McDermott, 1995) has been constructed to demonstrate and investigate the creation of FM. This is achieved through participants learning lists of words presented to them, associated through their taxonomic semantic category (e.g. education, school, classroom, etc). Participants are then asked to complete a free recall or recognition test and tend to include non-studied associated words (e.g. teacher) (Dewhurst, 2001; Gallo, 2010). Toglia, Neuschatz and Goodwin (1999) found that false recall rates remained high during a three-week period, suggesting that the DRM paradigm is a reliable elicitation of FM in the laboratory (Blair, Lenton and Hastie, 2002). However, there is disagreement as to whether the DRM is comparable to the natural creation of FM (Freyd and Gleaves, 1996) which limits its generalisability, but it is a good starting point. Nonetheless, the DRM has been widely tested, exhibiting the creation of FM in children (Howe *et al*., 2004), adults (Lo, Sim and Chee, 2014) and a range of personality differences (Zhu *et al*., 2010).

Associative process

Explanations for the formation of FM have been well-researched, with many suggesting it is due to strong associations, which is exemplified in the DRM paradigm through the critical lures recalled being associated to the lists. The relatively automatic nature of the associative process is shown through the consistent prevalence of poor results in associative memory tasks observed in young, old, neurologically impaired and in different languages (Wimmer, 2009). This shows the effect of this association is reliable. Supporting this is the backward association score created for each word list which is related to the probability of recalling a FM, with some critical false words having a high score of .353. The DRM word lists consist of 15 words per list which may increase the likelihood of recalling false critical lures through association, as list length has been found to interact with recall accuracy (Ward, 2002). However, Robinson and Roediger (1997) manipulated the number of associates in some of the word lists and did not find a change in the rate of critical word intrusions. This therefore raises the question of which factors do affect it. The ability to create FM highlights the fallible essence of recollection and memory.

Schacter (2001) provided an alternative explanation of the phenomena of creating FM as reflecting an adaptation to processing limits, which could explain why false recall is higher when a person’s attention is restricted, as they only remember the outline of the experience and not the detail. Pohl (2004) suggested an alternative explanation is that false words are a by-product of useful heuristics, which, during occasions of time restraint, suggest participants retain the meaning or association of information, then later reconstruct it (Gallo and Lampinen, 2015). However, during this reconstruction of information, they falsely recall words because they are associated. Both explanations imply processing limits reflect the inability to adequately rehearse information, which suggests working memory is a factor in producing FM. Results from a digit span test and the DRM paradigm carried out on undergraduates support this. The research concludes that poor working memory predicts FM (Peters *et al*., 2007) providing further support for this association. As people with musical ability have been found to have a superior verbal memory assisted by verbal rehearsal, this leads to the hypothesis that they would produce fewer FM in the DRM paradigm, which has not previously been researched.

Confidence Scores

The extent to which people believe their recollection is a true memory (TM) can be measured using confidence scores. The more confident people are generally correlates with the accuracy of information (Wells, Olson and Charman, 2002). However, there are also cases of confidence and accuracy diverging (Schacter and Dodson, 2001) which highlights the necessity to measure confidence scores. When recording confidence, people often mistake ease of accessibility of a memory for memory strength (Kurdi *et al.,* 2018) therefore confidence is often high for false critical lures too. The importance of understanding the effect of confidence scores with accuracy of memories is illustrated especially through its interaction with eye witness testimony (Venter and Louw, 2005).

Current study

The above research suggests that long-term musical training exerts beneficial effects on the verbal memory component of working memory (Franklin *et al*., 2008), and poor working memory predicts FM (Peters *et al.,* 2007). Building on this, the current study investigated the potential link between musicality and FM. The principle aim was to investigate whether participants with musical training produce fewer FM than participants with no musical training, and the extent to which this is influenced by verbal rehearsal. To pursue the above aim, 20 musical and 20 non-musical participants undertook a computerised memory test consisting of 12 associated word-lists from the DRM paradigm (Deese, 1959; Roediger and McDermott, 1995) as this recruits verbal memory and no previous study has done so using this paradigm. Articulatory suppression was implemented for half of the lists to interfere with and eliminate the effect of verbal rehearsal. It was hypothesised that musical students' superior verbal memory would have an advantageous effect on their TM and FM production, yielding higher true recall and fewer false critical lures recalled, which would be extinguished with the use of articulatory suppression. The results will contribute to the existing literature on effects of music training on verbal memory.

