Relationships between Music, Sport, and Executive Function Skills in University Students

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Abstract

Executive function skills are related to academic outcomes, implying that executive function could be important for academic success at university. In addition to academic achievement, executive function skills are also associated with music and sport, suggesting that involvement in music and sport *may* be helpful in improving executive function skills. This study examined and compared associations between music, sport, and executive function in university students. Participants answered an online questionnaire regarding music and sport experience, and completed three executive function tests, one for each executive function process: inhibition, shifting, and working memory. A follow-up interview was also conducted to investigate possible executive function skills that could be transferred from music and sport. Correlations indicated that there were relationships between music/singing ability and inhibition, sport perceptual ability and shifting, and combined music and sport perceptual ability/emotion and shifting. The results from the interviews suggested that skills, such as time management and collaboration, could be learned during music and sport and transferred to university studies, or the other way around. As there are many practical implications, future research could examine whether music and sport improve executive function skills or if there are other explanations for the associations between music, sport, and executive function. Possible practical implications could involve using music and sport to improve executive function skills, which could in turn increase academic achievement. Conversely, training in executive function could be helpful in improving sport and music performance.

Keywords: executive function, self-regulation, music, sport, university students

Relationships between Music, Sport, and Executive Function Skills in University Students

Education is important as there are many benefits for both the person receiving education and for society. It supports people in reaching their full potential (UNESCO & Right to Education Initiative, 2019). Executive function skills are related to academic success (Sheehan & Iarocci, 2015) and self-regulated learning (Follmer & Sperling, 2016). It is possible that improving executive function skills could lead to academic success (Holochwost et al., 2017) and better self-regulated learning. Music and sport training have been found to be associated with improved executive function (Okada & Slevc, 2018; Zheng et al., 2022). This implies that becoming involved in music and sport may help improve executive function skills, which could lead to better academic achievement. It is important to note, however, that while research into music, sport, and executive function is largely correlational, there have been some experimental designs to examine the causality of these relationships. For example, Holochwost et al. (2017) found that enrolment in a music programme led to improved executive function skills as well academic achievement, supporting the theory that music training may result in improved cognitive function and academic outcomes possibly through implicit training in skills that underpin academic achievement, such as executive function skills.

Executive function refers to the human capability of regulating your behaviour, including controlling your emotions, behaviour and thinking, remembering instructions, and focusing attention. It comprises three main processes: inhibition, shifting (or cognitive flexibility), and working memory (or updating) (Miyake et al., 2000). These form the basis of other executive functions, including problem solving. Inhibition refers to focusing attention, regulating emotions, and overruling instinct; refraining from saying the first thing that comes to mind, for example. Shifting refers to being able to adjust to changes and take different

perspectives of a person or problem. Working memory concerns keeping information uppermost in the mind and using it for tasks, such as creating to-do lists (Diamond, 2012).

Self-regulation is a related concept that refers to a person's ability to control their own behaviour. Self-regulation and executive function are similar, with self-regulation being considered an aspect of executive function (Nyongesa et al., 2019). Self-regulation is a narrower concept that has key similarities to the process of inhibition in executive function (Diamond, 2012). In this study, self-regulation will be considered part of executive function.

Studies have found that playing music and being trained to play a musical instrument are associated with improved executive function (Okada & Slevc, 2018). Playing an instrument is an activity that requires complex thinking: musicians are "multitaskers" who combine memory (e.g., memorising melody) with pattern identification (e.g., reading sheet music or recognising which chords are likely to appear in sequence in a particular key), auditory information (e.g., whether an instrument is in tune), and kinaesthetic control (e.g., the movements required by the fingers and body to play a violin or piano) (Barrett et al., 2013). As these tasks form part of the executive function processes and can all occur almost simultaneously during a musical performance, it can be argued that playing music requires high levels of executive function processes (Bialystok & DePape, 2009).

Most research into the relationship between music and executive function has focused on early childhood (Williams, 2018) and adolescence (Herrero & Carriedo, 2018). For example, it has been found that musical interventions in early childhood improved self-regulation skills (Williams & Berthelsen, 2019). This is important as it indicates that music influences executive function skills. Musical training and visual arts have been found to improve academic outcomes for children at risk (Brown et al., 2010), while musical training specifically has been found to improve self-regulation skills in at-risk children (Brown et al.,

2022). This focus on early childhood is presumably because this is an important developmental phase. It has been suggested that early learning of self-regulation or executive function improves developmental outcomes (Williams & Berthelsen, 2019). However, Herrero and Carriedo (2018) argued that as the brain continues to change throughout development, the focus should not only be on early childhood, hence their research into adolescents. They found that adolescent musicians performed better on inhibition tasks than non-musicians.

Another activity associated with improved executive function is physical activity, including sports. Studies regarding this relationship have focused mainly on people in middle-age and older people (e.g., Gasquoine & Chen, 2020) as part of research into healthy aging (Zheng et al., 2022). Executive function is one of the brain functions that decreases with age (Lv et al., 2022) and various forms of exercise are associated with improved executive function, such as aerobic exercise (e.g., swimming), resistance training (e.g., squats and weightlifting), and physical and mental exercise (e.g., yoga), with a combination of these being most effective (Zheng et al., 2022). One of the few studies into physical activity and executive function in children was conducted by Lakes & Hoyt (2004). They found children's self-regulation skills improved following a martial arts intervention.

Tai Chi is an example of a physical and mental exercise that has been found to improve executive function in older people. It was suggested that physical and mental exercise requires kinaesthetic control (e.g., performing the proper stance), memory of movement (e.g., where hands must move in the stance), and flexibility (e.g., being able to change between stances). Lakes & Hoyt (2004) also suggested that sports such as martial arts emphasise the significance of discipline and control, which bear similarities with self-regulation. As these are all part of executive function processes (Lv et al., 2022), it can be argued that playing sports involves high levels of executive function.

There has been less research on the relationships between music (referring to playing music and musical training), sport (referring to a physical activity that requires tuition/training), and executive function in people of university age. One study investigated the use of mindfulness as an intervention for executive function as well as mood, including a short yoga session. It was found that executive function improved after this intervention (Müller et al., 2021) but it was not clear how yoga contributed to this effect. There appear to be no studies specifically investigating music, sport, and executive function in university students.

Executive function is important for university students as improved executive functioning is associated with better academic outcomes (Sheehan & Iarocci, 2015). Follmer and Sperling (2016) also found a relationship between executive function and self-regulated learning in university students, while Rinaldi et al. (2021) established that executive function impairment in university students was associated with procrastination. Activities that lead to improved executive function are therefore important for university students if they are to succeed at university.

As music and sport are associated with improved executive function in early childhood and late adulthood, it is possible that the same relationships would be found in university students. A possible explanation for the relationship between music, executive function skills, and improved academic outcomes (e.g., Brown et al., 2010) is based on the theory that executive function skills can be transferred from one task to another (Diamond, 2012). For example, music could improve executive function skills as music training activates executive function processes (Bialystok & DePape, 2009), thus practising music also practises executive function skills. These improved executive function skills could be transferred from music and applied to learning subjects at university, resulting in better academic outcomes. A similar process could be present in sport as executive function processes also occur during sport (Lv

et al., 2022). However, it should be noted that this is only a possible explanation that cannot be confirmed through correlations. Perhaps those students who have better executive function skills tend to become involved in music and sport.

This study investigated executive function (including self-regulation as part of executive function), exploring the relationships between sport and executive function, music and executive function, and the combination of sport and music and executive function in university students.

