



**THE EFFECT OF WORKING MEMORY TRAINING  
ON THE ACHIEVEMENT OF MUSICAL DICTATION  
IN MUSICOLOGY MAJORS IN HIGHER EDUCATION  
INSTITUTIONS IN SHANXI PROVINCE, CHINA**

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**Abstract:**

This study investigated the efficacy of working memory training in enhancing music dictation proficiency among undergraduate musicology and music performance students in Shanxi Province, China. A quasi-experimental design involved 60 students divided into experimental and control groups. The experimental groups received targeted working memory training, while the control groups received conventional instruction. A researcher-designed dictation test was administered at three points: pre-test, post-test, and delayed post-test. Statistical analysis revealed significant main effects for group and time across both majors. For musicology students (Research Question 1), the experimental group showed significantly higher performance than the control group across all phases, especially in melodic and pitch dictation,  $F(1, 28) = 12.765$ ,  $p = .001$ ,  $\eta^2 = .314$ . Among music performance students. The results showed a significant overall main effect of time,  $F(1.20, 50.52) = 1429.02$ ,  $p < .001$ , partial  $\eta^2 = .971$ , reflecting a strong effect of the training across the three assessment points. Working memory training significantly improved music dictation achievement, particularly in total and melodic dictation, with partial retention after a delay. These findings indicate that working memory training positively impacts auditory-musical processing and sequential memory in music students. By incorporating cognitive training into higher music education, curriculum innovation and pedagogical advancement can be achieved. These implications extend to policy design, instructional practice, and interdisciplinary collaboration between music educators and cognitive psychologists, ultimately fostering effective learning outcomes in music education.

**Keywords:** working memory training, musical dictation, musicology majors, higher education institutions, China

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## 1. Introduction

Music is a complex and expressive auditory art form that relies heavily on the perceptual and cognitive abilities of the listener. Among the foundational elements of formal music education, ear training plays a crucial role in developing students' aural perception, musical literacy, and performance capabilities (Mankel & Bidelman, 2018). In higher education institutions, solfeggio—a core course comprising auditory analysis, sight-singing, and ear training—is essential for musicology majors. It is designed to help students internalize musical structures, accurately identify pitch and rhythm, and develop theoretical understanding in harmony, musical form, and notation (Chang & Gauthier, 2021). Ear training, particularly through musical dictation, is central to this process. It trains students to perceive, retain, and transcribe auditory stimuli in real time, thereby bridging the gap between hearing and writing music (Schneider *et al.*, 2022). Musical dictation is a cognitively demanding task that requires focused attention, short-term memory, and analytical listening. Through exercises in rhythmic, pitch, and melodic dictation, students develop not only auditory acuity but also mental organization and musical memory (Frischen *et al.*, 2019). However, mastering dictation is particularly challenging for undergraduates due to the high cognitive load required to temporarily store, process, and recall sequences of musical information.

In parallel with advances in music pedagogy, contemporary research in cognitive psychology has emphasized the critical role of working memory in musical skill acquisition. Working memory refers to a system for actively holding and manipulating information over short periods to guide behavior and learning (Nitin *et al.*, 2023). It supports tasks involving reasoning, comprehension, and auditory processing—functions that are particularly relevant for musical dictation (Talamini *et al.*, 2022). Research indicates that working memory capacity is positively correlated with musical performance, particularly in complex tasks like sight-singing and melodic transcription (Degé & Kerkovius, 2018; Grossberg, 2022).

Crucially, working memory is not a static trait but can be improved through structured interventions. Studies have shown that cognitive training—such as the adaptive n-back task—can enhance working memory capacity and lead to improved performance in both trained and untrained tasks, a phenomenon known as transfer effects (Barkus, 2020; Weng *et al.*, 2019). These findings have sparked interest in applying working memory training in educational settings, including music education, where such training may enhance students' ability to process and retain musical input in real time (Marie *et al.*, 2023).

Given the close alignment between the cognitive demands of musical dictation and the core functions of working memory, this study investigates the effect of working memory training on dictation performance among musicology majors in higher education institutions in Shanxi Province, China. It explores whether short-term cognitive training can enhance students' rhythmic, pitch, and melodic dictation skills, contributing to more effective solfeggio instruction and deeper engagement with music

learning. The integration of cognitive and pedagogical frameworks reflects a growing interdisciplinary interest in optimizing student learning through psychological insights and evidence-based instructional design.