Method

Participants

Forty participants were tested (15 male: 6 musical, 9 non-musical, 25 females: 14 musical, 11 non-musical), all of whom were 18-25 year-old university students, were recruited through opportunity sampling to take part. The mean age was 20.3. The non-musical sample consisted of twenty participants who have no history of undertaking musical training prior to the experiment. The twenty musical participants consisted of students who have undertaken a minimum of 5 years of regular music lessons with a professional teacher which began at the age of 10 or younger.

Design

The experiment used a 2x2 mixed design, in which the first independent variable (IV) was between subjects with musical ability vs. non. The second IV was within subjects in which the 2 levels were concurrent task vs non (articulatory suppression). There were also 6 dependant variables (DV) including the number of studied words recalled as DV 1, number of critical lures recalled (false memories) as DV 2, and non-critical words recalled as DV 3. Each DV will be further divided into confidence scores (DV 4-6).

Apparatus & Materials

Twelve-word lists (Appendix 1), each containing 15 items were chosen from the DRM false memory lists by Roediger and McDermott (1995) as a result of having a strong backward association to the critical false word. The chosen critical lures were: bread, car, chair, city, cold, doctor, fruit, king, music, needle, sleep, smell, and 180 words were presented in total. The lists have a mean BAS score of .268. Each of the 12 lists were randomly divided into two sets and paired with articulatory suppression and a no articulatory suppression condition. At the front of the answer booklet (Appendix 2) was the information sheet and consent form. The answer booklet had a separate page for each of the 12 lists to be recalled and next to each word was a confidence scale from 1 (least confident) to 5 (most confident). The lists were presented on a PC controlled by Microsoft PowerPoint slideshow.

Procedure

All participants were tested individually in a quiet room. Prior to the start of the test, participants asked to give written consent with their signature. They also filled out the form which included creating a unique participant identifier consisting of the last two letters of their first name, the last two digits of their postcode and the last two digits of their phone number to maintain anonymity of their data. They also had to indicate whether they were part of the musical group or not. The procedure was then briefly outlined, by which it was described as a memory test, but the false memory element was not mentioned to ensure the participants were unaware of the true aim to avoid demand characteristics. The articulatory suppression lists during which they were required to verbally repeat the word ‘the’ was specifically explained. They were informed before the start of each list whether articulatory suppression was required, which they would then indicate at the top of the answer page. When the experiment begun, participants were shown a computerised list of words, with one word appearing at a time. Each word was set to be presented for 2 seconds with no delay time between each word. During the articulatory suppression lists, participants were required to vocally repeat ‘the’ continuously while the list was presented. The words were positioned centrally on the screen in Calibri Body font, font size 60, uppercase, on a white background. Following the presentation of a list, the PowerPoint showed a blank screen for 2 minutes while the participants recalled as many words from that list as they could remember into the answer booklet. Additional to writing the words they recall, participants were asked to write how confident they felt that the word was on the list, rating it on a 5-point scale, 1 being least confident and 5 was most confident, by circling a number on the scale next to each word. This was repeated for each of the 12 word-lists. At the end of the experiment, the participants were offered debriefing.

Results

3.1. Overview of the Analyses.

Studied and non-studied items recalled over each recall trial for each condition were calculated together with the mean confidence scores. These were then analysed using a series of 2 (Subject; musical vs. non-musical) between-subjects by 2 (Experimental condition; articulatory suppression vs. no suppression) within-subject mixed ANOVAs (Appendix 3). The findings are presented below for each dependent variable.

3.2. True Memory – Recall of Studied Items.

(i). Overall True Memory

The descriptive statistics can be seen in Table 1.

Table 1

Total True Memory as a Function of Subject Type and Experimental Condition- means and standard deviations

	Subject Type	
	Musical **M SD**	**Non-Musical** **M SD**
Experimental Condition		
Articulatory Suppression	46.25 (7.75)	39.80 (10.73)
No Suppression	52.85 (7.89)	47.70 (9.10)

The analyses indicated a main effect of type of subject, $F(1, 38) = 4.88$, $p = .03$ showing better true memory for musical subjects. The main effect of articulatory suppression was also significant, $F(1, 38) = 47.04$, $p < .001$, showing lower true memory under suppression conditions. The interaction was not significant, $F(1, 38) = 0.38$, $p = .54$.

(ii). Confidence Responses for True Memory.