Research Questions

The first research question concerned whether there is a relationship between sport and executive function, music and executive function, as well as the combination of music and sport and executive function. As previous research provided evidence for these relationships, the hypothesis was that these relationships would be found. The second research question investigated whether there is a difference in the relationships between sport and executive function, music and executive function, and the combination of music and sport and executive function. The hypothesis was that there would be a difference between the combination of music and sport and executive function, and music or sport and executive function. If music and sport separately are associated with higher executive function, the combination of the two could be linked to even higher executive function than either music or sport alone. The third research question concerned possible skills related to executive function that could be developed by music and sport. This question was exploratory.

Method

Participants

The participants were university students, mostly from the Behavioural and Social Sciences faculty of the University of Groningen. A total of 45 participants initially responded to the survey. Those who did not complete the survey and those older than 35 were

eliminated, resulting in 25 participants. The final sample for this study comprised 6 male and 19 female participants between the ages of 18 and 35 years (M = 24.56, SD = 4.15). Participants included both Dutch (56%) and international students (44%) (see Table 1). All participants were university students with the majority being first year master students who had previously completed a bachelor degree (see Table 1). Of the final sample, 5 participants (1 male, 4 female) between the ages of 22 and 26 years (M = 24.40, SD = 1.67) also took part in the follow-up interview. In this follow-up sample, there were two Dutch, one Scottish, one Chinese, and one German participant, most of whom were studying for a master degree (1 x Bachelor Year 2, 3 x Master Year 1, and 1 x Master Year 2) and had a previous degree (1 x no previous degree, 1 x Bachelor, and 3 x Master).

Table 1
Participant Nationality and Education

Characteristic		Number of Participants
Nationality	Chinese	1
	Dutch	14
	English	1
	German	3
	Greek	1
	Irish	1
	Japanese	1
	Scottish	2
	Spanish	1
Education	Bachelor Year 1	2
	Bachelor Year 2	2
	Bachelor Year 3	3
	Bachelor Year 4+	1
	Master Year 1	13
	Master Year 2	3
	Master Year 3	1
Pre-Education	Bachelor	10
	Master	5
	N/A	8
	Pre-Master	2

Materials

An online questionnaire was created to examine the participants' music and sport experience. The Goldsmiths Musical Sophistication Index (Gold-MSI) was used: a widely validated and reliable self-report questionnaire. It provides information regarding musical experience through one general score (Musical Sophistication) and five subscales (Active Engagement, Perceptual Abilities, Musical Training, Singing Abilities, and Emotions) with a total of 39 items. Most items were answered on a 7-point Likert scale or with 7 options to choose from (such as ranges for the number of music events attended) but one item was open-ended (the instrument they play best) (Müllensiefen et al., 2014).

The questions from the Gold-MSI were also used for sport experience but were changed to refer to sport rather than music or instruments. For example, "I spend a lot of my free time doing music-related activities" was changed to "I spend a lot of my free time doing sport-related activities". The subscale Singing Abilities did not translate to sport, so this subscale was changed to Skill Mastery. The items were then changed to refer to how quickly the participant picked up a new sport skill or how well they performed this new skill rather than how quickly they picked up a melody or how well they could sing. There were also three items in the Perceptual Abilities subscale that were difficult to change directly to sport ("I usually know when I'm hearing a song for the first time", "I can tell when people sing or play out of time with the beat", "When I hear music I can usually identify its genre"). These items were instead replaced with items from the Athletic Coping Skills Inventory (ACSI-28) Concentration subscale ("I handle unexpected situations in my sport very well", "When I am playing sports, I can focus my attention and block out distractions", and "It is easy for me to keep distracting thoughts from interfering when I am watching or listening to sports.") (Smith et al., 1995). See the Appendix for the entire sports version of the Gold-MSI.

After the questionnaire, the participants completed three online executive function tests as part of the survey (see Figure 1). Instructions for these tasks were provided within the survey. After the executive function tasks were completed, participant characteristics were collected, such as level of current degree, level of previous degree, age, gender, and nationality.

Figure 1
Executive Function Tasks

Executive Function	Task Description
Inhibition (Stroop effect, n.d.)	A variation of the Stroop Colour-Word test. Essentially, participants had to say the colour of the text (but not the written words) out loud as fast as they could. The browser timed them, and they were asked to note down their time in the survey. They did this twice. For the first trial, the text and word colours were the same, while for the second trial, the text and word colours were different.
Shifting (EKR, n.d.).	A shifting task where participants needed to select the same half of the screen when a red square appeared and the opposite half when a blue square appeared. The participants were asked to complete 20 attempts and to note down their score and percentage of correct attempts.
Working Memory (Short Term Memory, n.d.).	A memory task where participants needed to remember an increasing number of letters. There were six trials. Participants had to remember two letters initially which then increased by two letters each trial, with the last trial ending in 12 letters. After each trial they had to note how many letters they remembered.

Interview questions were developed for the follow-up interview, which related to skills the participants thought they had learned through music or sport. These questions were open to allow participants to elaborate on their answers. If the initial question was closed, the subsequent questions were open. The questions examined the participants' perception of their executive function abilities and how these are related to their music and sport experience, the

importance of music and sport in the participants' lives, and skills learned through music and sport that were useful in other areas of their lives (see Figure 2).

Figure 2
Interview Questions

	Question	Encouraging Sub-Questions	Purpose
Executive Functions	How well do you think you did on the tasks in the survey?	-	Perception of executive function tasks and abilities
	Do you think you are good at ignoring distractions and concentrating?	a. Why do you think that? b. How does this relate to your music and sport experience?	Examining inhibition ability and relationship to music/sport experience
	Do you think you are good at switching between one task/activity and another?	a. Why do you think that? b. How does this relate to your music and sport experience?	Examining shifting ability and relationship to music/sport experience
	Do you think you are good at remembering things (such as people's names, phone numbers etc.) and instructions?	a. Why do you think that? b. How does this relate to your music and sport experience?	Examining working memory ability and relationship to music/sport experience
Music and Sport Experience	Would you say that music and sport have had any positive impact on your life?	In what way?	Importance and perception of music and sport
	Would you say that music and sport have had any negative impact on your life?	In what way?	Importance and perception of music and sport
	Which skills did you develop through your music and sport experience that have helped you in other areas of your life?	Such as at university?	Skills learned in music and sport that could be transferred, whether executive function skills or not

Procedure

Participants took part in the questionnaire and executive function tasks online in one anonymous survey in March-April 2023. The link to the survey was sent out in an email to bachelor students for the Pedagogy and Educational Sciences Department of the University of Groningen. The survey link was also sent to WhatsApp groups for bachelor students at the Psychology Department. As the response was limited, the link to the survey was sent by email to Master students for Pedagogy and Educational Sciences and via WhatsApp for Master students of both Pedagogy and Educational Sciences and Psychology. A link was also posted on LinkedIn. At the end of the survey, participants were offered the opportunity to participate in a follow-up interview after completing the questionnaire and executive function tasks. Those who wished to participate filled in their email address. After the quantitative analyses were completed, the participants who provided their email address were sent an email inviting them for an interview. Dates and times were provided for them to select, and they were also given the opportunity to indicate that they no longer wanted to participate in the follow-up interview.

Data were anonymised apart from those participants who had filled in their email address to sign up for the follow-up interview. Their data were linked to their email addresses for the interview and qualitative analyses. Once the interviews and qualitative analyses were completed, the email addresses were removed from the dataset.

