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RESEARCH ARTICLE

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The relationship between playing musical instruments and cognitive trajectories: Analysis from a UK ageing cohort

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Abstract

Background: The accumulation of age-associated cognitive deficits can lead to Mild Cognitive Impairment (MCI) and dementia. This is a major public health issue for the modern ageing population, as it impairs health, independence and overall quality of life. Keeping the brain active during life has been associated with an increased cognitive reserve, therefore reducing the risk of cognitive impairment in older age. Previous research has identified a potential relationship between musicality and cognition.

Objectives: Explore the relationship between musicality and cognitive function in a large cohort of older adults.

Methods: This was a nested study within the PROTECT-UK cohort, which collects longitudinal computerised assessments of cognitive function in adults over 40. Participants were invited to complete the validated Edinburgh Lifetime Musical Experience Questionnaire (ELMEQ) to assess their musical experience and lifetime exposure to music. Linear regression analysis was performed using cognitive data from PROTECT-UK.

Results: Analysis identified an association between musicality and cognition in this cohort. Playing a musical instrument was associated with significantly better performance in working memory and executive function. Significant associations were also found between singing and executive function, and between overall musical ability and working memory.

Conclusions: Our findings confirm previous literature, highlighting the potential value of education and engagement in musical activities throughout life as a means of harnessing cognitive reserve as part of a protective lifestyle for brain health.

KEYWORDS
ageing, cognition, dementia, longitudinal, music, Protect

Key points

- Playing a musical instrument was associated with significantly better working memory and executive function.
- Singing and overall musical ability was associated with more favourable cognition.
- Engagement with musical activities should be considered as part of public health initiatives to promote a protective lifestyle for brain health.

1 | INTRODUCTION

Many industrialised nations across the globe have an ageing population as a result of a decreased birth rate and increased life expectancy. Ageing is associated with multiple long-term concerns such as cardiovascular disease and neuropsychiatric conditions including dementia.[1,2] Dementia is characterised by a progressive worsening of cognitive function leading to a loss of function and independence.[2] Alzheimer's Disease is the main cause of dementia and a major cause of mortality. Importantly, dementia also represents a major public health issue, costing 1.3 trillion US dollars to international economies in 2019.[2] Dementia is preceded by gradual accumulation of cognitive deficits leading to Mild Cognitive Impairment (MCI), which represents the largest group of at-risk individuals in the community and affects 15.56% of people above the age of 50 worldwide, according to a recent meta-analysis.[3] It is therefore critical to fully understand the factors that influence the process of cognitive decline and risk of dementia in later life, including factors that occur throughout the life course.

There is well-established evidence to support the role of cognitive reserve in cognitive function. Several lifestyle factors that keep the brain active appear to increase cognitive reserve and are associated with more favourable cognitive trajectory.[4–6] These include employment, educational attainment and leisure activities, even when practiced later in life.[4] Scarmeas et al. also found that people who had engaged more with leisure activities were less likely to develop Alzheimer's Disease.[6] One such activity that warrants attention is engagement with music. Musical practice has been associated with healthy neurocognitive ageing.[7,8] It has also been associated with an increased volume of brain regions associated with memory, executive function, emotion and language.[9]

Musical practice has been shown to improve multiple aspects of cognitive function across the life-course, from childhood to older age.[7,10–14] Longitudinal studies have shown an increase in IQ in children who engage with music lessons[13,14] and improvements in concentration, reading, processing speed and total IQ even in children from low socioeconomic backgrounds.[14] This is important since playing a musical instrument is associated with a higher education and socioeconomical status.[15] Interestingly, the literature shows that some of these benefits can persist into adulthood.[15–18] A study from 2012 found that the auditory brain stem was more responsive in adults if they had received formal music lessons during childhood, although these effects decline over time.[16] Another study reported improved auditory function in 44 adults aged 55–76 after finishing their musical training.[19] Furthermore, it has been found that people over 65 who still play music have a better executive function.[17] Current and former musicians were also found to perform better on language, attention and processing speed tests compared to people who have never played music.[17] Multiple papers suggested that the benefit on cognition would be maximised by learning music earlier in life,[11,20,21] and if maintained during advanced age.[21]