## 2. Background

Solfeggio has historically served as the backbone of music education, providing students with a structured and systematic approach to internalizing and interpreting musical language. It combines theory with practice, teaching students how to decode and encode music both aurally and visually (Li, 2024). According to (Baldé *et al.*, 2025), solfeggio is considered both a key and challenging subject due to its dual focus on theoretical knowledge and practical application. Within the broader solfeggio framework, ear training is particularly crucial as it nurtures the student's musical hearing, memory, and sense of musicality. A major focus within ear training is musical dictation, which includes pitch dictation, rhythmic dictation, and melodic dictation. These exercises require students to accurately perceive musical input, retain it in short-term memory, and transcribe it in real time. As Demian and Nedelcut (Zhang *et al.*, 2020) explain, music dictation exercises are cognitively demanding and activate a range of mental processes, including memory, analytical thinking, and auditory discrimination. Pitch dictation involves identifying tonal intervals and accurately representing pitch relationships, whereas rhythmic dictation focuses on the perception and transcription of timing, accents, and meter (Bianco *et al.*, 2025; Villanueva *et al.*, 2024). Melodic dictation, being a composite of pitch and rhythm, is arguably the most complex and reflective of overall musical competence (Marion *et al.*, 2021).

One critical cognitive process involved in all these forms of dictation is memory—particularly working memory. Working memory is defined as a limited-capacity system for the temporary storage and manipulation of information necessary for complex cognitive tasks such as learning, reasoning, and comprehension (Marié & Defer, 2003). Unlike long-term memory, which stores information over extended periods, working memory operates on immediate, transient data that must be actively maintained in consciousness to guide behavior. In the context of musical dictation, students must hold sequences of sounds in working memory long enough to analyze and write them down—a task that becomes increasingly difficult as the complexity of the musical material increases.

Research has shown that working memory is malleable and can be enhanced through targeted cognitive training. The development of various training tasks, such as the adaptive n-back task, has enabled researchers to experimentally improve individuals' working memory capacity (Flak *et al.*, 2019; Forsberg *et al.*, 2020). These tasks involve continuously updating and manipulating information in real time, mimicking the demands of musical dictation. More importantly, several studies have demonstrated transfer effects from working memory training, meaning that improvements in memory performance generalize to other cognitive domains, including reasoning, language

processing, and academic performance (Sala & Gobet, 2020). In music education, this suggests that strengthening working memory through structured training may lead to improved aural perception, music reading, and performance.

Among the various forms of working memory training, the adaptive n-back task is particularly relevant to music education. It involves remembering a sequence of stimuli and identifying when the current stimulus matches one presented 'n' steps earlier. This dynamic tracking and updating process engages key aspects of working memory, including goal maintenance, interference control, information refreshment, and storage capacity (Trutti *et al.*, 2020). In tasks such as rhythmic and melodic dictation, students must maintain attention, inhibit distractions, and update internal representations of sound sequences—cognitive functions that align closely with the four dimensions trained in n-back exercises.

In recent years, due to the increasing research popularity of working memory in the field of psychology, more and more studies have been conducted on the combination of working memory and music, such as A Behavioral Study of Musicians and Non-Musical Tonal Working Memory, it is proposed that the number of notes, rather than the duration of notes, will significantly affect the effect of musicians and non-musical tonal working memory, and it is indicated that the N-back tonal task is a quantitative and sensitive measure to measure the effect of musical training on tonal working memory (Fennell *et al.*, 2020). However, in the academic field of combining working memory and ear training, especially the literature on working memory and ear-training, is not abundant internationally, and the research findings in China are even more scarce. Although many Chinese scholars have paid attention to this field, the depth and breadth of research still need to be strengthened. Most of the studies locally and abroad belong to working memory and pitch, including notes and melody, but there are almost no studies on working memory training and rhythm, especially working memory training and pitch dictation, rhythmic dictation and melodic dictation were studied together in even fewer.

Furthermore, recent studies in music cognition suggest that working memory is deeply involved in the mental construction of musical structure, the encoding of temporal and pitch-based information, and the comprehension of complex auditory patterns. This study thus builds upon a growing body of research that intersects music pedagogy with cognitive training, addressing the practical question of whether targeted working memory interventions can yield measurable improvements in students' dictation achievement. In summary, the combination of theoretical advances in working memory research and pedagogical challenges in ear training provides a timely and important opportunity for investigation. By implementing an experimental working memory training program and assessing its impact on musical dictation achievement, this study aims to contribute to both cognitive science and music education. It seeks not only to validate the role of working memory in music learning but also to propose actionable strategies for enhancing the effectiveness of solfeggio instruction in Chinese higher education institutions.

### 3. Statement of the Problem

Ear training, as a fundamental component of solfeggio courses in higher music education, plays a pivotal role in developing students' aural skills, including pitch and rhythm recognition, melodic memory, and musical reasoning. These competencies are directly dependent on cognitive functions such as memory, attention, and real-time information processing. Among these, working memory—the system responsible for temporarily storing and manipulating auditory information—has been identified as especially critical in dictation tasks, which require students to perceive, retain, and accurately transcribe musical input. Without adequate working memory, students struggle to retain tonal patterns, rhythmic sequences, and melodic contours, often resulting in poor dictation performance and slow progress in ear training courses (Baldé *et al.*, 2025; Marie *et al.*, 2023).