Data Analysis

The first two research questions were examined quantitatively. Figure 3 presents all the variables of music, sport, and executive function included in this study. The data from the Gold-MSI for music and sport were scored for each participant using the scoring templates available online (Gold, n.d.), which resulted in one score for each scale for every participant.

For the first research question, the scores on the scales of the Gold-MSI for music and sport were compared with the results of the executive function tasks in a series of Pearson correlations to determine whether there was a relationship between music and/or sport and executive function. For the combination of music and sport, the results of the scores for music and sport scales were simply added together. For example, the General Score for music and the General score for sport were added together, resulting in a combined General Score. This was repeated for the other subscales, apart from Singing Ability and Skill Mastery which could not be combined as they measure different concepts. Pearson correlation is a statistical analysis that measures association between two continuous variables, as is the case with all quantitative variables in this study. The correlation coefficient provides information about the correlation's magnitude (between -1 and 1) and direction (negative or positive).

For the second research question, significant correlations were compared using a Fisher Z-transformation to determine whether there was a significant difference between music and/or sport and executive function. In other words, is music, sport, or the combination of the two more closely correlated with different aspects of executive function? The Fisher Z-Transformation is a method of transforming Pearson correlation coefficients into z-scores so that correlations can be compared and the significance of the difference between two correlations can be tested. In this study, an online Fisher Z-transformation calculator was used (Weiss, 2011).

Figure 3
Variables of Music, Sport, and Executive Function

Variables	2nd Order Variables	Definition
Music	General Score	The general score for music experience incorporating aspects from all 5 subscales (Musical Sophistication)
	Active Engagement	How much time and money were spent on music
	Perceptual Ability	Accuracy of musical listening skills
	Music Training	Amount of formal musical training received
	Singing Ability	Accuracy of one's own singing
	Emotion	Ability to talk about emotions expressed through music
Sport	General Score	The general score for sport experience incorporating aspects from all 5 subscales
	Active Engagement	How much time and money were spent on sport
	Perceptual Ability	Accuracy of detecting visual and audio stimuli
	Sport Training	Amount of formal sport training received
	Skill Mastery	Ease with which new sport skills are acquired
	Emotion	Ability to talk about emotions expressed through sport
Combined	General Score	General score for music and sport added together
	Active Engagement	Active engagement score for music and sport added together
	Perceptual Ability	Perceptual ability score for music and sport added together
	Training	Training score for music and sport added together
	Emotion	Emotion score for music and sport added together
Executive Function	Inhibition	Being able to focus attention
	Shifting	Being able to unconsciously shift attention between one task and another
	Working memory	Continuously remembering information and replacing outdated information with new relevant data

The third research question was examined qualitatively. A small number of participants signed up for this follow-up. These participants were interviewed using the developed interview questions. Categories (top-down) (see Figure 4) were selected from previous research into the skills associated with self-regulation and executive function that relate to music and sport. The first eight categories were taken from Zimmerman (1998) who described self-regulatory processes present in athletes and musicians as these were relevant to the research question. Several categories were selected from the results of Andersen et al. (2019) who found that collaboration, conflict management, confidence, vocabulary, and inclusion improved after an art intervention involving music. The first four were included but inclusion was not selected as this is a similar concept to collaboration (in other words, teamwork). Emotional regulation was selected as Williams and Berthelsen (2019) found that a music and rhythm intervention had a positive effect on emotional regulation. The three main processes of executive function, inhibition, shifting, and working memory were also included (Miyake et al., 2000). Participants' answers were categorised accordingly to provide exploratory results regarding which executive function skills could be subject to further research in relation to music and sport.

Figure 4
Categories for Executive Function Skills related to Music and Sport

Categories	Examples for Athletes	Examples for Musicians
Goal setting	Setting daily training goals	Choosing how many pieces they want to learn before a certain time
Task strategies	Building up strength before trying a skill that requires strength	Playing a piece slowly to learn it
Imagery	Visualising taking a penalty before taking the shot	Imagining an audience
Time management	Planning rest times between competitions	Planning practice times before a performance
Self-monitoring	Keeping a record of competition wins	Keeping a record of the grade level of played pieces
Self-evaluation	Evaluating teamwork after a match	Evaluating performance after a concert
Self-consequences	Giving a reward for learning a new skill	Practising until a part of a piece is perfect
Help seeking	Asking for help from the coach about a team strategy	Asking the teacher for help with position changes
Collaboration	Working together in a team strategy	Playing in time with the rhythm section in a band
Conflict management	Maintaining good relationships with opponents	Handling differences of opinion about interpretation
Vocabulary	Learning sports related terms	Learning new words from lyrics
Confidence	Competing in front of spectators	Performing in front of an audience
Emotional regulation	Dealing with the stress of competitions	Handling stage fright
Inhibition	Ignoring spectators cheering	Singing in harmony with another singer
Working memory	Remembering a series of dance moves	Playing a melody from memory
Shifting	Switching between attacking and defending	Playing a fugue on the piano

Results

The descriptives for the variables are presented in Table 2. The descriptives for the general scores of music (M = 78.44, SD = 20.21, range: 36-109) and sport (M = 73.04, SD = 20.55, range: 40-106), suggested that the sample of participants had similar average levels for sport and music experience.

The frequency of the main instruments and sports mentioned by participants is presented in Table 3. The most common instruments played by this sample of participants were piano, guitar, voice, and drums. The most common sports played by this sample of participants were horse riding, basketball, dancing, and running.

Table 2
Descriptives for Variables

Variable		Mean	Standard Deviation	Min. Value	Max. Value
Music	General Score	78.44	20.21	36	109
	Active Engagement	36.92	9.64	17	56
	Perceptual Ability	46.80	9.73	24	61
	Music Training	26.40	10.66	7	47
	Singing Ability	30.68	7.87	18	49
	Emotion	34.16	5.10	23	42
Sport	General Score	73.08	20.55	40	106
	Active Engagement	29.96	11.00	13	50
	Perceptual Ability	40.40	9.32	21	55
	Sport Training	28.64	11.19	8	48
	Skill Mastery	28.12	8.23	16	45
	Emotion	24.24	7.89	9	38
Combined	General Score	151.52	26.70	100	208
	Active Engagement	66.88	14.26	34	92
	Perceptual Ability	87.20	12.86	62	114
	Training	55.04	16.31	26	80
	Emotion	58.40	9	45	77
Executive Function	Inhibition	6.04	4.83	0.188	21.98
	Shifting (%)	95.52	6.69	75	100
	Working memory	35.52	5.30	17	42

Table 3
Participants' Main Instrument and Sport

		Number of Participants
Instrument	Bass guitar	1
	Cello	1
	Drums	2
	Guitar	5
	N/A	1
	Piano	6
	Recorder	1
	Ukulele	1
	Violin	1
	Voice	5
	Xylophone	1
Sport	Archery	1
	Basketball	2
	Dancing	2
	Field hockey	1
	Horse riding	3
	Judo	1
	Kaatsen	1
	Lacrosse	1
	Rock climbing	1
	Rowing	1
	Running	2
	Squash	1
	Table tennis	1

Relationships Between Music, Sport, and Executive Function

The correlations between the music scores and the shifting and working memory tasks were non-significant (see Table 4). Only for the inhibition task were two of the correlations with music scores significant. The correlation between the general score for music experience and the inhibition task was significant, $r(23) = -.456$, $p = .022$. This suggests that the higher the score for music experience, the lower the time difference for the inhibition task. The correlation between singing ability and the inhibition task was significant, $r(23) = -.480$, $p = .015$. This suggests that the better the singing ability, the lower the time difference for the inhibition task.