The literature identified a positive association between playing a musical instrument and multiple aspects of cognition,[20,22] and a recent systematic review and meta-analysis suggested that playing a musical instrument reduced the risk of MCI and dementia.[23] Another study showed that formal musical training may lead to better episodic and semantic memory in older age.[11] Moreover, a small cross-sectional study[24] found that active choir singers above the age of 60 performed better in verbal flexibility compared to non-singers. Lastly, there seems to be a strong association between musicianship and working memory.[25–28] In fact, a study that explored the basis of musical memory found that musicians had better visuospatial, musical and verbal memory compared to non-musicians.[27] Furthermore, it has been suggested that musical training has beneficial effects on multiple specific aspects of the working memory.[26] A meta-analysis also found better performance in long-term, short-term and working memory tasks in musicians.[28]

There is an opportunity to explore these associations further in a large cohort of older adults. The PROTECT-UK (Platform for Research Online To invEstigate Cognition and geneTics in ageing) online ageing cohort conducts longitudinal computerised cognitive assessment and supports bespoke data collection through a full consent-for-contact process. This study describes an analysis of the association between cognitive performance and engagement with music across the life-course using the well validated Edinburgh Lifetime Musical Experience Questionnaire (ELMEQ) questionnaire[29] to explore whether the associations reported in previous literature apply in this large well-characterised cohort. The primary hypothesis is that the participants who have engaged with musical practice throughout their lives will have more favourable cognitive function compared to those who did not.

2 | MATERIALS AND METHODS

2.1 | Study design

This is an analysis of cognitive and musicality data collected in a nested study, SCALE (MuSiCALExperience and Healthy Ageing),

which was delivered through the online PROTECT-UK cohort study. SCALE received ethical approval from the University of Exeter Medical School Research Ethics Committee (ref: 489,789), was launched 1st April 2022 and closed 23rd April 2023. PROTECT-UK (http://www.protectstudy.org.uk/) was launched in November 2015 and received ethical approval from the UK London Bridge National Research Ethics Committee (Ref: 13/LO/1578). Cognitive data included in this study was collected between March 2019 and March 2022.

2.2 | Participants and eligibility criteria

Participants were aged 40 and over, required access to a computer and the Internet and did not have a diagnosis of dementia. All participants were already enroled in the PROTECT cohort and had at least 1 year of cognitive data. Enrolment to the SCALE study was completed via the PROTECT study website. PROTECT participants were contacted by email and signposted to the SCALE study on their PROTECT study dashboard. Participants provided electronic informed consent through a validated online registration and consent process.

2.3 | Demographic data collection

All participants provided demographic information at baseline through an online questionnaire adapted from the Office of National Statistics, which included age, sex, ethnicity, and education level. Education level was categorized from secondary education (GCSE/O-Levels) (score of 1) to Doctorate (PhD) (score of 6).

2.4 | Questionnaire data

The participants completed an adapted version of the ELMEQ questionnaire,[29] which assesses self-reported musical expertise. It comprises four sections: playing a musical instrument, singing, reading music and listening to music, which represent validated factors in musical expertise.

2.5 | Cognitive assessment

Cognitive performance was measured using a computerised cognitive test system embedded in the PROTECT study platform. Data for each participant registered in the SCALE study was requested from PROTECT via an established data access request process. Participants complete the cognitive test system up to three times at each annual timepoint. The test system includes three tests for working memory (Paired Associate Learning (PAL), Digit Span (DS) and Self-Ordered Search (SOS)) and one test for executive function (Baddeley's Verbal Reasoning (VR)), all of which have been described in detail elsewhere.[30] For each individual task the outcome measure is the total score of correct responses with total number of errors removed. The tests are also components of the recently published FLAME composite,[31] which has produced evidence of sensitivity for detection of cognitive change. Scores from Paired Associate Learning, Digit Span and Self-Ordered Search tasks can be combined to provide a validated composite measure for working memory.

2.6 | Data analysis

Musicality data from the ELMEQ was extracted to provide descriptive statistics for musical experience. The data were combined into validated factors based on a previously published factor analysis[29] to provide four factors (playing a musical instrument, singing, listening to music and self-reported ability), shown in Table 1. Cognitive data was included for all participants with at least three testing sessions available. The working memory composite measure was calculated according to the FLAME working memory composite published elsewhere[31] to give a total of five cognitive outcomes (SOS total score, PAL total score, DS total score, VR total score and working memory composite). Cognitive data were pooled and averaged, and a linear regression analysis was performed to assess the extent to which the music factors, current engagement with music and type of instruments played contribute to cognitive scores. The model covaries with sex, age, educational attainment, and the number of times a participant had completed the cognitive tests. These variables were modelled as continuous factors. Results are presented as effect sizes with confidence intervals and associated null hypothesis probabilities.