The descriptive statistics can be seen in Table 2.

Table 2

Total True Memory Confidence Scores as a Function of Subject Type and Experimental Condition- means and standard deviations

	Subject Type	
	Musical M SD	**Non-Musical** M SD
Experimental Condition		
Articulatory Suppression	4.69 (.33)	4.59 (.33)
No Suppression	4.57 (.25)	4.70 (.24)

The main effect of type of subject on confidence scores of true memory was not significant $F(1,25) = .02$, $p = .88$. The main effect of articulatory suppression was not significant, $F(1,25) = .01$, $p = .91$. However, the interaction was significant $F(1,25) = 4.31$, $p = .05$. Typically, simple main effects analyses would be performed but, due to the fact that confidence scores were missing for a number of subjects, these were not undertaken.

3.2. False Memory – Recall of Non-Studied Critical Items.

(i). Overall False Memory.

The descriptive statistics can be seen in Table 3.

Table 3

Total False Memory as a Function of Subject Type and Experimental Condition- means and standard deviations

	Subject Type	
	Musical M SD	**Non-Musical** M SD
Experimental Condition		
Articulatory Suppression	3.15 (1.60)	2.70 (1.38)
No Suppression	2.10 (1.89)	2.25 (1.48)

The analysis on the overall recollection of false critical lures revealed a non-significant main effect between musical and non-musical subjects $F(1, 38) = .12$, $p = .73$. The main effect for articulatory suppression was significant $F(1, 38) = 8.39$, $p = .006$, showing higher false memories under suppression conditions. The interaction was not significant $F(1, 38) = 1.34$, $p = .254$.

(ii). Confidence Responses for False Memory.

The descriptive statistics can be seen in Table 4.

Table 4

Total False Memory Confidence Scores as a Function of Subject Type and Experimental Condition- means and standard deviations

	Subject Type	
	Musical **M SD**	**Non-Musical** **M SD**
Experimental Condition		
Articulatory Suppression	2.80 (1.28)	3.99 (1.24)
No Suppression	1.93 (2.27)	3.23 (1.59)

A significant main effect of type of subject was found for confidence scores $F(1,25) = 9.09$, $p = .01$, with higher confidence for musical subjects. The main effect of articulatory suppression was not significant, $F(1,25) = 2.59$, $p = .12$, nor was the interaction, $F(1,25) = .01$, $p = .91$.

3.3. Summary of Findings.

As hypothesised, the analysis revealed that musical subjects produced significantly more TM than non-musical subjects. The use of articulatory suppression also produced a significant reduction in the number of true words recalled, with musical participants still recalling more, thus showing musical training has a positive effect on verbal TM. There was no interaction between the factors.

The results of the analysis of the confidence scores of TM did not reveal a significant difference between the type of participant, and the implementation of articulatory suppression also did not show a difference in confidence scores between the two groups. The interaction was significant. However, caution must be exercised in interpreting this finding since confidence scores were missing for several participants.

The analysis of the number of false critical lures recalled did not yield a significant difference between types of subject. The introduction of articulatory suppression however, increased the number of FM. There was no interaction between the factors.

Finally, musical participants were significantly more confident than non-musical participants in their recall of FM. However, there was not a significant difference between the groups' confidence scores when articulatory suppression was introduced. There was no interaction.

<u>Discussion</u>

(i). The Current Work in Relation to the Hypotheses.

The aim of this study was to investigate the level of true and false memories in musical participants, and the extent to which these results are attributable to verbal rehearsal by comparing the results to non-musical participants. The TM and FM results will be discussed separately.

With regard to TM, the musical participants correctly remembered more TM than the non-musical participants, which supports previous research and the hypothesis for the current work. It was hypothesised that articulatory suppression would interact with the type of participant and, based on past work, have a larger effect on musical subjects. However, articulatory suppression (AS) reduced TM which occurred as a main effect and was therefore irrespective of the participant group. This was not predicted, and the finding is problematic for previous accounts of the effects of musical training on memory that specify an interaction (Wallentin *et al.,* 2010; Brandler and Rammsayer 2003; Ho et *al.,* 2003). The possible reasons for this are considered later in the true memory section below.