Table 4
Correlations Between Music and Executive Function

		General Score	Active Engagement	Perceptual Ability	Music Training	Singing Ability	Emotion
Inhibition	r	-.456*	-.351	-.231	-.346	-.480*	-.274
	p	.022	.085	.267	.090	.015	.185
Shifting	r	.147	.173	.162	.262	.019	.187
	p	.483	.408	.440	.205	.928	.371
Working memory	r	-.044	-.100	-.118	.122	-.116	-.009
	p	.835	.633	.573	.563	.582	.965

*significant at 0.05 level

The correlations between the sport scores and the inhibition and working memory tasks were non-significant (see Table 5). Only for the shifting task was one of the correlations for sport scores significant. The correlation between the perceptual ability and the shifting task was significant, $r(23) = .415$, $p = .039$. This suggests the higher the score for perceptual ability, the higher the percentage of correct answers for the shifting task.

Table 5
Correlations Between Sport and Executive Function

		General Score	Active Engagement	Perceptual Ability	Sport Training	Skill Mastery	Emotion
Inhibition	r	.042	-.007	.175	-.053	.079	.111
	p	.843	.972	.402	.802	.708	.599
Shifting	r	.199	.138	.403*	.298	.070	.358
	p	.340	.509	.046	.149	.740	.079
Working memory	r	-.072	.030	.106	-.151	-.070	.083
	p	.734	.888	.614	.473	.738	.695

*significant at 0.05 level

The correlations between the combination of music and sport scores and the inhibition and working memory tasks were non-significant (see Table 6). Only for the shifting task were correlations with two of the combined scores significant. The correlation between the combined perceptual ability and the shifting task was significant, $r(23) = .403$, $p = .046$. This suggests the higher the score for perceptual ability in music and sport, the higher the percentage of correct answers for the shifting task. The correlation between combined emotion and the shifting task was also significant, $r(23) = .419$, $p = .037$. This suggests the more emotionally invested in music and sport, the higher the percentage of correct answers for the shifting task.

Table 6
Correlations Between Combined Music and Sport and Executive Function

		General Score	Active Engagement	Perceptual Ability	Training	Emotion
Inhibition	r	-.313	-.243	-.047	-.262	-.058
	p	.128	.242	.822	.205	.782
Shifting	r	.265	.224	.415*	.376	.419*
	p	.201	.282	.039	.064	.037
Working memory	r	-.088	-.045	-.013	-.024	.067
	p	.675	.831	.952	.910	.750

*significant at 0.05 level

Comparison Between Relationships

A Fisher-Z transformation analysis was conducted only on the significant correlations that overlapped between music and/or sport and executive function. There was only one such pair of correlations: between sport perceptual ability and shifting and combined perceptual ability and shifting. This Fisher Z-transformation analysis was conducted using a Fisher-Z transformation calculator developed by Weiss (2011). The difference between these correlations was not significant, z-test statistic = 0.048, $p = 0.962$. This suggests that there is no difference between the correlation for the combination of music and sport perceptual ability and shifting, and the correlation of sport perceptual ability alone and shifting.

Possible Links Between Music, Sport, and Executive Function

Five participants also took part in a follow-up interview. They will be referred to as *A, B, C, D,* and *E*. These interviewees' scores were categorised in comparison to the mean for the survey sample (see Table 7). Their scores were compared to the mean scores of the sample to determine whether their scores were a standard deviation above or below the mean. However, the significance of these differences was not examined. There were three categories: below average (one standard deviation below the mean), average (no standard deviation below or above the mean), and above average (one standard deviation above the mean) (see Table 8). It is important to note that it is the opposite for inhibition as the inhibition score is the time difference for the word-colour task. The lower the score, the better the inhibition. For example, below average would instead be one standard deviation above the mean while above average would be one standard deviation below the mean. Another point to note is that the shifting score is a percentage, so the maximum score is 100. It is impossible for there to be a score that is a standard deviation (6.69) above the sample mean (95.52). Instead, a score of 100 will be considered above average.

Table 7
Mean and Score Comparisons for Interviewees

Variable		Mean	Standard Deviation	A	B	C	D	E
Music	General Score	78.44	20.21	107	71	46	77	64
	Active Engagement	36.92	9.64	36	33	23	34	39
	Perceptual Ability	46.80	9.73	61	41	33	44	40
	Music Training	26.40	10.66	44	17	12	23	23
	Singing Ability	30.68	7.87	44	32	21	34	20
	Emotion	34.16	5.10	35	28	28	27	31
Sport	General Score	73.08	20.55	73	44	81	98	99
	Active Engagement	29.96	11.00	22	21	28	46	36
	Perceptual Ability	40.40	9.32	45	25	43	45	51
	Sport Training	28.64	11.19	34	9	31	37	40
	Skill Mastery	28.12	8.23	34	19	32	39	38
	Emotion	24.24	7.89	13	20	26	27	30
Executive Function	Inhibition	6.04	4.83	6.74	6.26	21.98	3.02	9.20
	Shifting (%)	95.52	6.69	100	83	95	82	96
	Working memory	35.52	5.30	36	31	30	38	35

Executive Function Tasks

Generally, the participants thought that they performed quite well on the executive function tasks. *A* mentioned that the shifting and working memory tasks were easier than the inhibition task. This was reflected somewhat in their score as they scored average for inhibition and working memory and above average for shifting, which they found easiest. *E* also agreed with this, saying that the inhibition task was the most difficult, the shifting task

was the easiest, while the working memory task became more difficult as it went on but was still easier than the inhibition task. *E* scored average for all tasks. *D* noted that these tasks were familiar, specifically the inhibition and working memory tasks, as they like to do brain games. This was reflected somewhat in *D*'s scores as they scored average for inhibition and working memory but below average for shifting. *D* may have had more practice with tasks similar to the inhibition and working memory tasks in this study than the shifting task.

Table 8
Categories based on Mean Score and Individual Score Comparisons

Variable		A	B	C	D	E
Music	General Score	Above Average	Average	Below Average	Average	Average
Sport	General Score	Average	Below Average	Average	Above Average	Above Average
Executive Function	Inhibition	Average	Average	Below Average	Average	Average
	Shifting	Above Average	Below Average	Average	Below Average	Average
	Working Memory	Average	Average	Below Average	Average	Average

Music and Sport Experience

The participants all stated that music and sport were important and had a very positive impact on their lives. See Table 9 for their main instrument and sport. *A*, *B*, and *C* mentioned the positive influence on their social lives. *B* and *C* stated that they had made lifelong friendships, from choirs for *B* and from playing in teams for *C*. According to *A*, music and sport were also something that can transcend language as, even if you do not speak the same language, you can still play together. Music and sport are international. *C* also mentioned that playing sports allowed them to travel to different countries and meet people. *A*, *D*, and *E*

described the positive emotional experience of music and sport. *A* stated that music is something they enjoy doing and *E* mentioned that there is a familial connection with music as their father also really enjoys music, so it is something they do together. *D* mentioned that both music and sport helped with depression as they ran a marathon and played piano as a form of distraction.

