Research Article

The Impact of Musical Competence on Working Memory and Speech-in-Noise Performance

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Highlights

- Self-perceived musical competence impacts cognitive skills, including WM and SPIN
- Musicians with higher MC perform superiorly on WM and SPIN tasks
- 2n and backward span tests best differentiate the high andlow MC groups

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ABSTRACT

Background and Aim: The concept of Musical Competence (MC) encompasses a unique amalgamation of innate aptitude and cultivated skill, encompassing elements of formal training, informal practice, and real-time musical performance. While musical attitude and training influence speech processing abilities and Working Memory (WM), the study examines whether the self-perceived MC plays any role in these processes. This study aimed to investigate whether an individual's self-perceived MC has an impact on their WM, Speech Perception in Noise (SPIN), and Listening Effort (LE) abilities.

Methods: A non-experimental, standard group comparison research design was employed. Various cognitive tasks, including WM tests, SPIN, and National Aeronautics Space Administration-Task Load Index (NASA-TLX), are administered to gauge different skills within groups.59 musicians were categorized into high self-perceived MC (MChigh) and low self-perceived MC (MClow), as assessed on scores of Edinburgh lifetime musical experience questionnaire, were evaluated for their WM and SPIN abilities.

Results: Mann Whitney U test was carried out to find group differences, while Fisher Discriminant Analysis (FDA) was performed for group membership prediction. MChigh scored significantly greater scores WM and SPIN scores than MClow, but there were no significant group differences in LE. Cognitive tasks effectively distinguish between groups. Fisher discrimination analysis confirmed the predictive value of tasks like 2n-back and backward-span in group differentiation.

Conclusion: This study underscores potential cognitive and auditory processing benefits derived from the self-belief of musicians. Musicians with higher MC exhibit enhanced cognitive skills, particularly in WM tasks and auditory processing.

Keywords: Musical competence; musicians; working memory; speech perception in noise; cognitive abilities; listening efforts

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Introduction

Music, bridges cultures and sparks emotions. Varying musical abilities result from training, aptitude, and Musical Competence (MC), making each person's musical experience unique. MC influences how listeners perceive, remember, and discriminate musical melodies and rhythms [1]. MC is a composite skill that blends inherent talent with acquired abilities, covering various aspects like formal training, informal practice, and live music performance, such as playing instruments or singing. Research has demonstrated that musical training has positive effects on cognitive abilities and can slow down age-related declines in auditory processes [2-4]. However, specific advantages are yet to be explored.

Self-perceived MC is a subjective evaluation of an individual's musical abilities and skills. Those with high MC are likely to have undergone extensive musical training and accumulated significant experience, potentially leading to enhanced auditory processing skills compared to individuals with lower perceived MC.

While there is extensive research on the impact of formal musical training on Working Memory (WM) in musicians, there is a lack of studies exploring the influence of self-perceived MC [5]. Musical competence reflects musicians' subjective evaluation of their musical abilities, while WM refers to the number of cognitive resources required to complete a task while various cognitive processes are being planned and carried out [6]. Investigating how self-perception relates to WM can provide insights into the role of individual beliefs and attitudes in shaping cognitive abilities. By exploring the impact of self-perceived MC on WM, the study can offer valuable information for music educators and trainers. It can help design effective and targeted training programs to enhance cognitive skills in musicians.

In addition to MC influencing WM, it can also be hypothesized to influence their attention skills, which is important in speech understanding of noise and listening effort (LE) [7-9]. As musicians undergo rigorous training and gain expertise over time, their cognitive and sensory capacities tend to improve, leading to more efficient processing of speech in complex situations, including its perception in noisy conditions [10]. LE refers to the deliberate allocation of mental resources to overcome barriers in goal pursuit when carrying out a cognitive task listener [11]. The Framework for Understanding Effortful Listening (FUEL) model can be applied to musicians to explain the relationship between LE and MC [12]. The FUEL model suggests that LE is influenced by three interrelated components: a) the listening task, b) an individual's capacity for, and c) the listening environment. These components interact and determine the overall LE experienced by an individual. Extrapolating the component of an individual's capacity from the FUEL model, those with higher MC by their better-developed and rightly acknowledged capacities, can be hypothesized to perform better in auditory processing tasks in general (SPIN) and WM in particular [12]. Similarly, on listening tasks from the FUEL model, musicians with high MC can handle complex and demanding musical tasks with relative ease. Proficient musicians exhibit versatility in musical styles and improvisation, reducing cognitive load. Their high MC aids adaptation in adverse conditions, minimizing cognitive strain. However, Escobar et al. [13] found no significant reduction in LE in musicians showing no music advantage. This study uses the FUEL model to investigate how musicians' self-perceived MC affects auditory processing (SPIN), cognitive performance (WM tasks), and cognitive load (LE) in different WM tasks. The purpose of the study was to investigate the influence of self-perceived MC on auditory and cognitive abilities, specifically WM, SPIN and LE, by examining how self-belief in musical ability, beyond formal training, affects these skills, this study aimed to provide insights into the role of individual beliefs and attitudes in shaping cognitive capacities. Fostering self-efficacy in musical tasks may benefit those with auditory challenges, reducing cognitive strain and improving resilience in noise. This insight would inform personalized cognitive and auditory interventions and educational programs, emphasizing self-belief as a tool to boost cognitive performance and manage listening effort.