With regard to false memory, it was expected that the musical participants would recall fewer due to the influence that musical training has on verbal working memory. However, this was not supported. In spite of this, an overall effect of articulatory suppression was found on FM; FM was increased under suppression conditions. Numerically, there is a possible trend, as although the means with non-articulatory suppression are equivalent between groups, under articulatory suppression the increase is numerically greater for musical participants. This could be further researched with more subjects and different suppression techniques to investigate this result. More generally, the possible reasons for the findings are considered in the false memory sections below.

The findings for the confidence scores were hampered by the fact that confidence scores were not collected for all subjects. The main findings were that musical participants were more confident when recalling FM. This highlights the utility of considering confidence scores when comparing subjects.

(ii). The Current Findings in Relation to Past Work & Theory.

True Memory

The TM findings are consistent with previous studies that have shown musicians to have an advantageous verbal memory, observed by higher recall of TM in participants with musical training than participants with no prior music training (Franklin *et al.,* 2008; Chan *et al.,* 1998; Ho *et al.,* 2003). This is not just a result of the memorisation of musical notes during training, as this would lead to the memorisation of purely auditory (e.g. pitch, timbre, note) information. Instead, it supports the idea of musical training enhancing memory beyond this domain to include at least verbal memory. The current findings can be understood in terms of previous research as cited in the introduction. For example, the experience of music training serves as a type of sensory stimulation that improves the development of the cortical system in a specific pattern resulting in cortical reorganisation (Schlaug, 1995; Bever and Chiarello, 1974; Elbert *et al.,* 1995) in a predictable way, facilitating cognitive function (Rauscher et al. 1997) such as enhanced verbal memory. However, the idea that it is verbal memory more specifically is challenged by the current findings related to articulatory suppression.

True Memory and Articulatory Suppression

This current study contradicted some of the previous research and the introduction which hypothesised that musical participants' recall of TM would be reduced more under AS due to their use of verbal rehearsal (VR), as both subject types' TM were reduced. This challenges the idea that the effects of musical training are purely in the domain of verbal memory. The findings are in line with Taylor and Dewhurst (2017), who tested different types of memory and found musical training enhances general cognition, not specific to the domain of music. The musician group produced higher scores overall, but both musician and control groups showed the same pattern when suppression was introduced. Therefore, there is no supporting evidence that a suppression task would reduce memory in musicians more favourably than control groups. Further supporting this concept, Allen, Baddeley and Hitch (2006) found AS disrupts the maintenance of any item in working memory showing it is not only specifically the verbal rehearsal encoding process that is affected by AS. Although AS is thought to interrupt VR, it might also have unintended consequences related to other mechanisms. For example, Soto and Humphreys (2008) found AS prevented the information being translated into long-term memory, which suggests encoding plays a role. Alternatively, attentional processing of information interacts closely with working memory during the encoding of information (Fougnie, 2008), therefore it is possible that the interference of attention with AS could explain the disruption of memory and thus the reduction in the recollection. However, there is little agreement on the role of attention across the models, so consequently the exact interaction between AS, attention and memory is yet to be investigated. Due to this uncertainty of interactions and the wide range of different strategies adopted to maintain words in the articulatory rehearsal loop (Gregg, Freedman and Smith, 1989), purer methodologies are needed to disrupt VR and measure the additional processes that might also be disrupted.

False Memory

This study assumed an outcome of musical participants recalling fewer FM due to a superior working memory and verbal rehearsal mechanism compared to non-musicians. Contrary to this assumption, both subject types recalled FM. This suggests that verbal rehearsal is not necessary to produce FM in the DRM procedure. Confirmation of this is evident in Seamon *et al*. (2002) where participants were made to think of both critical lures in one condition and in another condition were not. False recall occurred in both conditions. A possible explanation was found by Johnson (2006), where describing an event acts as verbal rehearsal and increases vividness and confidence. Therefore, verbal rehearsal is not necessary to exert a benefit in this context, but it can influence recall. This is supported by participants reporting rehearsing critical lures an equivalent amount to studied words (Marsh and Bower, 2004).

False Memory and Articulatory Suppression

The findings of the effect of AS on FM from the current study contradict some of the previous research and the potential indication which arose from the introduction of AS increasing FM for musical participants. However, one major finding was found whereby AS increased FM overall, irrespective of subject type, therefore the production of FM is not only a result of preventing verbal rehearsal. This corroborated with Dewhurst and Farrand's (2004) who found that articulatory suppression among other distraction tasks increased the FM responses of both musical and non-musical participants, therefore it is not solely the suppression of VR which creates FM. In a similar manner to TM, these findings indicate the more general role for attention and FM production, regardless of potential general verbal memory ability. An explanation for this could be attributed to divided attention, as AS has a general capacity delimiting effect (Van Damme *et al.*, 2010). The present results are consistent within themselves in that AS decreases TM overall and increases FM overall, irrespective of participant group.