Despite the well-documented theoretical linkage between working memory and musical dictation, teaching practices in many institutions, including those in Shanxi Province, still rely heavily on traditional, monotonous methods such as rote listening and repeated transcription. These methods typically do not aim to directly improve working memory capacity, and as such, they often yield limited progress, especially for students with weak memory skills (Ahmadian, 2018; Aldugom *et al.*, 2020). Teachers frequently report that students lack auditory retention and struggle with musical memory, which hinders their ability to distinguish intervals, notate rhythms, or transcribe melodies effectively (Baldé *et al.*, 2025). Moreover, while prior studies have explored the neural and cognitive mechanisms of working memory in music (Malleret *et al.*, 2024; Marie *et al.*, 2023). There remains a scarcity of empirical research specifically examining the effect of working memory training on improving dictation achievement across pitch, rhythm, and melody dimensions. Existing studies have either focused on children and adolescents, used qualitative approaches without empirical validation, or examined only one aspect of dictation, such as melodic recall (Jakubowski *et al.*, 2017; Lukács & Honbolygó, 2019).

This gap highlights the need for comprehensive, data-driven research on how structured working memory training can enhance music dictation skills in higher education settings, especially in China's music education institutions. This study aims to empirically test the effect of working memory training on musicology majors' dictation achievement (total, rhythmic, pitch, and melodic) over time, compared to traditional instruction. It also seeks to determine whether working memory training leads to significant progress across multiple time points. Addressing this gap will contribute to a better understanding of the role of working memory in music learning and provide practical insights into innovative teaching strategies for solfeggio and ear training.

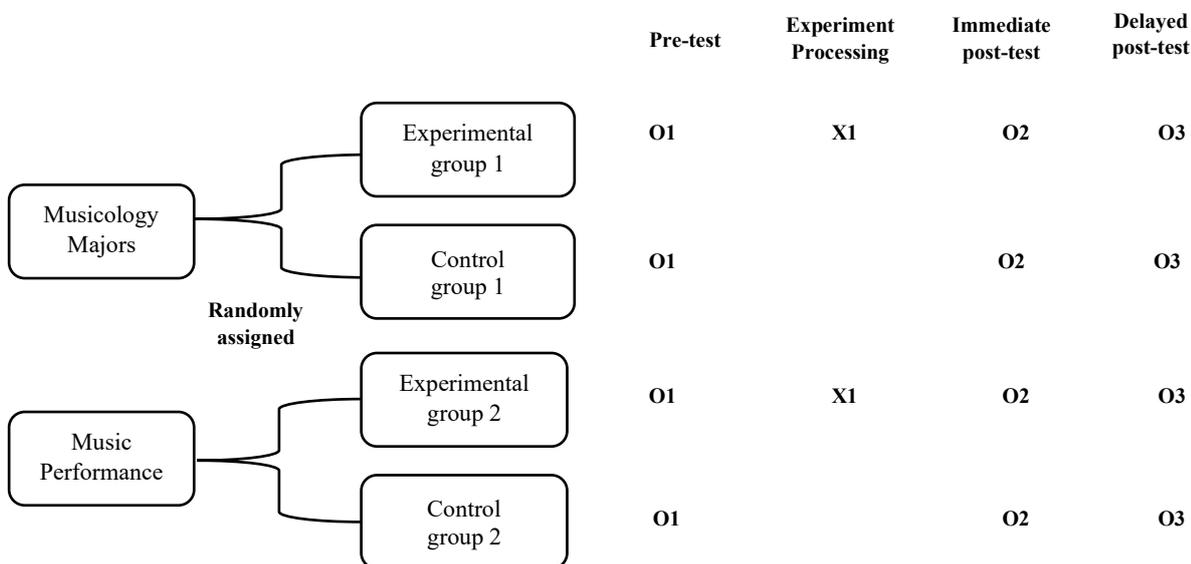
### 4. Research Methodology

This study employed a quasi-experimental, non-equivalent group design with pre-test, post-test, and delayed post-test measures to investigate the effect of working memory training on music dictation achievement. The design included four groups: Experimental Group 1 (music performance), Control Group 1 (music performance), Experimental Group 2 (musicology), and Control Group 2 (musicology). Each group consisted of approximately 15 students, drawn through cluster random sampling from first-year music majors at Jinzhong College, Shanxi Province.

Over eight weeks, all participants attended weekly 50-minute solfeggio classes. Each session included a 20-minute lecture and a 30-minute dictation component. The experimental groups received n-back working memory training using pitch and rhythm stimuli during the dictation segment, while the control groups followed traditional dictation methods.

Participants completed three assessments: a pre-test before the intervention, a post-test immediately after, and a delayed post-test two weeks later. All tests measured dictation achievement in pitch, rhythm, and melody. A double-blind procedure was used to minimize bias—neither the students nor the assessors were aware of group assignments. Data were anonymized for analysis. Figure 1 presents the research design for the study.