3 | RESULTS

3.1 | Cohort characteristics

In total, 1570 PROTECT participants consented to the SCALE nested study and completed the questionnaire on the PROTECT-UK website, and 1107 were included in our analysis. The population was 83% female with a mean age of 67.82 years (SD 7.04). The average education was between degree level and post-graduate degree (mean of 3.69, SD 1.29), on a scale of 1 (GCSE/O-levels) to 6 (Doctorate, PhD).

3.2 | Characterisation of musical experience in the SCALE cohort

Data from the ELMEQ questionnaire showed that 89% of participants had experience of playing a musical instrument, with 44% continuing to play currently (Table 2). The majority of participants who reported playing an instrument played either a keyboard or woodwind instrument (Figure 1), and the majority had played either

TABLE 1 Breakdown of items included in the factor analysis, based on the research previously published by Okely et al [15,20,29].

	Question items included
Factor 1: Playing a musical instrument	• Have you ever learned to play a musical instrument? • On how many musical instruments could you comfortably perform a short piece of music (either in the past or currently)? • How many years of formal musical training did you complete? • For how many years of your life in total would you say that you regularly (e.g. at least once a week) played a musical instrument of some kind (not including breaks)? • During the years you played your instrument(s) regularly, how many hours per week did you practise, on average (not including group practise)? • Overall, what would you say is the highest level of musical performance that you reached?
Factor 2: Singing	• For how many years in total have you sung in a group (choir/band or ensemble) not including breaks? • During the years you sang in a group (choir/band or ensemble), for how many hours per week did you practise, rehearse or perform together, on average? • How many years of formal solo vocal training did you complete?
Factor 3: Listening to music	• On average, over the course of your life, how many hours per week would you say that you have actively listened to recorded music such as via the stereo, radio, or other device, by choice? • On average, over the course of your life, how many live music concerts or gigs do you/have you attended per year? • As a child, how often do you think your parents sang lullabies, nursery rhymes, or other songs in the home?
Factor 4: Self-reported ability	• How easy do you find it to clap your hands in time to music? • How easy do you find it to dance in time to music? • How easy do you find it to sing a melody in tune?

TABLE 2 SCALE participant responses to key questions across the ELMEQ questionnaire, based on the study previously published by Okely et al.[29].

		Yes	No	Missing
Have you ever learned to play a musical instrument?	N (%)	1392 (89)	178 (11)	0 (0)
Do you still play a musical instrument currently?	N (%)	690 (44)	702 (45)	178 (11)
Have you ever played with a band, ensemble or orchestra?	N (%)	695 (44)	696 (44)	179 (11)
Have you ever sung in a group (choir, band, or another kind of ensemble)?	N (%)	1118 (71)	451 (29)	1 (0)
Did you have any formal solo vocal training (e.g. school lessons, private lessons or conservatoire training)?	N (%)	228 (15)	1341 (85)	1 (0)
Have you ever learned to read any kind of music notation?	N (%)	1306 (83)	262 (17)	2 (0)

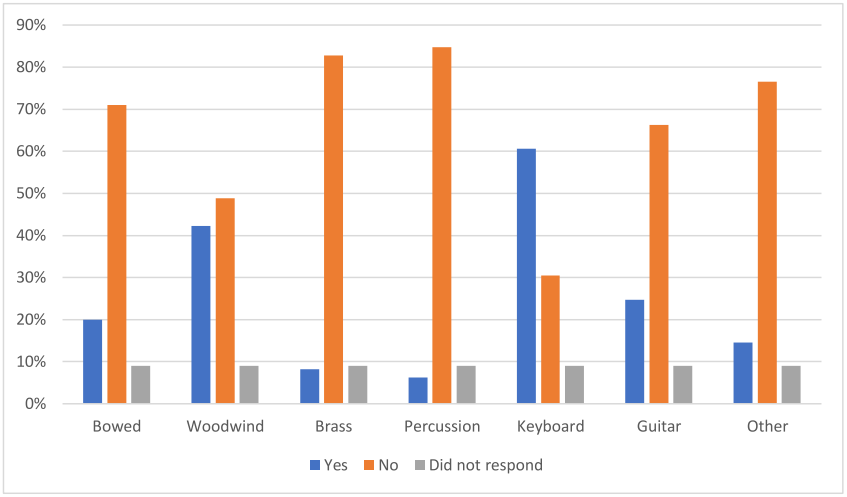

FIGURE 1 Types of musical instrument played by the SCALE cohort. Bowed instruments include violin, viola, violoncello and double bass.

one (28%) or two (23%) instruments although 4% reported playing five or more. 44% had been involved in instrumental group musical activity (Table 2).