Methods

Participants

The study comprised 59 musicians aged 19–32 years (mean: 25.08±2.99 years), consisting of 31 males and 28 females recruited through purposive sampling method. All participants had undergone formal training in musical instruments like string instruments, piano, or percussion for 1–2 years and practised music for at least 1–2 hours per week. Based on self-perceived MC ratings obtained from the Edinburgh Lifetime Musical Experience Questionnaire (ELMEQ) rating scale [14] participants were divided into two groups: MC_{high} (mean age:24.9±2.95 years, 18 males, and 11 females) and MC_{low} (mean age=25.07±3.08 years, 13 males, and 17 females).

Before participating in the study, informed consent was obtained from all participants. The study adhered to ethical guidelines prescribed for bio-behavioral research [15]. Participation was voluntary, and data confidentiality was ensured.

Procedure

Participants completed a Google form containing questions related to demographic details and musical experience. The ELMEQ is a musical questionnaire in the English language with four sections and 30 items that focus on brain aging, cognition, and musical training. It offers details on the scope and makeup of musical education and experience. Additionally, it asks about musical talent, singing experience, reading music notation, and listening to music of any type (such as jazz, classical, folk, pop, or rock). It is proven to be an effective tool for quantifying self-reported musical experience and abilities and categorising musicians based on the score obtained in the scale [14]. Music instruments, singing, reading music notation, and listening to music are the four subsections of the ELMEQ. Participants could score up to a maximum of 15. The questionnaire was administered using Google Forms. The participant's proficiency in the three ELMEQ subsections of singing, playing musical instruments, and listening to music is evaluated on a 5-point scale. To determine self-perceived talents, three of these questions were taken into consideration and are highlighted in Appendix 1. Ratings were added to obtain aggregate scores and those above a score of 12 were categorized as having high self-perceived MC, while those scoring ≤8 were classified as having low MC. Scores from 8–12 were excluded for clearer group differentiation.

Cognitive allocation was gauged through mental load and WM tasks (forward span, backward span, operation span, 2n-back) using Smriti Sharavan 3.0 Software [16]. LE was assessed with the National Aeronautics Space Administration-Task Load Index (NASA-TLX) [17], and SPIN performance was evaluated using the SPIN in Indian English (SPIN-IE) version [18].

Cognitive tests

Mental load assessment

Forward and backward digit span

In the forward digit span test, participants heard a series of random numbers (1–9) through headphones with a 1000 ms gap between each number, as illustrated in Figure 1. The test ranged from simple (2 digits) to complex (9 digits), with 3 practice rounds. Participants had to repeat the digits in the same order within 5000 ms. The backward span test was similar but required participants to type the digits in reverse order. Scores were based on the maximum correct digits repeated in the correct or reverse order, displayed by the software.

Auditory 2n back

Participants must repeat the second-to-last number heard in a series via headphones. There were

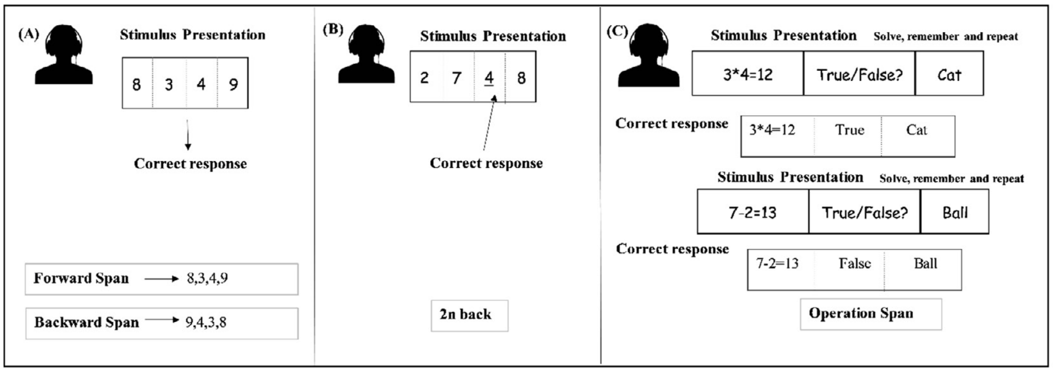

Figure 1. Schematic representation of the stimuli and response presented in (A) forward span and backward span, (B) 2n back, and (C) operation span task

15 trials, each with a 1000-millisecond interval, a 5000-millisecond time limit, and varying string lengths from 4 to 10 numbers, as outlined in Figure 1. Scoring depended on correct responses by participants.