**Figure 1:** Research steps followed



### 4.1 Assumption Testing

Prior to conducting inferential analyses, key assumptions for parametric tests were evaluated. Descriptive statistics revealed that skewness and kurtosis values for all variables—Total Score, Pitch, Rhythm, and Melodic Dictation—fell within acceptable limits ( $|skewness| < 2$ ,  $|kurtosis| < 3$ ), suggesting approximate normality. Although formal normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) showed significant p-

values ( $p < .05$ ), indicating non-normality, these results were interpreted with caution due to the tests' sensitivity to sample size. Given the mild deviations and the robustness of repeated-measures ANOVA and t-tests to minor violations of normality, the data were deemed suitable for parametric analysis. Furthermore, an examination of extreme values confirmed that no scores exceeded  $\pm 3$  standard deviations or fell outside the expected scoring range, supporting the integrity of the dataset. Independent samples t-tests on pre-test scores showed no significant differences between the experimental and control groups across all measures ( $p > .05$ ), confirming group equivalence at baseline and ensuring the validity of subsequent treatment comparisons.

## 5. The Findings

### 5.1 Effect of Working Memory Training on Dictation Achievement Among Musicology Majors

The study involved two primary factors: a between-subjects factor (Group) and a within-subjects factor (Test Time). The between-subjects factor was Group, with two levels: the experimental group ( $n = 30$ ) and the control group ( $n = 30$ ). Each group consisted of 30 musicology majors, making the total sample size 60 participants. The within-subjects factor was Test Time, which included three repeated measures: Pre-test, Immediate Post-test (Post-test 1), and Delayed Post-test (Post-test 2). Each of the three time points included 30 observations per group, indicating that a subset of 30 students from each group completed each of the repeated measures. This structure supports a 2 (Group: Experimental vs. Control)  $\times$  3 (Time: Pre, Post 1, Post 2) mixed factorial ANOVA. Before conducting inferential analyses, descriptive statistics were computed to summarize the distribution of dictation achievement scores across the experimental and control groups at each time point (Pre-test, Immediate Post-test, and Delayed Post-test).

**Table 1:** Descriptive Statistics for Dictation Achievement Scores by Group and Test Phase

	Group	Test	Mean	Std. Deviation	N
Total Score	Exp	Pre-test	71.60	13.902	15
		Post-test 1	82.27	14.180	15
		Post-test 2	79.33	10.465	15
		<b>Total</b>	<b>77.73</b>	<b>13.454</b>	<b>45</b>
	Control	Pre-test	71.73	9.346	15
		Post-test 1	80.67	9.401	15
		Post-test 2	77.73	7.630	15
		<b>Total</b>	<b>76.71</b>	<b>9.411</b>	<b>45</b>
	Total	Pre-test	71.67	11.639	30
		Post-test 1	81.47	11.849	30
Post-test 2		78.53	9.035	30	
<b>Total</b>		<b>77.22</b>	<b>11.556</b>	<b>90</b>	
Pitch Dictation	Exp	Pre-test	42.53	9.086	15
		Post-test 1	48.93	7.778	15
		Post-test 2	47.33	6.997	15

	Control	<b>Total</b>	<b>46.27</b>	<b>8.286</b>	<b>45</b>	
		Pre-test	42.67	5.839	15	
		Post-test 1	47.07	5.444	15	
		Post-test 2	46.00	4.899	15	
	Total	<b>Total</b>	<b>45.24</b>	<b>5.613</b>	<b>45</b>	
		Pre-test	42.60	7.504	30	
		Post-test 1	48.00	6.664	30	
		Post-test 2	46.67	5.973	30	
	Rhythmic Dictation	Exp	Pre-test	14.13	3.335	15
			Post-test 1	15.47	3.662	15
Post-test 2			14.93	2.815	15	
<b>Total</b>			<b>14.84</b>	<b>3.261</b>	<b>45</b>	
Control		Pre-test	14.13	2.560	15	
		Post-test 1	17.33	3.266	15	
		Post-test 2	16.00	2.619	15	
		<b>Total</b>	<b>15.82</b>	<b>3.070</b>	<b>45</b>	
Total		Pre-test	14.13	2.921	30	
		Post-test 1	16.40	3.539	30	
	Post-test 2	15.47	2.726	30		
	<b>Total</b>	<b>15.33</b>	<b>3.187</b>	<b>90</b>		
Melodic Dictation	Exp	Pre-test	14.93	2.815	15	
		Post-test 1	17.87	3.335	15	
		Post-test 2	17.07	2.374	15	
		<b>Total</b>	<b>16.62</b>	<b>3.070</b>	<b>45</b>	
	Control	Pre-test	14.93	1.831	15	
		Post-test 1	16.27	1.831	15	
		Post-test 2	15.73	1.033	15	
		<b>Total</b>	<b>15.64</b>	<b>1.667</b>	<b>45</b>	
	Total	Pre-test	14.93	2.333	30	
		Post-test 1	17.07	2.766	30	
Post-test 2		16.40	1.923	30		
<b>Total</b>		<b>16.13</b>	<b>2.505</b>	<b>90</b>		