Seventy eight% of participants reported receiving formal musical training, most commonly for two to 5 years. Moreover, the majority of participants had played for a limited number of years in their lives, most commonly five or less (27%). During the years they were regularly playing a musical instrument, participants reported practicing two to 3 hours a week (37%) or less (27%) (Figure 2).

With regards to vocal musical experience, 71% had taken part in a singing group whilst 15% had received formal solo training. As a marker of ability, most people reported reaching an intermediate level of musical performance (44%) whilst 83% reported that they had learned to read musical notation (Table 2).

3.3 | Association of musical experience with cognition

Analysis of cognitive performance with responses to the four factors of musicality (Table 3) showed significant associations across the factors, but particularly in Factor 1 ('Playing'). Participants who responded positively to the 'Playing' factor questions performed significantly better in working memory and executive function tasks,

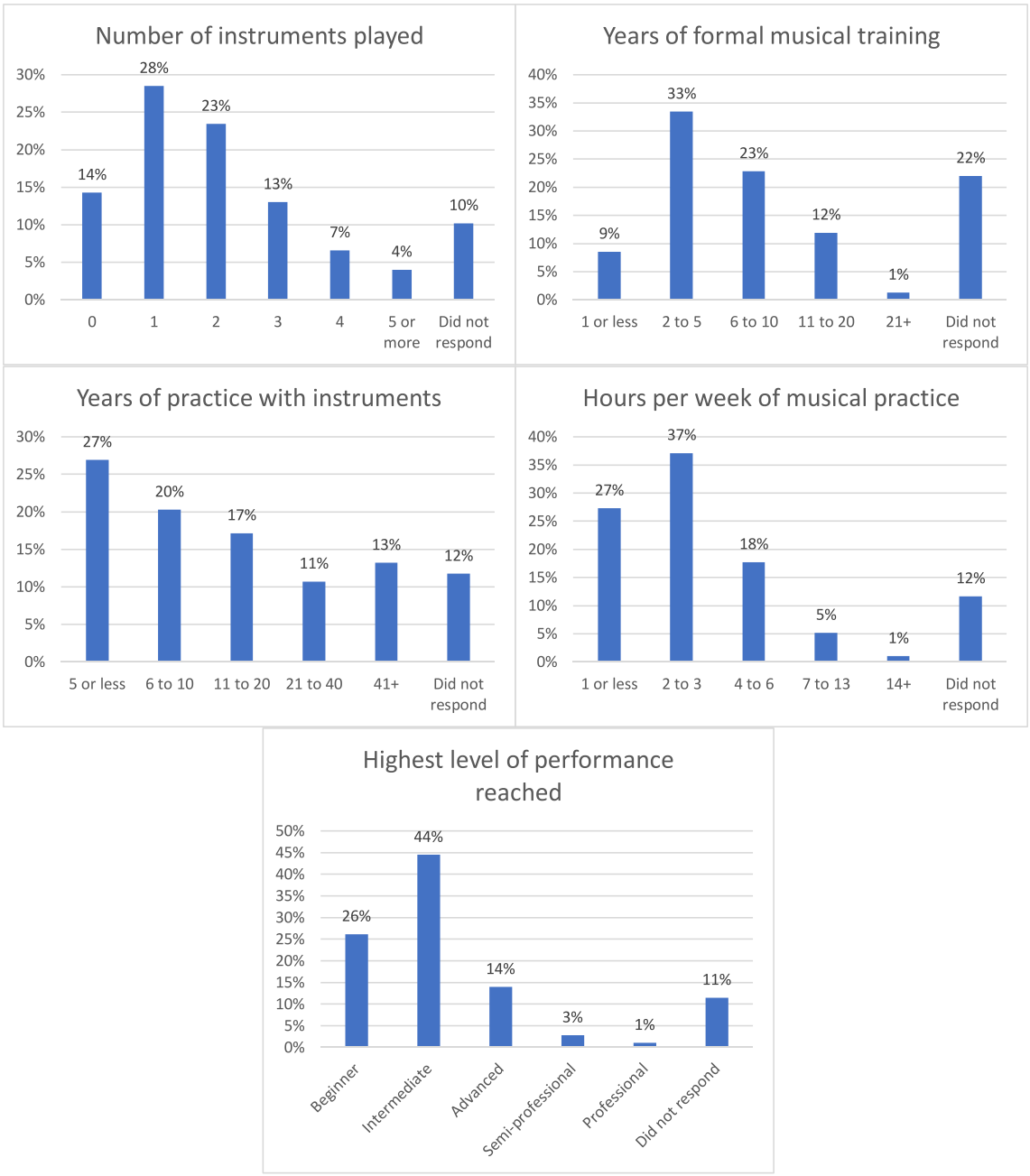

FIGURE 2 SCALE participant responses for the questions included in the analysis of 'Factor 1: Playing a Musical Instrument'.

TABLE 3 Association of cognitive performance with scores on the four factors of musicality in the ELMEQ questionnaire.

	Factor 1		Factor 2		Factor 3		Factor 4	
	Playing a musical instrument		Singing		Listening to music		Musical ability	
	Effect size (CI)	P	Effect size (CI)	P	Effect size (CI)	P	Effect size (CI)	P
Verbal reasoning	0.17 (0.05, 0.29)	0.005	0.15 (0.03, 0.28)	0.014	0.04 (−0.09, 0.16)	0.564	0.09 (−0.02, 0.21)	0.121
Digit span	0.15 (0.04, 0.27)	0.011	0.12 (0.00, 0.24)	0.056	0.12 (0.00, 0.24)	0.058	0.15 (0.03, 0.27)	0.011
Paired associate memory	0.24 (0.12, 0.35)	<0.0001	0.07 (−0.05, 0.20)	0.243	−0.02 (−0.14, 0.10)	0.723	0.07 (−0.05, 0.18)	0.265
Self-ordered search	0.21 (0.09, 0.33)	0.0004	0.09 (−0.03, 0.21)	0.155	−0.12 (−0.24, 0.00)	0.051	0.03 (−0.09, 0.15)	0.602