Operation span

In this task, the participant's ability to remember the target stimuli was assessed. The stimulus was presented along with a secondary task. Here the secondary task was a distracting stimulus that involved solving an arithmetic problem, which was followed by a bi-syllabic Kannada target word that was recalled (e.g. is (7–4) *4=12 --- true or false? —- /ball/) (Figure 1). The participant was instructed to solve the arithmetic problem, then to judge whether the arithmetic problem is true or false and then remember the target word. Similarly, a series of arithmetic problems and target word difficulties were randomized such that the numbers of elements were unpredictable at the outset of an item.

Speech Perception in Noise-Indian English

The SPIN-IE test employs phonemically balanced words that are spoken in Indian English. These words are played alongside a background of 8 Indian English speakers in a noisy environment at a signal-to-noise ratio of 0 Db [18]. The SPIN-IE test consists of 25 carefully selected words designed to represent various phonemes and are presented in the presence of babble noise generated by eight different talkers also speaking Indian English. To prevent listener fatigue, gaps were introduced in the babble noise. The lengths of these noise segments varied between 310 ms and 620 ms, and each interruption had a fixed duration of 75. Importantly, the interruptions were strategically positioned to avoid overlap with the word stimuli. There was a consistent 5-second gap between the presentations of consecutive stimuli. To ensure an equal intensity level, the average amplitude of each noise segment was adjusted to match that of the corresponding word stimulus, thus achieving a signal-to-noise ratio of zero. 1 kHz calibration tone was included before the test.

Listening effort assessment

For each of the WM and SPIN tasks, participants were asked to rate the LE across 6 domains of the NASA task load using a visual analog scale [17]. The 6 dimensions are discussed below:

1) Mental demand-the extent of cognitive involvement, including thinking, decision-making, and calculation, needed to execute the task.

2) Physical demand-the quantity and intensity of physical effort required to accomplish the task.

3) Temporal demand-the sense of urgency and temporal constraints associated with completing the task.

4) Effort-the degree of exertion necessary for the participant to sustain their performance level.

5) Performance-the degree of success attained in accomplishing the task.

6) Frustration level-the emotional state experienced by the participant, encompassing feelings of insecurity, discouragement, confidence, or contentment during the task.

Participants in the WM tasks rated their workload across domains using a scale. They then determined factor weights in a workload tally sheet. Using these weights, they calculated adjusted ratings and, ultimately, a weighted rating for each task by dividing the sum of adjusted ratings by 15. Based on the weighted rating, the difference in the LE between the two groups was compared. Higher scores indicate greater LE. The NASA-TLX is given in Appendix 2.

Statistical analysis

The data collected underwent analysis utilizing SPSS version 25.0 (IBM Corp., Armonk, NY, USA). To evaluate the normality of the data, the Shapiro-Wilk test was employed. Group differences in Working Memory (WM) scores, Life Events (LE) ratings, and SPIN scores were identified using the Mann-Whitney test. In instances where a statistically significant difference emerged between the groups, the effect size was determined using the Rosenthal formula (r_e=/Z//√N) [19]. Additionally, Fisher Discriminant Analysis (FDA) was applied to discern crucial variables distinguishing between groups, relying on their performance in the 5 tests. The study employed a standard mathematical operation (Di=a+b1x1+b2x2+...+bnxn; where Di is the predicted discriminant score, a is a constant, x represents predictors, and b denotes discriminant coefficients) for group categorization. The error analyses on the predicted membership through the FDA to the original score (membership) were also performed to understand the classification accuracy.