Descriptive statistics in table 4 summarize students' performance across three time points for four dependent variables: total score, pitch dictation, rhythmic dictation, and melodic dictation. These statistics are presented separately for the experimental and control groups. The experimental group's mean total score increased from pre-test ( $M = 71.60$ ,  $SD = 13.90$ ) to post-test 1 ( $M = 82.27$ ,  $SD = 14.18$ ), then slightly decreased at post-test 2 ( $M = 79.33$ ,  $SD = 10.47$ ). The control group's scores rose from pre-test ( $M = 71.73$ ,  $SD = 9.35$ ) to post-test 1 ( $M = 80.67$ ,  $SD = 9.40$ ), then slightly decreased at post-test 2 ( $M = 77.73$ ,  $SD = 7.63$ ). Both groups improved, with the experimental group showing a marginally higher gain. The experimental group improved from 42.53 to 48.93 at post-test 1, then slightly decreased to 47.33 at post-test 2. The control group improved from 42.67 to 47.07 at post-test 1 and 46.00 at post-test 2. The experimental group showed a larger gain, suggesting a greater improvement in pitch dictation. They improved from 14.13 to 15.47 at post-test 1 and slightly declined to 14.93 at post-test 2. The control group increased from 14.13 to

17.33 at post-test 1 and modestly decreased to 16.00 at post-test 2. Rhythmic dictation improvements were more pronounced in the control group. The experimental group improved from 14.93 to 17.87 at post-test 1 and maintained a high score at post-test 2. The control group improved from 14.93 to 16.27 at post-test 1 and 15.73 at post-test 2. The experimental group's sharper gains and higher consistency suggest working memory training had a stronger effect on melodic dictation skills.

Both groups improved across all measured domains: total score, pitch dictation, rhythmic dictation, and melodic dictation. However, the experimental group, trained in working memory, consistently showed greater mean improvements in total score, pitch dictation, and melodic dictation compared to the control group. The control group gained slightly more in rhythmic dictation, but the intervention positively influenced tasks requiring melodic and pitch accuracy. These preliminary findings support the hypothesis that working memory training enhances musical dictation in higher education music students. Further analysis is needed to determine significance.

Table 2 presents the results of the Multivariate Analysis of Variance (MANOVA) conducted to address the main research questions involving the effects of group membership (experimental vs. control), time (pre-test, post-test 1, post-test 2), and their interaction on multiple dependent variables (i.e., total score, pitch dictation, rhythmic dictation, and melodic dictation).

**Table 2:** Multivariate Test Findings for Research Question One

Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	
Intercept	Pillai's Trace	.983	1556.102 <sup>b</sup>	3.000	82.000	.000	.983
	Wilks' Lambda	.017	1556.102 <sup>b</sup>	3.000	82.000	.000	.983
	Hotelling's Trace	56.931	1556.102 <sup>b</sup>	3.000	82.000	.000	.983
	Roy's Largest Root	56.931	1556.102 <sup>b</sup>	3.000	82.000	.000	.983
Group	Pillai's Trace	.127	3.965 <sup>b</sup>	3.000	82.000	.011	.127
	Wilks' Lambda	.873	3.965 <sup>b</sup>	3.000	82.000	.011	.127
	Hotelling's Trace	.145	3.965 <sup>b</sup>	3.000	82.000	.011	.127
	Roy's Largest Root	.145	3.965 <sup>b</sup>	3.000	82.000	.011	.127
Test	Pillai's Trace	.159	2.387	6.000	166.000	.031	.079
	Wilks' Lambda	.842	2.448 <sup>b</sup>	6.000	164.000	.027	.082
	Hotelling's Trace	.186	2.507	6.000	162.000	.024	.085
	Roy's Largest Root	.178	4.919 <sup>c</sup>	3.000	83.000	.003	.151
Group * Test	Pillai's Trace	.077	1.113	6.000	166.000	.357	.039
	Wilks' Lambda	.923	1.121 <sup>b</sup>	6.000	164.000	.352	.039
	Hotelling's Trace	.084	1.128	6.000	162.000	.348	.040
	Roy's Largest Root	.082	2.259 <sup>c</sup>	3.000	83.000	.088	.075
a. Design: Intercept + Group + Test + Group * Test							
b. Exact statistic							
c. The statistic is an upper bound on F that yields a lower bound on the significance level.							