Working memory composite	0.24 (0.12, 0.36)	<0.0001	0.12 (0.00, 0.24)	0.054	−0.02 (−0.14, 0.10)	0.706	0.10 (−0.01, 0.22)	0.084

TABLE 4 Association of cognition with type of instrument played.

	Keyboard		Woodwind		Brass instrument	
	Effect size (CI)	P	Effect size (CI)	P	Effect size (CI)	P
Verbal reasoning	0.11 (−0.01, 0.23)	0.077	0.13 (0.005, 0.25)	0.04	0.03 (−0.15, 0.09)	0.660
Digit span	0.14 (0.01, 0.26)	0.030	0.03 (−0.15, 0.09)	0.652	0.14 (−0.26, 0.01)	0.025
Paired associate memory	0.26 (0.13, 0.38)	<0.0001	0.06 (−0.06, 0.19)	0.031	0.15 (0.28, 0.03)	0.014
Self-ordered search	0.18 (0.06, 0.31)	0.004	0.11 (−0.01, 0.23)	0.077	0.06 (−0.18, 0.06)	0.30
Working memory composite	0.23 (0.11, 0.35)	<0.0001	0.06 (−0.06, 0.19)	0.305	0.14 (−0.26, 0.02)	0.028

Note: Instruments with no significant association (percussion, bowed, guitar and 'other') are not shown.

with effect sizes exceeding 0.2 in Paired Associate Learning (ES 0.24, $p < 0.0001$), Self-Ordered Search (ES 0.21, $p = 0.0004$) and the working memory composite (ES 0.24, $p < 0.0001$) and above 0.1 in Digit Span (ES 0.15, $p < 0.011$) and Verbal Reasoning (ES 0.17, $p < 0.005$). The effect on working memory was particularly seen in individuals who reported playing the keyboard (either alone or in combination with other instruments), with these participants showing significantly more favourable performance in all three working memory tasks (Paired Associate Learning ES 0.26 $p < 0.0001$; Self-Ordered Search ES 0.18 $p = 0.004$; Digit Span ES 0.14 $p = 0.03$; Working memory composite ES 0.23 $p < 0.0001$). Working memory was also significantly better in people who played a brass instrument (Paired Associate Learning ES 0.15, $p = 0.014$; Digit Span ES 0.14, $p = 0.025$; Working memory composite ES 0.14, $p = 0.028$)). Participants who played a woodwind instrument showed significantly better performance in the executive function task (ES 0.13, $p = 0.04$) (Table 4). There was no significant difference when comparing participant who played single instruments with those who played multiple instruments.