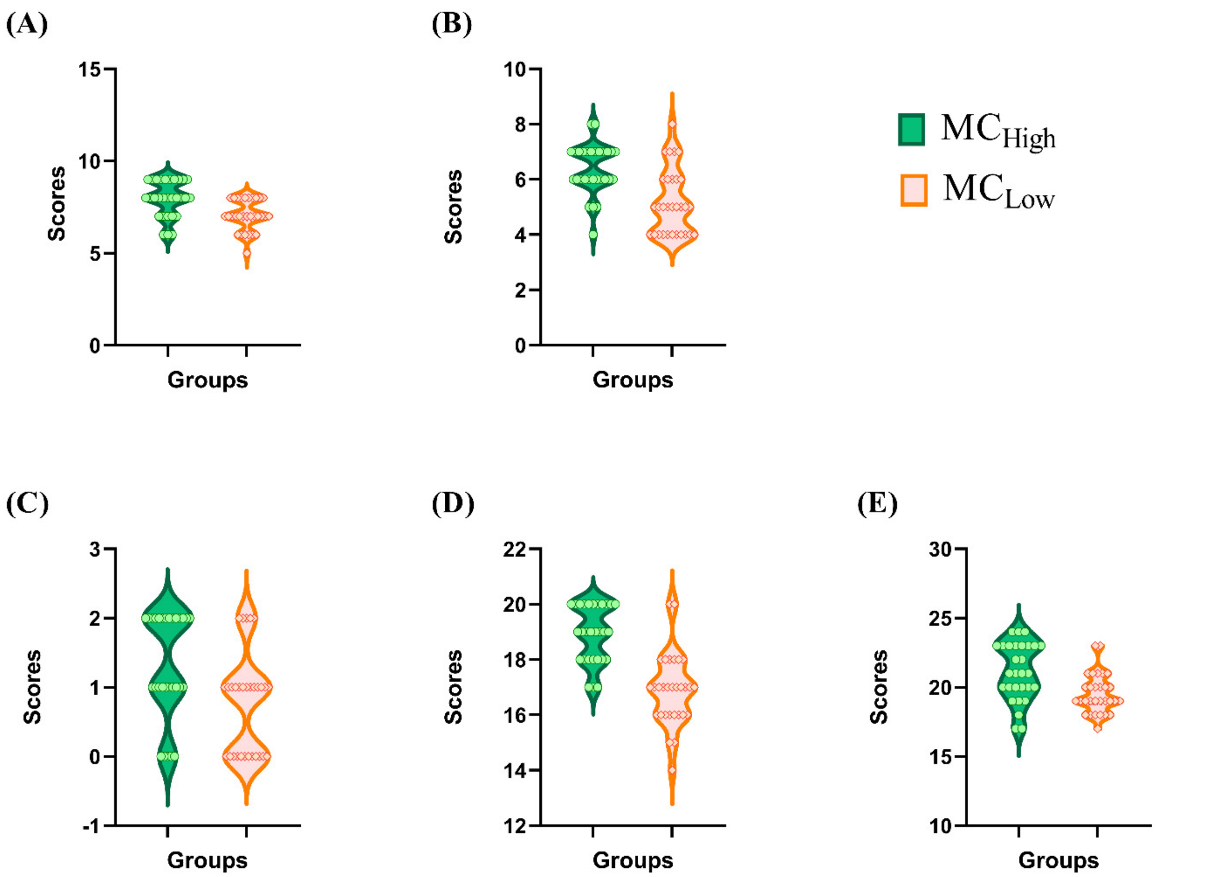

Figure 2. Comparisons between groups across various working memory tests (A) forward span, (B) backward span, (C) operational span, (D) 2n back and (E) speech perception in noise test, respectively: 29 high self-perceived musical competence group and 30 low self-perceived musical competence group. Green circles and orange diamonds indicate the individual scores in tests for the high competence group and low competence group, respectively. MC_{high}; high self-perceived musical competence group, MC_{low}; low musical competence group

This was carried out by comparing case-wise statistics of participants' DF scores against their original pre-verified group membership.

Results

The Shapiro-Wilk test revealed a non-normal distribution of the data ($p<0.05$). The MC_{high} group outperformed the MC_{low} group on all WM tasks and SPIN-IE, as indicated by higher median scores of former groups on the tests considered in the study as shown in Figure 2. Mann-Whitney tests confirmed significant group differences in all WM test scores and SPIN-IE scores. Participants with higher MC demonstrated better performance on the forward span ($Z=3.47$, $p=0.001$, $r_e=0.64$), backward span test ($Z=3.86$, $p<0.001$, $r_e=0.71$), 2n back ($Z=5.14$, $p<0.001$, $r_e=0.95$), operational span task ($Z=2.66$, $p=0.008$, $r_e=0.49$), and SPIN test ($Z=3.17$, $p=0.002$, $r_e=0.58$) compared to the MC_{low} group.

Similarly, the results of the Mann-Whitney U test found no statistically significant group differences in the NASA task force scores ($p>0.05$) across the tests (forward span: $Z=0.98$, $p>0.001$, $r_e=0.12$; backward span test: $Z=0.33$, $p>0.001$, $r_e=0.04$; 2n back: $Z=1.73$, $p>0.001$, $r_e=0.22$; operational span task: $Z=1.77$, $p>0.0001$, $r_e=0.23$; and SPIN test: $Z=0.83$, $p>0.001$, $r_e=0.10$). Participants in the MC_{high} did not rate their LE significantly differently from the MC_{low} group for any WM or SPIN task as depicted in Figure 3.