The multivariate tests revealed a statistically significant main effect of Group on the combined dependent variables, Wilks'  $\Lambda = .873$ ,  $F(3, 82) = 3.97$ ,  $p = .011$ , partial  $\eta^2 = .127$ .

This indicates that students in the experimental and control groups performed differently on musical dictation and total score. There was also a statistically significant main effect of Test (time) on the combined dependent variables, Wilks'  $\Lambda = .842$ ,  $F(6, 164) = 2.45$ ,  $p = .027$ , partial  $\eta^2 = .082$ , suggesting significant score variation across time points regardless of group. However, the Group  $\times$  Test interaction effect was not significant, Wilks'  $\Lambda = .923$ ,  $F(6, 164) = 1.12$ ,  $p = .352$ , partial  $\eta^2 = .039$ . This implies the pattern of change over time didn't differ between groups. Collectively, these results suggest that group and test timing significantly affected musical performance, but the interaction was weak enough not to reach significance. Follow-up univariate tests are needed to examine each dependent variable individually.

The Pairwise Comparisons provide a detailed analysis of the differences between the experimental and control groups across dependent variables. The adjusted mean differences and statistical significance were assessed using Bonferroni correction. For the Total Score, the mean difference between the groups was 1.022 (SE = 2.338), not statistically significant ( $p = .663$ ), with a 95% CI from -3.627 to 5.671. This indicates no meaningful difference in overall performance. In Pitch Dictation, the experimental group again showed a non-significant advantage (mean difference = 1.022, SE = 1.439,  $p = .480$ , 95% CI from -1.840 to 3.885). The wide and overlapping confidence intervals suggest a negligible group effect. In Rhythmic Dictation, the control group slightly outperformed the experimental group (.978 points, SE = .647,  $p = .135$ , -2.265 to .309). This difference was not statistically significant, and the confidence interval included zero, supporting the absence of a reliable difference. In Melodic Dictation, the experimental group outperformed the control group (.978, SE = .490,  $p = .049$ , .003 to 1.953). This finding supports the MANOVA result and suggests a measurable and specific positive effect on melodic dictation performance.

The mixed-design ANOVA revealed significant main effects of time across all four dependent variables: total score, pitch dictation, rhythmic dictation, and melodic dictation. Students' performance improved significantly over the three test sessions, regardless of group assignment. Medium effect sizes suggest educational meaning. The main effect of group was not significant for total score, pitch dictation, or rhythmic dictation, but a statistically significant difference was found for melodic dictation. Working memory training enhanced melodic dictation skills compared to traditional instruction. No significant Group  $\times$  Time interaction effects were found, implying similar trends in performance over time. However, the experimental group consistently outperformed the control group in post-test sessions, especially in melodic and pitch dictation. The findings partially support the hypothesis: working memory training positively affected melodic and pitch dictation achievement among musicology majors, especially in the immediate post-intervention phase. Cognitive training can enhance specific aspects of musical skill acquisition.

## **6. Progression of Dictation Achievement Over Time Among Musicology Majors Following Working Memory Training**

To examine whether there were statistically significant changes in dictation achievement (total, pitch, rhythmic, and melodic) over time among the experimental group, a repeated measures multivariate analysis of variance (MANOVA) was conducted. The within-subjects factor was time, which consisted of three levels: pre-test, immediate post-test, and delayed post-test.

**Table 3: Multivariate Tests**

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
factor1	Pillai's Trace	.976	537.992 <sup>b</sup>	3.000	40.000	.000	.976
	Wilks' Lambda	.024	537.992 <sup>b</sup>	3.000	40.000	.000	.976
	Hotelling's Trace	40.349	537.992 <sup>b</sup>	3.000	40.000	.000	.976
	Roy's Largest Root	40.349	537.992 <sup>b</sup>	3.000	40.000	.000	.976
factor1 * Test	Pillai's Trace	.174	1.301	6.000	82.000	.266	.087
	Wilks' Lambda	.826	1.333 <sup>b</sup>	6.000	80.000	.252	.091
	Hotelling's Trace	.209	1.362	6.000	78.000	.241	.095
	Roy's Largest Root	.207	2.832 <sup>c</sup>	3.000	41.000	.050	.172
a. Design: Intercept + Test Within Subjects Design: factor1							
b. Exact statistic							
c. The statistic is an upper bound on F that yields a lower bound on the significance level.							

As presented in Table 3, the multivariate test for the main effect of time (factor1) was statistically significant across all test criteria: Pillai's Trace = .976, Wilks' Lambda = .024, Hotelling's Trace = 40.349, and Roy's Largest Root = 40.349, all with  $F(3, 40) = 537.99$ ,  $p < .001$ , indicating a substantial effect of time on the combined dependent variables. The partial eta squared value ( $\eta^2 = .976$ ) reflects a very large effect size, suggesting that approximately 97.6% of the variance in the combined dictation scores was associated with the effect of time. In contrast, the interaction between time and test type (factor1 × test) was not statistically significant based on Wilks' Lambda = .826,  $F(6, 80) = 1.33$ ,  $p = .252$ , partial  $\eta^2 = .091$ . This indicates that while dictation scores changed significantly over time, the pattern of change did not differ significantly across the four dictation dimensions (total, pitch, rhythmic, and melodic). These findings suggest that working memory training led to significant overall improvements in dictation performance over time, but the effect was relatively consistent across different types of dictation tasks.