With regard to the other musical factors, there was a significant association between singing and executive function, with an effect size of 0.15 ($p < 0.014$) in the total verbal reasoning outcome. Higher musical ability was also associated with better performance on the numerical working memory task of Digit Span (ES 0.15, $p < 0.011$). No statistically significant associations were seen between listening to music and cognitive performance.

A comparison of participants who currently play a musical instrument with those who have done previously showed significantly better performance in two of the three measures of working memory (Paired Associate Learning ES 0.13, $p = 0.043$; Digit Span ES 0.21, $p = 0.0013$) and the working memory composite (ES 0.17, $p = 0.0076$) in people who currently engage in music. No significant effect was seen in the Self-Ordered Search task or in executive function.

4 | DISCUSSION

This study reports on the association of musicality and cognition in a large cohort of older adults, confirming clear, significant associations between key musical factors and cognitive performance. The study shows that playing a musical instrument is associated with better working memory and executive function. We also found positive associations between singing and executive function, and between overall musical ability and working memory. The findings confirm those reported in previous studies, adding strength to the evidence base relating to musical engagement and cognitive health, and highlighting the potential value of education and engagement in musical activities throughout life as a means of harnessing cognitive reserve as part of a protective lifestyle for brain health.

The effect sizes for the associations reported in this study were statistically significant and ranged from 0.15 to 0.24. Whilst these effect sizes are small when considered in the context of a

pharmacological intervention, they are considerable when applied to a population health perspective. In particular, the analysis of Factor 1 (experience playing a musical instrument) produced statistically significant effect sizes for all cognitive measures, and particularly in visuospatial working memory and the working memory composite. This aligns with previous findings by Okely et al. who also conducted a longitudinal cognitive assessment with the ELMEQ questionnaire.[15,20,29] In fact, Okely et al. published a study in 2022, which found a small positive association between the use of musical instruments and lasting improvements in cognition.[15] A further study by Okely et al.[20] also found that greater experience playing a musical instrument led to better verbal memory, processing speed, and visuospatial and verbal abilities, hence improving cognition in general but also under specific aspects.

These findings and the ones by Okely et al.[20] support the theory that learning to play a musical instrument has lasting impacts on multiple aspects of cognition, including executive function and working memory.[22,26,28,32,33] The findings particularly point towards a greater benefit to working memory, but not to executive function, when musical engagement is continued into older age. Many musicians that took part in this study played the keyboard, which has previously been associated with better executive function and a greater activity among the pre-frontal and mid-central regions of the brain 34. In this study however, keyboard and, to a lesser extent, brass instrument play was strongly associated with better working memory, with executive function favoured in woodwind players. A study reported that this benefit, even if to a lesser extent, is also found with singing.[33] This was in line with the findings in this study, as singing was associated with verbal reasoning (executive function) but not memory. Similarly to the explanation proposed by Mansens et al.,[33] this difference may be due to the multiple cognitive demands of playing a musical instrument (musical notation, listening and understanding tonality, physical coordination of playing), as opposed to singing. Moreover, group singing has been associated with improvements in verbal memory[35] and verbal fluency,[36] so this may be an underlying mechanism contributing to the findings in this study for verbal reasoning. However, there is less literature regarding singing and cognition in older age, as opposed to playing a musical instrument, so more research is needed in this field. Group musical activities such as choral and instrumental groups incorporate social components in addition to engagement with music. Social engagement is known to be associated with cognitive health[37] so there may be interplay in the related benefits of musical activity and social activity in participants taking part in these types of music.

With regards to musical ability (Factor 4), the small impact seen on numerical working memory may be attributed to learning rhythm patterns. A study found that rhythm competence was associated with better auditory working memory, as opposed to melody competence, and suggested that processing a musical rhythm puts greater strain on the working memory.[38] Interestingly, another study[39] found that salsa dancers had better executive function but no difference in spatial memory, compared to non-dancers. Even though dancing and hand-clapping ability were included in the analysis of Factor 4, this study did not find an improvement in executive function for this factor. This may be due to limitations of the ELMEQ questionnaire in assessing dancing and rhythm ability. Future research should examine this domain to elucidate its link with cognitive function.