Table 9
Instruments and Sports of Interviewees

Participant	Instrument	Sport
A	Violin	Squash
B	Voice	Horse-riding
C	Recorder	Volleyball
D	Piano	Dancing
E	Piano	Lacrosse

All participants stated that music and sport did not negatively impact their lives. *A* mentioned that even things that could be considered negative, such as having to practise for long hours before a concert or not performing well on stage or during a match, had been positive experiences as these developed relevant skills. The only negative aspect that *D* could think of was that being taught music and sport costs money while *E* mentioned injuring their knee but did not attribute that to playing lacrosse stating, “I think that could have happened anywhere”.

Goal Setting and Self-Evaluation

Setting goals or evaluating their own performance was rarely mentioned by participants. *C* described being able to handle responsible positions, such as student representative, because they learned to plan tasks and create goals while *E* mentioned how

listening to music helped them reflect by putting them in the mood to evaluate their own performance.

Time Management

Two of the participants described how time management was developed by their music and sport experience. *A* mentioned being skilled at time management and being able to "juggle between" different tasks easily, revising while listening to a lecture, for example. This is due to having learned to design a strict schedule of different tasks that need completing. According to *E*, such strategic planning can translate from sports to university studies. Turning up for practice at specific times is important. This means that other activities need to be planned around practice times. Sport takes priority. This also helps in university studies: classes or the thesis, for example, take priority and other activities must be planned around those.

Collaboration and Conflict Management

Four participants described the importance of teamwork for both music and sport. For collaboration, *A* mentioned that if you play music with others, you also need to communicate with them while playing, observe them, listen to them and so on. *B* also supported this with their description of singing in a choir. In sport, *E* suggested that communication is essential when you are playing a match, for example. Team members rely on each other. As *C* stated, "if you are a field hockey goalkeeper, your team members rely on you to be the last defender". Conflict management was less explicitly discussed although *B* and *E* both stated that singing in a choir and playing in a team helped them with teamwork in different situations, including working with others in more professional settings and during professional disagreements.

Confidence and Emotional Regulation

In the interviews, confidence was referred to once as being the result of learning emotional regulation. *C* suggested that doing music and sport comes with more opportunity for feedback. Both receiving praise and criticism leads to learning how to deal with feedback without it having an immediate effect on performance. This promotes confidence in your own ability and your ability to adapt to feedback. *A* and *E* described the support of emotional balance. *A* mentioned that whenever setbacks occur, they know they can handle them as they learned to accept that things can go wrong at crucial times during music performances and sports competitions. *A* also described how this has been helpful in their studies and has helped them stay balanced and "on an even keel". Similarly, *E* suggested that sports competitions supported them in becoming more balanced because "you win some, you lose some". This enabled *E* to learn how to manage their emotions so that they are not impacted by a loss. Additionally, *E* suggested that listening to music is calming and stress reducing. Depending on *E*'s mood, *E* listens to different kinds of music which also helps with emotional regulation.

Vocabulary

Only *E* mentioned vocabulary. *E* stated that listening to music helped them to learn English. *E* had to look up the meaning of English words in song lyrics as they wanted to know the story of the song.

Inhibition

All the participants mentioned that they are capable of concentrating and ignoring distractions if they are interested in the task or find it meaningful. *A* and *B* stated that listening to music can distract them from the task at hand, with *A* explaining that they start to analyse the music instead of getting on with the task, while *B* uses music as a break in between tasks. In contrast, *E* suggested that listening to non-vocal music helps them focus on what they are doing. *B* somewhat agreed with this as they described listening to music as motivation when

performing tasks that do not require much thinking, such as cleaning. Four participants stated that they can concentrate while playing music and sports. For example, *A* mentioned shutting out the audience, *C* described being able to focus on where the ball is and the intentions of one player even if the immediate surroundings are filled with other players, *D* said that music training, such as practising guitar and piano like in a boot camp, helped them ignore phone notifications, and *E* mentioned that enjoying sports enables them to focus while playing with their team.

Shifting

Three of the participants stated that they were good at shifting quickly between tasks, while *C*, for example, explained that they quite often need a breather between tasks but that this does not apply when playing sports. When defending, they have to coordinate with other defenders and focus on the ball. Only once the game has moved elsewhere on the field can they take a breather. *E* also mentioned that in sports, it is important to focus on the big picture. *E* may be running with the ball and looking to score but they also must keep an eye on the opposing players and their own team members. *A* and *D* described being good at shifting in academic contexts, with *A* mentioning that they sometimes need to manage completing essays, exam revision, lectures, work, and music practice at almost the same time, while *D* stated that they had been trained to take control of several tasks at the same time since they were young. For music, *A* described how you need to accomplish many tasks simultaneously when playing the violin or piano. When practising, *A* needs to switch between different tasks very quickly. For example, with the violin *A* may play the left-hand notes in various positions before *A* feels comfortable with them and then concentrates on the bow arm, working out exactly where on the bow to play each note. *D* supported this saying that for piano and guitar “you have to concentrate on both hands”. The tasks are divided between each

hand. According to *D*, this is also the same for dancing as *D* needs to both watch and mimic the teacher.

Working Memory

The participants agreed that they can remember things, such as people's names and phone numbers, as long as they make the effort to do so. *B* mentioned using repetition to remember while *E* uses bridges, such as in the working memory task where they made sentences from the letters to remember each letter. However, *D* stated that they find it harder to remember things in English than their own language, as there are huge differences between their first language and English. For music, *A* described often having to play music from memory while *B* mentioned their ease with learning song lyrics. For sport, *A* explained that they have to remember things like hand signals, *C* described the importance of remembering players' names during a game, whether a team member or opponent, *D* stated that in ballet they need to remember movements as well as the beat on which each movement occurs, and *E* mentioned having to remember hand positions when holding the lacrosse stick and how to move when passing the ball.

Categories Unmentioned

There were several categories that were not mentioned by participants. Self-monitoring and self-consequences are similar to self-evaluation but were not specifically discussed by participants as something important for music and sport training. Task strategies, help seeking, and imagery were not mentioned at all by participants.

Other

Several aspects mentioned by participants do not fit into any of the selected categories. *A* mentioned that gross and fine motor skills, coordination, and perseverance are also relevant for playing an instrument. *D* described several skills including spatial cognition. When they were young, *D* could not imagine geometric shapes, but later became involved in sports,

which improved *D*'s spatial cognition abilities. For music, *D* mentioned a problem with recognising or remembering people's faces, especially people of a different race. Music helped *D* recognise people's voices in more detail instead of recognising faces. Exercise is also motivating for *D*. It "refreshes my brain in the morning and makes me very energetic for the entire day". *E* suggested that music helped them appreciate the smaller things, especially when listening to stories in the lyrics.

Discussion

This study investigated the relationship between music, sport, and executive function. For music, the results indicated a relationship for the general music score and singing ability score and the time difference on the executive function task for inhibition. For sport, the results indicated a relationship for the perceptual ability score and the percentage of attempts correct score on the executive function task for shifting. For the combination of music and sport, the results indicated a relationship for the combined perceptual ability score and combined emotion score, and the percentage of attempts correct score on the executive function task for shifting. In addition, there appeared to be no significant difference in the correlations between perceptual ability for sport alone and shifting or combined perceptual ability and shifting.

Relationships Between Music, Sport, and Executive Function

The correlation between the general score and the inhibition task score suggests a general relationship between music experience and the executive function process, inhibition. In other words, the more experience and involvement in music, the better the inhibition ability. Inhibition involves focusing attention and concentration. This could be argued as being important for music (Barrett et al., 2013). For example, concentration could be important when performing in a band. A possible explanation could be that band members have to focus on their own part, but they cannot completely ignore their band members as

they need to listen to each other to play together. A similar correlation was also found for singing ability and inhibition. This suggests that the better the singing ability, the better the inhibition ability. A possible example for how inhibition is important for singers could be singing in harmony. In a choir, there are often different sections that sing different harmony parts. These singers must be able to sing their own part in time with others, while also not being put off by the harmony part of another section.