Before interpreting the repeated measures ANOVA results, Mauchly's Test of Sphericity was conducted to assess the assumption of sphericity for the within-subjects factor (time). As shown in Table 4, Mauchly's Test was statistically significant,  $W = .045$ ,  $\chi^2(5) = 126.65$ ,  $p < .001$ , indicating that the assumption of sphericity was violated. As a result, corrections to the degrees of freedom were applied using the Greenhouse-Geisser ( $\epsilon = .401$ ) and Huynh-Feldt ( $\epsilon = .426$ ) estimates of sphericity to reduce the likelihood of Type I error in subsequent within-subjects tests. These adjusted epsilon values were used

in interpreting the results from the repeated measures ANOVA to ensure valid statistical inferences.

**Table 4: Mauchly's Test of Sphericity**

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon	
					Greenhouse-Geisser	Huynh-Feldt
factor1	.045	126.652	5	.000	.401	.426

To examine whether working memory training significantly influenced the overall dictation achievement over time among musicology majors, a repeated measures ANOVA was conducted. As the assumption of sphericity was violated (see Table 4.34), the Greenhouse-Geisser correction was applied.

**Table 5: Tests of Within-Subjects Effects**

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	118676.711	3	39558.904	1429.020	.000	.971
	Greenhouse-Geisser	118676.711	1.203	98655.048	1429.020	.000	.971
	Huynh-Feldt	118676.711	1.278	92872.066	1429.020	.000	.971
	Lower-bound	118676.711	1.000	118676.711	1429.020	.000	.971
factor1 * Test	Sphericity Assumed	415.289	6	69.215	2.500	.026	.106
	Greenhouse-Geisser	415.289	2.406	172.613	2.500	.082	.106
	Huynh-Feldt	415.289	2.556	162.495	2.500	.078	.106
	Lower-bound	415.289	2.000	207.644	2.500	.094	.106
Error (factor1)	Sphericity Assumed	3488.000	126	27.683			
	Greenhouse-Geisser	3488.000	50.524	69.037			
	Huynh-Feldt	3488.000	53.670	64.990			
	Lower-bound	3488.000	42.000	83.048			

The results showed a significant main effect of time,  $F(1.20, 50.52) = 1429.02, p < .001$ , partial  $\eta^2 = .971$ , indicating a very large effect size. This suggests that students' overall dictation scores changed significantly across the three time points (Pre-test, Post-test 1, and Post-test 2). The interaction effect between time and dictation subtests (Total, Pitch, Rhythmic, and Melodic) was not statistically significant using the Greenhouse-Geisser correction,  $F(2.41, 50.52) = 2.50, p = .082$ , partial  $\eta^2 = .106$ . Although the p-value was slightly above .05, the partial eta squared indicates a small to moderate effect, suggesting that while there were visible differences among the subtests across time, they did not reach statistical significance when corrected for sphericity.

To further explore the nature of the significant changes in dictation achievement over time among musicology majors in the experimental group, within-subjects contrast analyses were conducted.

**Table 6: Tests of Within-Subjects Contrasts**

Source	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Linear	103769.884	1	103769.884	1514.433	.000	.973
	Quadratic	12433.422	1	12433.422	1511.006	.000	.973
	Cubic	2473.404	1	2473.404	392.703	.000	.903
factor1 * Test	Linear	321.849	2	160.924	2.349	.108	.101
	Quadratic	68.978	2	34.489	4.191	.022	.166
	Cubic	24.462	2	12.231	1.942	.156	.085
Error (factor1)	Linear	2877.867	42	68.521			
	Quadratic	345.600	42	8.229			
	Cubic	264.533	42	6.298			