This study did not find a link between listening to music and cognitive ability. This may be due to limitations in the study in assessing this domain and to results varying based on the type of music that people listened to. For example, Rauscher et al.[40] proposed that listening to Mozart's KV448 improved spatial ability, which became known as the 'Mozart Effect'. However, a meta-analysis from 2010 discovered that the effect of this enhanced performance was small in size and in fact similar to listening to other types of music.[41] Future research could gain more information about the type and habits of music listening to explore whether this has an impact on different aspects of cognition.

The present study had a large population size of 1570 total participants, of which 89% played a musical instrument, meaning the data is meaningful and at scale. However, this also created an uneven split with the 'non-musician' group (11%), which could have affected the results for this group. The non-musician group may represent a biased group since these individuals chose to complete the questionnaire despite not having a musical history. Data was not collected regarding their motivations. Moreover, the population comprised of more women (83%) than men (17%). The PROTECT cohort itself is over-represented in females so in part this may explain this lack of balance. There is a known gender difference in cognitive trajectory in ageing so this may also have introduced a component of bias, but this was controlled for in the analysis. It is possible that there may have been other confounding factors which were not identified and therefore not controlled for in this study. For example, Okely et al.[15] also controlled for childhood cognitive ability, childhood and adulthood economic status, and other confounding variables. Another limitation of our study is that the results of the questionnaire are self-reported from the participants, which could have introduced some bias. The cohort is also self-selected with limited diversity in ethnicity and so caution should be taken when applying the findings on a population scale. Lastly, since the study employed a brief cognitive test battery it may not have detected impacts to other cognitive domains. Future research could make use of a more in-depth capture of musicality, including key aspects such as testing proficiency in musical notation, musical theory or objective measures of proficiency, or to investigate other aspects of cognition including attention and episodic memory to explore how they are affected by music. Moreover, examination of the longitudinal impact of playing a musical instrument, singing, listening to music and musical ability would be of interest. The PROTECT study offers the opportunity to achieve this through analysing cognitive trajectory within the existing cohort.

5 | CONCLUSION

This study found that playing a musical instrument was associated with improved working memory and executive function in older adults, while singing and overall musical ability was also associated with more favourable performance. Continuing engagement with

music into later life is also associated with better working memory function. Although more research is needed to investigate this relationship, our findings suggest that promoting the exposure to music during life can increase cognitive reserve and reduce the risk of cognitive impairment in older age. Given the potential population-wide impact of these findings in the wider context of cognitive research and the well-established impact of lifestyle choices on the risk of cognitive decline, the strength of evidence in this field warrants consideration when forming policy in musical education in early life. Furthermore, public health interventions to promote healthy ageing and dementia risk reduction should consider including advice for adults on engaging with music. In particular, adults may be encouraged to take part in community music or singing groups or to re-engage with an instrument they have played in former years. There is considerable evidence for the benefit of music group activities for individals with dementia, and this approach could be extended as part of a health ageing package for healthy older adults to enable them to proactively reduce their risk and to promote brain health.

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CONFLICT OF INTEREST STATEMENT

CB has received consulting fees from Acadia pharmaceutical company, AARP, Addex pharmaceutical company, Eli Lily, Enterin pharmaceutical company, GWPharm, H.Lundbeck pharmaceutical company, Novartis pharmaceutical company, Janssen Pharmaceuticals, Johnson and Johnson pharmaceuticals, Novo Nordisk pharmaceutical comapny, Orion Corp pharmaceutical company, Otsuka America Pharm Inc, Sunovion Pharm. Inc, Suven pharmaceutical company, Roche pharmaceutical company, Biogen pharmaceutical company, Synexus clinical research organization and tauX pharmaceutical company and research funding from Synexus clinical research organization, Roche pharmaceutical company, Novo Nordisk pharmaceutical company and Novartis pharmaceutical company. AC discloses financial relationships with Suven and Janssen pharmaceutical companies for consultancy work; HB discloses directorship of cognitive testing company ECog-Pro; AH discloses directorship of cognitive testing company Future Cognition; GV, GW, AP, EP and MR report no financial relationships with commercial interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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