Results of FDA identified the 2n back and backward span test as the best measure that can distinguish the groups based on their WM test scores. The canonical Discriminant Function (DF), accounted for 100% of the variance (Wilks lambda, λ (5)=0.43, $\chi^2(5)=45.94$, $p<0.001$). An examination of the weights for each test indicated that 2n back followed by backward span were heavily weighed (canonical coefficients) on DF_1, as shown in Table 1. Based on the weights (Table 1),

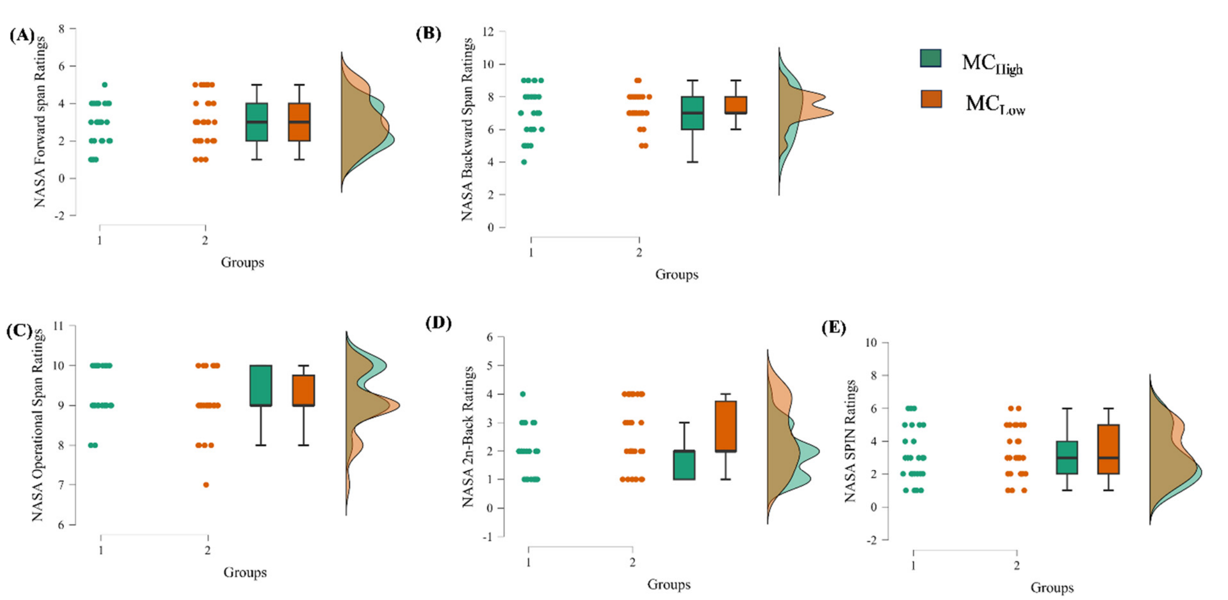

Figure 3. Comparisons between the listening effort rating across the two groups for the working memory tests: (A) forward span, (B) backward span, (C) 2n back, (D) operational span, and (E) speech perception in noise test, respectively: 29 high self-perceived musical competence group and 30 low self-perceived musical competence group. Bars represent median values; green and orange dots indicate the high competence group and the low competence group, respectively. MC_{high}: high self-perceived musical competence group, MC_{low}: low self-perceived musical competence group, NASA: National Aeronautics Space Administration, SPIN: speech perception in noise.

Table 1. Contribution (weights) of auditory tests for group membership prediction of high self-perceived musical competence high and low self-perceived musical competence Low groups

Discriminating variable	Canonical coefficients	Structure matrix
Backward span	0.45	0.51
Forward span	0.15	0.44
2n back	0.60	0.77
Operation span	0.33	0.32
SPIN	0.35	0.40

SPIN; speech perception in noise

Table 2. Accuracy of discriminant function analyses comparing predicted and original group memberships. Total participants from of high self-percieved musical competence high and low self-percieved musical competence low groups are tabulated with the corresponding percentage in parentheses

	Predicted group membership		
Original group	**MC_{high}**	**MC_{low}**	**Total**
MC_{high}	26(89.77%)	3(10.33%)	29(100%)
MC_{low}	5(16.77%)	25(83.33%)	30(100%)

MC_{high}; musical competence high, MC_{low}; musical competence low

the canonical DF obtained in the study is given by the equation below

DF=(0.60×2n back)+(0.45×backward span)+(0.15×forward span)+(0.33×operation span) +(0.35×SPIN)

The error rate in the FDA analysis indicated an overall 86.40% accuracy in the classification, indicative of the clear segregation of the groups based on the weights obtained in the FDA, as indicated in Table 2.