The results of this study support previous findings that music is associated with improved executive function (e.g., Okada & Slevc, 2018). This also provides support for hypothesis one. However, no correlations were found for music, shifting, and working memory. This does not support the previously found significant correlations between music and shifting (Moradzadeh et al., 2014) and music and working memory (Okada & Slevc, 2018). Interestingly, Okada and Slevc (2018) also implemented the Gold-MSI with a battery of executive function tasks (three per process) and found no correlations between the general score or any of the subscales and shifting. These findings support the results in this study, in which there were also no correlations between music and shifting. Perhaps shifting is not an executive function process that is closely related to music, or it is a process that is not related to a dimension of music measured by the Gold-MSI. Okada and Slevc (2018) found correlations between music and inhibition, apart from the subscales musical training and perceptual abilities. This study also did not find correlations between musical training or perceptual abilities and inhibition, and, in contrast, *only* found correlations for the general score/singing ability and inhibition. In addition, Okada and Slevc (2018) found correlations between music (apart from singing abilities) and working memory, while this study found no correlations between music and working memory.

The correlation between sport perceptual ability and shifting suggests those who are better at detecting and evaluating visual and audio stimuli in sport are better at shifting.

Shifting involves moving quickly from one task to another. This ability is important for sport (Lv et al., 2022). For example, when moving from attacking to defending and vice versa. Different tasks can occur very quickly and converge when adjustments need to be made. The better the shifting ability, the faster an athlete can make these decisions and adjustments (Lv et al., 2022).

The correlations between sport and executive function support previous findings that various forms of exercise have been found to be associated with improved executive function (Zheng et al., 2022). This also supports hypothesis one. Indeed, one of the few studies examining university students also found improvements in shifting specifically after a mindfulness intervention involving yoga (Müller et al., 2021). However, in this study, no correlations were found between sport and inhibition. This does not support previous research that found a relationship between sport and inhibition (e.g., Wang et al., 2013). This could possibly be explained by the sports played by the participants of this study.

In general, sports may be categorised into two types: open skill and closed skill sports. Open skill sports are sports where players need to react to constant changes and are unpredictable. For example, tennis, football, basketball and so on. Closed skill sports are the opposite of open skill sports. These sports remain the same, are predictable, and allow players to play at their own pace. For example, running, yoga, swimming and so on (Wang et al., 2013). Wang et al. (2013) compared inhibition ability between people who play tennis (an open skill sport) and those who swim (a closed skill sport). There was also a control group of those who did not play sports. The tennis playing group had better inhibition ability than both the swimming and the control group, suggesting that open skill sports are more closely related to inhibition. These results are supported by Takahashi and Grove (2019) who referred to open skill sports as complex sports. In their research, they found that one session of badminton, an open skill sport, led to a larger improvement in inhibition ability than a session

of running, which is a closed skill sport. In this study, the majority of sports mentioned by participants could be argued to be closed skill (or less complex) sports. The most common sports were horse riding, basketball, dancing, and running with only basketball being an open skill sport. It could be that correlations between sport and inhibition would have been found in a sample of participants who played more open skill sports.

The result of the comparison between the correlation of combined sport (visual and audio stimuli) and music (listening skills) perceptual ability and shifting, and the correlation of sport perceptual ability and shifting was non-significant. This does not support hypothesis two and suggests there was no combined effect of music and sport on shifting in this study. There was only one pair of correlations in which the same variable was significantly correlated with music, sport, and the combination of these, so only this comparison could be made. It is unknown whether combined effects would be present for other variables. Other correlations could possibly have been compared if correlations had been found between, for example, music and shifting (Moradzadeh et al., 2014), music and working memory (Okada & Slevc, 2018), or sport and inhibition (Wang et al., 2013), as have been found in previous research.

The correlation between the combination of music and sport perceptual ability and shifting supports hypothesis one. A more unusual finding (also supporting hypothesis one) was the correlation between combined emotion and shifting. This suggests the greater emotional investment in music and sport, the better the shifting ability. It is possible that there is a combined effect of music and sport for emotion and shifting, however, no comparison can be made as there were no significant correlations for emotion and shifting for music or sport alone. After examining the music and sport emotion subscales it appears that some of the items mentioned watching and listening to music and sports to evoke emotion. For music, one possible explanation is that participants are listening to music while doing another task and

are then practising their shifting skills between listening and this other task. In fact, listening to music has been found to improve cognitive performance, which is known as the Mozart effect. One such aspect of cognitive performance is mental flexibility (Schellenberg, 2012), otherwise known as shifting. For sport, it is possible that exciting sports moments involve moments where an athlete achieves something unexpected and impressive, such as a difficult save in volleyball. At such a moment, the athlete is demonstrating their sporting as well as shifting abilities. One possible explanation is that those watching these moments are implicitly practising their sport and shifting abilities, leading to such a correlation. Indeed, it has been found that watching someone perform a sport skill can lead to improvements in that skill (Nojima et al., 2015).

Possible Links Between Music, Sport, and Executive Function Skills

Participants in the interviews provided evidence to support the inclusion of the three processes of executive function and several skills related to executive function that can be trained through music and sport, and possibly transferred to other areas of their lives, such as university. For inhibition, the participants mentioned that they could concentrate if they enjoyed an activity or found it meaningful. Some participants suggested that listening to music was a way of improving concentration while others said it was a distraction. This difference could be due to the type of music they were listening to. It has been found that up-tempo music may negatively affect inhibition ability while slower music has no impact on inhibition (Xiao et al., 2020). This suggests that slower music does not provide a distraction. All participants agreed that music and sport practice involves inhibition. This supports previous results that found relationships between music and inhibition (Okada & Slevc, 2018), and sport and inhibition (Wang et al., 2013), as well as the results in this study, which found a relationship between music experience and inhibition.

For shifting, the participants described how shifting was important to both playing a team sport or dancing, and playing instruments, such as a violin or piano. This is not supported by the quantitative results of this study, but previous research has found a relationship between music and shifting (Moradzadeh et al., 2014). Two participants also suggested that they were good at shifting during their university studies, for example, shifting between writing an essay and listening to a lecture, demonstrating the importance of shifting for academic performance.

For working memory, the participants stated that they could remember things if they made the effort to do so, for example, through repetition. All participants provided examples of how memory was important for music and sport, such as having to play music from memory or memorising lyrics, and remembering movements for ballet or different lacrosse stick holds. This is not supported by the quantitative results of this study, but previous research has found a relationship between music and working memory (Okada & Slevc, 2018). However, for all three executive function processes, participants did not mention whether or how they thought these processes were transferred from music and sport to their university studies.

According to two participants, time management was one skill that could be learned through music and sport, as those who do music and sport need to plan time for and prioritise these activities. This is supported by research as it has been found that musicians who are regularly trained in music and guided through music practice are better at practising alone and planning their own practice times (Prichard, 2021). Time management is also considered a topic of interest for research into the well-being of athletes. Athletes who have trained for longer are more likely to manage their time by finding solutions while newer athletes base time management more on their emotions (Macquet & Skalej, 2015). This ability to manage

time could also be used during university studies when planning and prioritising classes and writing theses, for example.