(iii). Methodological Limitations & Future Recommendations

There are a number of limitations to the research above, which are mentioned below together with potential future research possibilities.

The current results indicate that music training improved TM, however participants in this study were not tested or matched for general cognitive ability, therefore it is not certain whether general cognitive ability affected the results. Further evidence for this is demonstrated by Schneider and Niklas's (2017) longitudinal study where academic achievement correlated with verbal memory abilities, suggesting that general cognitive ability could be a factor influencing participants verbal memory scores. Therefore, accounting for this would eliminate it as an extraneous variable. In attempt to ensure comparable results, all the participants in the current study were university students between the age of 18-25. Future work could be more conclusive by implementing a cognition test prior to the memory test in order to match the participants more accurately, such as the Wechsler Adult Intelligence Scale (Wechsler, 2008).

Other data not obtained in this study was the exact length of participant's musical training. This could provide more specific causal evidence, as it is not possible to infer this relationship from this study alone. Supporting this, Jakobson, Cuddy and Kilgour (2003) concluded that duration of training was related to the degree of improvement in memory. It has been suggested that even if the musical training is terminated, verbal memory performance remains stable, and the advantage is not lost (Ho *et al.,* 2003). Therefore, duration of training should be considered for future research. This could be implemented with a longitudinal study incorporating participants who are currently studying music, have previously studied but are no longer practicing musicians. These groups should specify duration of training and music practice and should be compared with a control group of participants who have never studied music. This would provide stronger evidence for cognitive changes.

Also contributing to the accuracy of the causal evidence would be considering the age at which the participants began music training. Brain plasticity is higher in young children (Kolb and Gibb, 2011), therefore it is thought that music training would have more of an effect on memory if this training was initiated at a young age, hence why this study required the musical participants to have 5 years of musical training which commenced at the age of 10 or younger. However, collecting the specific age at which they began lessons in future research would provide more accurate data.

Another potential drawback is the incomplete confidence scores data set, therefore the effect of musical participants being more confident in their recall of FM is not reliable. There is previous research that have shown confidence scores to be a predictor of accuracy of recall (Wells, Olson and Charman, 2002) and contradictory studies which support our findings have found a negative relationship (Schacter and Dodson, 2001). Collecting this information is thought to aid the understanding of the memory processes that contribute to the conscious experience of memory (Hirshman and Master, 1997). However, it depends on the conditions of testing as other factors influence confidence. For this reason, future research should implement different measurements of subjective confidence, such as the Remember-Know Paradigm (Tulving, 1985) which would allow insight into whether participants had a detailed recollection or general familiarity of the words recalled. Further research into this would facilitate the progression of this subject area and potentially provide evidence of a relationship or lack of between musicality, confidence scores and memory.

Some research has argued that music training has this apparent effect on verbal memory, but others have found personality traits and other pre-existing differences in the participants' background or brain structure may favour verbal memory ability (McDougall and Pfeifer, 2012). It has also been argued that musical people could have an innate musical talent leading to an enhanced memory (Norton, 2005) which would contradict the suggestion that musical training leads to this enhancement. To overcome this, future research could test participants' personality to explore any possible relationships between these factors.

This current study also had a gender imbalance, as more females volunteered than males. Future studies should aim for an even sample as there is an abundance of research which has highlighted gender to be a factor that interacts with verbal memory (Sundermann *et al*., 2016; Hogervorst *et al*., 2012; Kramer *et al*., 2003; Trenerry *et al*., 1995). Therefore, collecting a balanced number for each condition would allow for gender to be accounted for, and thus any results would be attributable to musical training.

The number of participants recruited for this study may indicate that the results are not representative of the population, as it was a relatively low amount. Future studies should aim for a larger cohort of participants to ensure their results are accurate and allow for any outliers.

(iv). Summary and Conclusion

The current study contributed to the growing evidence of music training being associated with enhancements of cognitive processes. It has highlighted the importance of implementing music training early in childhood with benefits exerted on true memory recall, no effect on false memory and an absence of interaction with AS. This has advantages as it is easy to engage children in activities involving musical instruments and requires very little verbal skills so is suitable for all children.

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