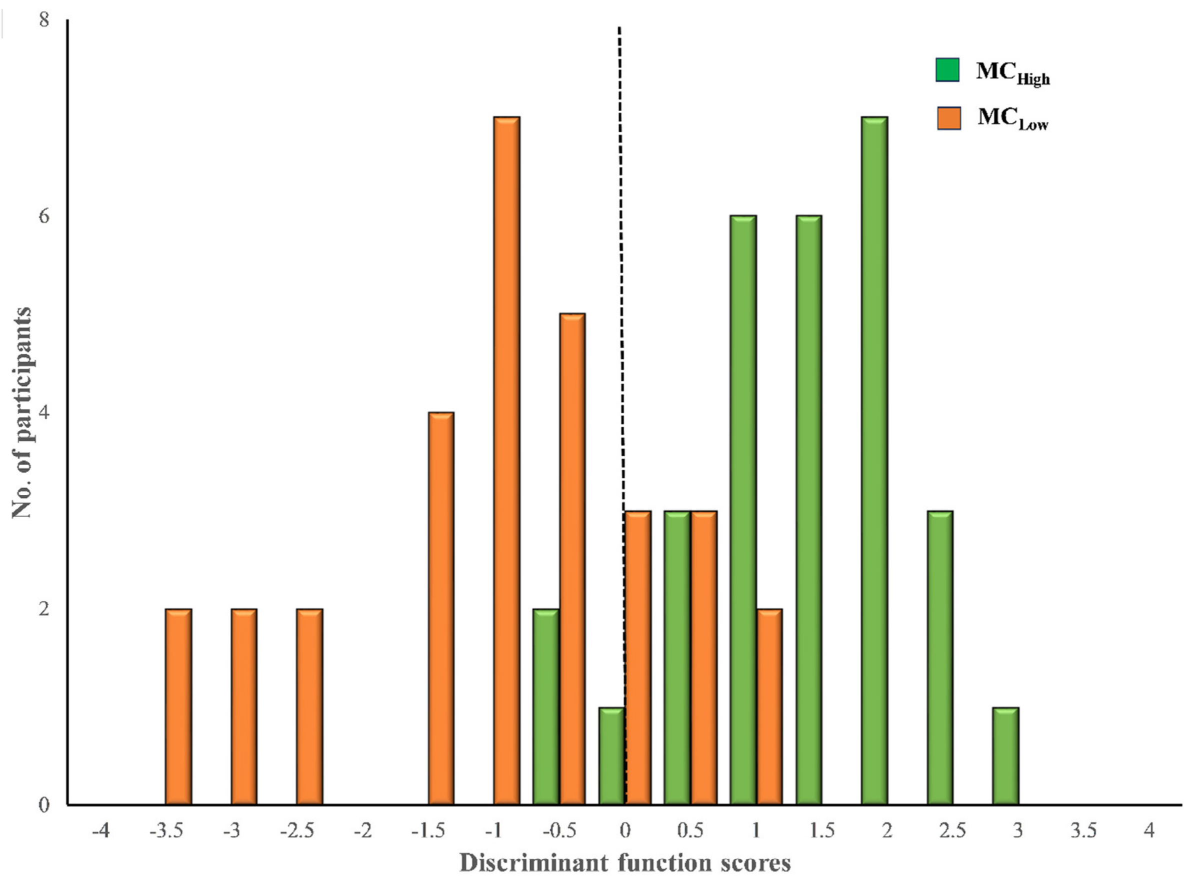

Figure 4. Bar graphs representing the discriminant function scores for the segregation of both groups. The dotted line serves as a reference for cut-off scores between the high self-perceived musical competence and low self-perceived musical competence groups on the discriminant function. MC_{high}; high self-perceived musical competence group, MC_{low}; low self-perceived musical competence group

The separate group plot was obtained using the results of FDA, plotted using the score on the DF1 on abscissa and frequency on the ordinate, as shown in Figure 4.

Discussion

The study found that the MC_{high} group performed significantly better than the MC_{low} group in mental load tasks (Figure 3), indicating a notable impact of MC on task performance ($p<0.05$). The current study hence highlights and extends the literature evidence that superior performance of musicians in speech-in-noise tasks and WM tasks reflect not only musical aptitude or the duration of musical training but also refined based on their self-perception of MC [5, 20, 21]. Those musicians who had a stronger self-belief in the learned musical skills and experience performed better than those who did not.

The MC_{high} group's better performance in WM tasks suggests a potential link between meta-cognition and cognitive function. Meta-cognition involves overseeing and controlling your thinking processes, like memory and problem-solving, significantly influencing cognitive abilities [22]. Self-beliefs about MC and meta-cognition can influence each other. Greater confidence and a positive self-view in MC can improve a musician's ability to set effective practice goals and strategies, boost motivation to learn, and enhance task performance confidence. The study used established tasks like forward span, backward span, 2n back, and operational span to assess executive control and memory manipulation. The MC_{high} group's superior performance suggests that individuals with better metacognitive skills are more effective at managing their cognitive resources, maintaining information, and executing simple and complex cognitive processes [23]. The study revealed that individuals with higher self-perceived MC performed better on the SPIN-IE test, indicating improved interpretation of speech in noisy environments. This finding has significant implications for their social interactions and relationships.