Four participants suggested that collaboration (and conflict management to some degree) was a skill that was very important in both music and sport. For sport, it has indeed been found that teamwork is important, but this can be influenced by competition. Team sports are better at improving teamworking skills as cooperative aims within the team mitigate competitive aims against other teams (Landkammer et al., 2019). Learning teamwork skills in music and sports helped two participants with working in groups in more academic and professional settings. This transfer of teamwork skills from music to academic settings is supported by the findings of Andersen et al. (2019). Following an art intervention involving music, participants had improved their collaboration, conflict management, and inclusion skills in the classroom.

Participants also mentioned emotional regulation. Playing or listening to music helped them work through their emotions, and sports competitions and music performances helped them learn how to deal with stress and losses. This supports results that have previously been found by Williams and Berthelsen (2019): a music and rhythm intervention had a positive effect on emotional regulation.

There was not much discussion on how goal setting and self-evaluation is learned through music and sport, but listening to music was mentioned as a method to reflect. There were also several categories that were not mentioned at all by participants: self-monitoring, self-consequences, task strategies, help seeking, and imagery. This suggests that these skills are not salient to participants and perhaps should not be the main focus of subsequent research. One participant did mention vocabulary as a skill that could be transferred from music to university studies. Listening to English songs improved their knowledge of English.

This is supported by the results of Pavia et al. (2019) who found that listening to songs can assist in learning vocabulary and that repeated listening has a greater impact on improving vocabulary.

The participants' perception of their executive function skills appeared to be somewhat reflected in their scores when comparing their performance to the means of the sample. People tend to have more favourable views of their own skills but those with better self-awareness acknowledge their own weaknesses (Kruger & Dunning, 1999). Perhaps, these participants had better self-awareness skills as this is an executive function skill (Kruger & Dunning, 1999). Music and sport were also very important to and had a positive impact on the participants' lives. According to the participants, music and sport are enjoyable, and are also social activities, useful for both making friends and spending time with family. This is supported by previous research. Playing music is associated with life satisfaction and it has been suggested by Koehler et al. (2021) that this association is partly due to the flow state that music can induce. Lera et al. (2021) found that sport is associated with happiness and suggest that the social aspects of sport play a role in this relationship.

Strengths and Limitations

There are several strengths of this study. First is the use of the Gold-MSI. This is a validated and reliable self-report questionnaire of music experience in the general population (Müllensiefen et al., 2014). Research conducted into its internal reliability used three different analyses (Guttman's lambda, McDonald's omega total, and Cronbach's alpha). It was found that all the scales had good or very good levels of internal reliability. Additionally, correlations between the scales were also conducted and the correlation coefficients were all positive with low to moderate magnitude. This suggests that the different subscales are related but do not measure the same concepts (Müllensiefen et al., 2014). The Gold-MSI has also

previously been used in research investigating the link between music and executive function (e.g., Okada & Slevc, 2018).

Second, this study uses a mixed methods approach. This means that both quantitative and qualitative techniques have been combined (Johnson & Onwuegbuzie, 2004). Qualitative results can add insight to quantitative results while quantitative results can add precision to qualitative results. A mixed methods approach can also be used to compensate for the weaknesses of a single approach. For this study, the most relevant strengths of the mixed methods approach are the corroboration of results (using two different approaches to find similar results) and the possibility for more insight into the results than might be found with a single approach (Johnson & Onwuegbuzie, 2004). For example, the results of the correlations for inhibition are corroborated by the results of the interviews, and the quantitative approach in this study (survey and correlations) allow for more generalizable, replicable data while the qualitative approach (interviews) can start to explain these correlations, providing new insights.

Third, this study adds to the literature on the relationships between music, sport, and executive function. It highlights that there is less research on these relationships for university students. Executive function is still important for this group (e.g., Sheehan & Iarocci, 2015), so research should be conducted to investigate possible interventions that can improve executive function (Holochwost et al., 2017). The fact that are some significant relationships between music and/or sport and executive function, and that interviewed participants mentioned how executive function skills are present in music and sport as well as in their university studies, suggests that research focusing on more experimental designs with music and sport interventions could be useful to determine whether music and sport improve executive function skills, and thereby academic outcomes, in university students. There is also not much research on comparisons between music and sport or within music (between

different instruments) and sport (between different sports) and executive function (e.g., Wang et al., 2013). The results of this study do not provide much clarity regarding the comparison of music and sport, but it does suggest that further research could be conducted to determine whether there any combined effects of music and sport, such as emotion and shifting.

There are also several limitations to this study. First, there are some drawbacks to the selected executive function tasks. They may not estimate executive function abilities as accurately as executive function tasks designed for research, such as the battery used by Okada and Slevc (2018). The executive function tasks for this study were found online. The inhibition and working memory tasks were found on a website for primary school pupils to learn about cognition, and the shifting task was an example from a package of executive function tasks that could be purchased. Therefore, one drawback is that the inhibition and working memory tasks could be too simple as they are aimed at children, and the shifting task could also be too simple as it is only one stage of a battery of executive function tasks. For the shifting task, several participants had 100% correct attempts, suggesting that it was not difficult. Asking participants to complete more attempts may have made it more accurate or the task itself should have had another aspect to make it harder. The inhibition task may have been confusing as it would not have been clear to all participants if they had not read the instructions in the survey. In both trials, they had to read the colour of the font rather than the word.

For the inhibition task, there is also another limitation. There were Dutch and international participants in this study, with only four participants (English, Irish, and Scottish) having English as their first language. For the inhibition task, the words were written in English, so international participants may have taken longer to complete the task as they first had to translate the word for the colour from their first language to English before saying it out loud. However, international participants who said the colours out loud in their first

language rather than English may have been at an advantage. They may not have been as distracted by the word in English as they were thinking in their own first language and focusing on the colour of the font instead of reading the English word. For certain international participants, the working memory task may also have been more difficult. Specifically, for Chinese and Japanese participants as their first language uses Chinese or Japanese characters and phonetic symbols, which are different from the letters used in the Roman alphabet. It may have been more difficult for these participants as they would have had to remember letters that are not part of their first language.

Second, this study had a small sample size. Only 25 participants completed the survey and five participants took part in the follow-up interview. A small sample size can result in low power. This means that there is a higher chance of a type II error (Schweizer & Furley, 2016). For example, where the results indicate a non-significant correlation when there actually is a significant correlation. The significant result is then missed. This limits the generalisability of the results as the results may not be representative of the larger population (Schweizer & Furley, 2016).

Third, this study used a self-report questionnaire for music and sport experience, which could be subject to self-report bias. Self-report bias is a measurement error that refers to the difference between data that are self-reported and their true values. This then affects the results of the statistical analyses conducted using these self-reported data. Data that are self-reported can be influenced in several different ways, whether the participants themselves are aware or unaware. Participants may consciously choose answers that make them seem better than they are or may exaggerate for the same reason. There is also the possibility of unconscious bias. Participants' memories are not video clips, so they could give answers that are not entirely accurate, as their memory is not clear (Robins et al. 2010). Some items of the self-report questionnaire should be investigated through self-report as they ask about personal

experience, such as emotions experienced by the participants. However, there are also some items that could have been independently observed, limiting the possibility for self-report bias. For example, how many hours they practice an instrument in a day or how well they sing along to a recording. An observer may be more accurate for these items than a self-report alone.