The results revealed that the effect of time (factor1) on dictation achievement followed a significant linear trend,  $F(1, 42) = 1514.43, p < .001$ , partial  $\eta^2 = .973$ , as well as a significant quadratic trend,  $F(1, 42) = 1511.01, p < .001$ , partial  $\eta^2 = .973$ . These results suggest that the pattern of improvement was not only steady but also curvilinear, with a peak likely occurring at Post-test 1 and a slight decline by Post-test 2. Additionally, a significant cubic trend was also observed,  $F(1, 42) = 392.70, p < .001$ , partial  $\eta^2 = .903$ , indicating a more complex pattern of change across the three time points. However, the interaction between time and test type (i.e., total, pitch, rhythmic, and melodic dictation) revealed only a significant quadratic interaction,  $F(2, 42) = 4.19, p = .022$ , partial  $\eta^2 = .166$ , suggesting that the dictation subtests did not all follow the same trend over time. This points to the possibility that specific types of dictation may have improved more rapidly or differently than others, particularly around the Post-test 1 time point. The linear and cubic interactions were not statistically significant, with  $p = .108$  and  $p = .156$  respectively. Post hoc pairwise comparisons were conducted to examine differences in overall dictation scores across the three time points within the experimental group (pre-test, post-test 1, and post-test 2). A significant increase was found between the pre-test and post-test 1 scores,  $M$  difference =  $-5.33$ ,  $SE = 2.37, p = .029$ , 95% CI  $[-10.11, -0.56]$ , indicating that students performed significantly better immediately after working memory training. However, the difference between pre-test and post-test 2 scores was not statistically significant,  $M$  difference =  $-3.87$ ,  $SE = 2.37, p = .110$ , 95% CI  $[-8.64, 0.91]$ , though it trended in the same direction. Likewise, no significant difference was observed between post-test 1 and post-test 2 scores,  $M$  difference =  $1.47$ ,  $SE = 2.37, p = .539$ . These results suggest a significant immediate improvement following the intervention, with some decline over time, although the performance remained above the pre-training level.

Working memory training significantly improved students' dictation performance across time, as indicated by repeated measures ANOVA. Despite a violation of sphericity, Greenhouse-Geisser corrections were applied. The overall main effect of time was significant, reflecting a strong effect of the training across assessment points. Contrast analysis revealed linear and quadratic trends, showing a sharp increase from pre-test to immediate post-test, a slight decline at the delayed post-test, and still-above-baseline performance. Pairwise comparisons confirmed a statistically significant gain from pre-test to immediate post-test, but not from post-test 1 to post-test 2. This suggests

meaningful and sustained improvement in music dictation achievement, particularly in total and melodic dictation, with partial retention of gains after a delay. Working memory training effectively enhances dictation skills among musicology students, making it an instructional intervention in music education settings.

## 6. Conclusion

Research aimed to investigate whether working memory training significantly improved dictation achievement—total, rhythmic, pitch, and melodic—over time compared to traditional teaching methods among musicology majors in Shanxi Province. A mixed-design ANOVA revealed key findings: significant main effects of time across all four dependent variables, indicating improved performance in musical dictation over the three test sessions, regardless of group assignment. The medium effect sizes (partial  $\eta^2$  ranging from .090 to .136) suggest that these improvements were educationally meaningful. Second, while the main effect of group was not significant for total score, pitch dictation, or rhythmic dictation, a statistically significant difference between the experimental and control groups was found for melodic dictation ( $F = 3.977$ ,  $df = 1, 84$ ,  $p = .049$ , partial  $\eta^2 = .045$ ). Working memory training enhanced melodic dictation skills compared to traditional instruction. No significant Group  $\times$  Time interaction effects indicated similar trends in performance over time. However, the experimental group consistently outperformed the control group in post-test sessions, especially in melodic and pitch dictation. The findings partially support the hypothesis: working memory training positively affected melodic and pitch dictation achievement among musicology majors, especially in the immediate post-intervention phase. Cognitive training can enhance specific musical skill acquisition.

The findings for investigating if there a significant difference in dictation achievement (total, rhythmic, pitch, and melodic) over three time points among the experimental group of musicology majors?" — indicate that working memory training had a statistically significant effect on students' dictation performance across time. Repeated measures ANOVA revealed significant within-subject differences, with Mauchly's test indicating that the assumption of sphericity was violated; hence, Greenhouse-Geisser corrections were applied. The results showed a significant overall main effect of time,  $F(1.20, 50.52) = 1429.02$ ,  $p < .001$ , partial  $\eta^2 = .971$ , reflecting a strong effect of the training across the three assessment points. Further contrast analysis revealed significant linear and quadratic trends, suggesting that performance increased sharply from pre-test ( $M = 35.80$ ,  $SD = 1.67$ ) to immediate post-test ( $M = 41.13$ ,  $SD = 1.67$ ), with a slight decline at the delayed post-test ( $M = 39.67$ ,  $SD = 1.67$ ), yet still above baseline. Pairwise comparisons confirmed that the gain from pre-test to immediate post-test was statistically significant ( $p = .029$ ), while the decline from post-test 1 to post-test 2 was not. This indicates that the working memory training led to a meaningful and sustained improvement in music dictation achievement, particularly in total and melodic dictation, with partial retention of gains observed after a delay. Collectively, these results affirm

the effectiveness of working memory training in enhancing dictation skills among musicology students, highlighting its potential as an instructional intervention in music education settings.

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### **Conflict of Interest Statement**

The authors declare that they have no known financial or personal relationships that could have appeared to influence the work reported in this paper.

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