The study identified significant differences across all tests and employed FDA to pinpoint which tests exhibited the most pronounced group distinctions. The findings revealed that the 2n back and backward span tests were the most effective indicators of group disparities among all the tests used. This can be attributed to the fact that these two tests evaluate cognitive functions related to reverse order memory of target stimuli and recalling stimuli positioned amidst distractors, respectively. It's possible to hypothesize that individuals' self-perceived cognitive abilities positively influenced their performance in challenging activities, potentially leading to a significant factor in group membership or segregation. Conversely, improvements in tasks such as forward digit span and SPIN may be attributed to cumulative cognitive enhancement. The operational span test evaluates the capacity to remember specific information while managing distractions, mirroring real-world tasks. However, the test involves arithmetic calculations and demands finer and sophisticated attention and memory capacity to fulfill the demands of the task, the normative score lies around 50% making the test commonly tough for all the participants [24].

FDA yielded two distinct groups based on DR scores (Figure 4) and the error in the classification of FDA was 10 to 18% (Table 2), representative of the high accuracy of the classification. In the WM tasks and SPIN, the MC_{high} group performed significantly better than the MC_{low} group, with both groups finding them equally mentally demanding according to NASA-TLX ratings. However, the Mann-Whitney test did not uncover significant group differences in NASA ratings for the WM tasks and SPIN. This contrast between the WM tasks and NASA-TLX scores warrants further discussion. Although participants perceived a consistent LE, the cognitive load they experienced during the WM tasks was not proportional to their LE ratings. Cognitive load refers to the number of mental resources required to complete a task, and it can vary based on task complexity and demands [17]. The WM tasks may have placed a higher cognitive load on participants, even though they did not perceive it as significantly more effortful.

The study's limitations would be the potential self-report biases in metacognitive assessments and the lack of longitudinal data that limit the generalizability to non-musician populations or diverse age groups. Future research should explore larger and more diverse samples along with an objective assessment of musical aptitude in combination with self-perceived musical competence. Insights into neural correlates of metacognitive and cognitive functions in musicians could also supplement existing understanding of the musician's advantage. The study indicates that higher self-confidence and musical skills improve performance in cognitive tasks like working memory and speech processing.

Conclusion

Study findings highlight the importance of self-belief in musical abilities in shaping cognitive abilities and speech perception in noise. The musicians with high self-perceived Musical Competence (MC) displayed superior performance in cognitive tasks compared to those with low self-perceived MC. The discriminant analysis highlighted the importance of the 2n back test in distinguishing between the groups based on working memory scores.

Ethical Considerations

Compliance with ethical guidelines

The study strictly adhered to ethical guidelines established for bio-behavioral research, as outlined by AIISH Ethics Committee in 2009, Reference Number- (no. SH/CDN/ AUD-11/2023-24).

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Authors' contributions

YS: Acquisition of data, statistical analysis and drafting the manuscript; HM: Interpretation of results and drafting of the manuscript; DC: Acquisition of data; NKV: Study design and supervision, interpretation of results, and critical revision of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

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References

1. Swaminathan J, Mason CR, Streeter TM, Best V, Kidd G Jr, Patel AD. Musical training, individual differences and the cocktail party problem. Sci Rep. 2015;5:11628. Sci Rep. 2015;5:14401. [DOI:10.1038/srep11628]

2. Depp CA, Jeste DV. Definitions and predictors of successful aging: a comprehensive review of larger quantitative studies. Am J Geriatr Psychiatry. 2006;14(1):6-20. [DOI:10.1097/01.JGP.0000192501.03069.bc]

3. Rowe JW, Kahn RL. Successful aging. Gerontologist. 1997;37(4):433-40. [DOI:10.1093/geront/37.4.433]

4. Müllensiefen D, Gingras B, Musil J, Stewart L. The musicality of non-musicians: an index for assessing musical sophistication in the general population. PLoS One. 2014;9(2):e89642. [DOI:10.1371/journal.pone.0089642]

5. Hansen M, Wallentin M, Vuust P. Working memory and musical competence of musicians and non-musicians. Psychol Music. 2012;41(6):779-93. [DOI:10.1177/0305735612452186]

6. Barak O, Tsodyks M. Working models of working memory. Curr Opin Neurobiol. 2014;25:20-4. [DOI:10.1016/j.conb.2013.10.008]

7. Jain C, Mohamed H, Kumar AU. The Effect of Short-Term Musical Training on Speech Perception in Noise. Audiol Res. 2015;5(1):111. [DOI:10.4081/audiores.2015.111]

8. Parbery-Clark A, Strait DL, Anderson S, Hittner E, Kraus N. Musical experience and the aging auditory system: implications for cognitive abilities and hearing speech in noise. PLoS One. 2011;6(5):e18082. [DOI:10.1371/journal.pone.0018082]

9. Yates KM, Moore DR, Amitay S, Barry JG. Sensitivity to Melody, Rhythm, and Beat in Supporting Speech-in-Noise Perception in Young Adults. Ear Hear. 2019;40(2):358-67. [DOI:10.1097/AUD.0000000000000621]

10. Zendel BR, West GL, Belleville S, Peretz I. Musical training improves the ability to understand speech-in-noise in older adults. Neurobiol Aging. 2019;81:102-15. [DOI:10.1016/j.neurobiolaging.2019.05.015]

11. Pichora-Fuller MK, Kramer SE, Eckert MA, Edwards B, Hornsby BW, Humes LE, et al. Hearing Impairment and Cognitive Energy: The Framework for Understanding Effortful Listening (FUEL). Ear Hear. 2016;37 Suppl 1:5S-27S. [DOI:10.1097/AUD.0000000000000312]

12. Phillips NA. The Implications of Cognitive Aging for Listening and the Framework for Understanding Effortful Listening (FUEL). Ear Hear. 2016;37 Suppl 1:44S-51S. [DOI:10.1097/AUD.0000000000000309]

13. Escobar J, Mussoi BS, Silberer AB. The Effect of Musical Training and Working Memory in Adverse Listening Situations. Ear Hear. 2020;41(2):278-88. [DOI:10.1097/AUD.0000000000000754]

14. Okely JA, Deary IJ, Overy K. The Edinburgh Lifetime Musical Experience Questionnaire (ELMEQ): Responses and non-musical correlates in the Lothian Birth Cohort 1936. PLoS One. 2021;16(7):e0254176. [DOI:10.1371/journal.pone.0254176]

15. Venkateesan S. Ethical guidelines for research involving human participants Version 1.0. Internet Mysuru: AIISH; 2024 [cited 2024 Feb 22]. Available from: http://www.aiish.in/ethical-guidelines

16. Kumar AU, Sandeep M. Development and test trail of computer based auditory-cognitive training module for individuals with cochlear hearing loss. Departmental Project [unpublished], Mysore: All India Institute of Speech and Hearing; 2013.

17. Cao A, Chintamani KK, Pandya AK, Ellis RD. NASA TLX: software for assessing subjective mental workload. Behav Res Methods. 2009;41(1):113-7. [DOI:10.3758/BRM.41.1.113]

18. Yathiraj A, Vanaja CS, Maturation of Auditory Processes in Children aged 6 to 10 years. Departmental Project [unpublished], Mysore: All India Institute of Speech and Hearing; 2009. Available from: http://192.168.100.26:8080/xmlui/handle/123456789/4080

19. Rosenthal R, Rubin DB. r equivalent: A simple effect size indicator. Psychol Methods. 2003;8(4):492-6. [DOI:10.1037/1082-989X.8.4.492]

20. Nisha KV, Neelamegarajan D, Nayagam NN, Winston JS, Anil SP. Musical Aptitude as a Variable in the Assessment of Working Memory and Selective Attention Tasks. J Audiol Otol. 2021;25(4):178-88. [DOI:10.7874/jao.2021.00171]

21. Coffey EBJ, Mogilever NB, Zatorre RJ. Speech-in-noise perception in musicians: A review. Hear Res. 2017;352:49-69. [DOI:10.1016/j.heares.2017.02.006]

22. Mahmood S, Batool IN, Shahid K, Bhopal KF, Bhopal SF, Shahid N. Metacognition. Rawal Medical Journal. 2016;41(4):467-70.

23. Eser BN, Şerbetçioğlu MB. Auditory Short-Term Memory Evaluation in Noise in Musicians. J Am Acad Audiol. 2022;33(7-08):375-80. [DOI:10.1055/a-1896-5129]

24. Beaman CP. The irrelevant sound phenomenon revisited: what role for working memory capacity? J Exp Psychol Learn Mem Cogn. 2004;30(5):1106-18. [DOI:10.1037/0278-7393.30.5.1106]

Appendix 1. Questions from the Edinburgh Lifetime Musical Experience Questionnaire (ELMEQ), used to assess the competence of the participants from 3 subsections: Musical Instruments, Singing and Listening to music.

Question	Options				
Score Weightage	1	2	3	4	5
How easy do you find it to clap your hands in time to music?	Very Difficult	Difficult	Not Sure	Easy	Very Easy
How easy do you find it to dance in time to music?	Very Difficult	Difficult	Not Sure	Easy	Very Easy
How easy do you find it tossing a melody in tune?	Very Difficult	Difficult	Not Sure	Easy	Very Easy

Appendix 2. NASA Task Load Index (NASA-TLX) Questionnaire

Dimension	Question
Mental demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating remembering looking searching etc. was the task easy or demanding, simple or complex, exacting or forgiving.
Physical demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal demand	How much time pressure did you feel due to the rate of pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Effort	how hard did you have to work (mentally and physically) to accomplish your level of performance?
Performance	How successful do you think you were in accomplishing the goals, of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals
Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?