Fourth, another possible limitation is the adaptation of the Gold-MSI for sport. The Gold-MSI is a validated and reliable self-report questionnaire of *music experience* (Müllensiefen et al., 2014) but the changed items and subscales for sport have not been investigated. While most items only had a word switch from music to sport, there were also some items that were replaced entirely with another item from the ACSI-28 (e.g., Smith et al., 1995). This sport version of the Gold-MSI has not been investigated for reliability, so it is unknown how reliable the items are. It may be that this sport version is measuring other constructs than intended. However, this adaptation was necessary as no sport self-report questionnaire equivalent to the Gold-MSI could be found. Sport self-report questionnaires focus more on skills that occur during sports (e.g., Smith et al., 1995) rather than overall time of physical activity when playing sports or the amount of training received and so on. In sum, there are several limitations to this study, nevertheless, the results contribute to the literature on music, sport, and executive function, and indicate areas for further research.

Future Research

Future research could focus on determining causality. A longitudinal study could be conducted to examine whether participants who participated in more music and sport had improved executive function skills. It could also be used to provide support for the theory that executive function skills lead to improved academic outcomes if academic performance is also recorded. However, such a longitudinal study would take time. Experimental designs with random assignment and interventions could also be implemented to investigate causality.

Findings from this future research could be used to create a model for the relationships between music, sport, executive function, and academic outcomes.

Future research could also focus on how executive function processes are transferred and whether related executive function skills could be transferred from music and sport to university studies. From previous research and the interviews, it appears that goal setting, self-evaluation, time management, collaboration, conflict management, confidence, emotional regulation, and vocabulary could be transferred from music and sport to academic activities. In addition, other aspects that were not part of the selected categories were mentioned. Motor skills, coordination, perseverance, spatial cognition, and voice recognition could also be influenced by music and sport. These may be relevant for research into the skills that music and sport can enhance.

Conclusion

There are relationships between music, sport, and executive function in university students. Based on the results of this study, these relationships are between music/singing ability and inhibition, sport perceptual ability and shifting, and combined perceptual ability/emotion and shifting. Correlations have been found in previous research between music, sport, and all executive function processes (e.g., Okada & Slevc, 2018; Zheng et al., 2022). However, the causality is still not certain so future research should examine whether music and sport improve executive function or if there is another explanation for these relationships (Holochwost et al., 2017) as this was not possible within this particular study. It is possible that music and sport experience results in improved executive function or that better executive function results in more or better music and sport experience. For example, skills, such as time management and collaboration could be learned during music and sport and transferred to university studies or the other way around. Either way, there are possible implications for university students. Music and sport could be used to improve executive

function skills, and thereby academic outcomes, or training in executive function could improve sport and music performance.

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Appendix

Please circle the most appropriate category:	**1 Completely Disagree**	**2 Strongly Disagree**	**3 Disagree**	**4 Neither Agree nor Disagree**	**5 Agree**	**6 Strongly Agree**	**7 Completely Agree**
1. I spend a lot of my free time doing sport-related activities.	1	2	3	4	5	6	7
2. I sometimes choose to watch sports games/moments that can trigger shivers down my spine.	1	2	3	4	5	6	7
3. I enjoy writing about sports, for example on blogs and forums.	1	2	3	4	5	6	7
4. If somebody starts playing a physical activity-related game or demonstrating a sport skill I don't know, I can usually join in.	1	2	3	4	5	6	7
5. I am usually able to judge whether someone is a good athlete or not.	1	2	3	4	5	6	7
6. I handle unexpected situations in my sport very well.	1	2	3	4	5	6	7
7. I can easily imagine the actions and movements necessary for a sports skill (e.g. a kick or racket hold).	1	2	3	4	5	6	7
8. I'm intrigued by sports (or variations of which) I'm not familiar with and want to find out more.	1	2	3	4	5	6	7
9. Watching or listening to sports rarely evokes emotions for me.	1	2	3	4	5	6	7
10. I am able to follow along with the actions someone is demonstrating (e.g. following a yoga pose).	1	2	3	4	5	6	7

Please circle the most appropriate category:	**1 Completely Disagree**	**2 Strongly Disagree**	**3 Disagree**	**4 Neither Agree nor Disagree**	**5 Agree**	**6 Strongly Agree**	**7 Completely Agree**
11. I find it difficult to spot mistakes of athletes in the moment even if I know the sport well.	1	2	3	4	5	6	7
12. I can compare and discus differences between two performances or versions of the same skill in a sport.	1	2	3	4	5	6	7
13. I have trouble recognizing a familiar skill or movement when performed in a different way or by a different athlete.	1	2	3	4	5	6	7
14. I have hardly ever been complimented for my talents as an athlete.	1	2	3	4	5	6	7
15. I often read or search the internet for things related to sports.	1	2	3	4	5	6	7
16. I often pick certain sport match/moments to watch or listen to, or certain sport skills to practice to motivate or excite me.	1	2	3	4	5	6	7
17. I find it difficult to use a new skill, especially when someone else is performing a skill I know well.	1	2	3	4	5	6	7
18. It is easy for me to keep distracting thoughts from interfering when I am watching or listening to sports.	1	2	3	4	5	6	7
19. I am able to identify what is special to me about a sport or a sport match/moment.	1	2	3	4	5	6	7
20. I am able to talk about the emotions that a sports match/moment evokes for me.	1	2	3	4	5	6	7

Please circle the most appropriate category:	**1 Completely Disagree**	**2 Strongly Disagree**	**3 Disagree**	**4 Neither Agree nor Disagree**	**5 Agree**	**6 Strongly Agree**	**7 Completely Agree**
21. I don't spend much of my disposable income on sports.	1	2	3	4	5	6	7
22. I can tell when people are not playing sports very well.	1	2	3	4	5	6	7
23. When I play sports, I have hardly any idea whether I'm doing well or not.	1	2	3	4	5	6	7
24. Sport is kind of an addiction for me - I couldn't live without it.	1	2	3	4	5	6	7
25. I don't like practicing (especially new skills) in public.	1	2	3	4	5	6	7
26. When I am playing sports, I can focus my attention and block out distractions.	1	2	3	4	5	6	7
27. I would not consider myself an athlete.	1	2	3	4	5	6	7
28. I keep track of new sports, teams, matches, or athletes that I come across.	1	2	3	4	5	6	7
29. After seeing a new skill (e.g., a kind of kick or throw) demonstrated two or three times, I can usually do it by myself.	1	2	3	4	5	6	7
30. I only need to see a new skill or movement once and I can still remember and imagine it hours later.	1	2	3	4	5	6	7
31. Sport can evoke my memories of past people and places.	1	2	3	4	5	6	7

Please circle the most appropriate category:

32. I engaged in regular, daily practice of a sport(s) for **0 / 1 / 2 / 3 / 4-5 / 6-9 / 10 or more** years.

33. At the peak of my interest, I practiced **0 / 0.5 / 1 / 1.5 / 2 / 3-4 / 5 or more** hours per day on my primary sport.

34. I have attended **0 / 1 / 2 / 3 / 4-6 / 7-10 / 11 or more** live sporting events as an audience member in the past twelve months.

35. I have had formal training in theory (e.g., sport rules, team plays, names for racket holds or kicks) **0 / 0.5 / 1 / 2 / 3 / 4-6 / 7 or more** years.

36. I have had **0 / 0.5 / 1 / 2 / 3-5 / 6-9 / 10 or more** years of formal training in a sport (e.g., team practice, lessons) during my lifetime.

37. I play **0 / 1 / 2 / 3 / 4 / 5 / 6 or more** sports.

38. I watch or listen to sports attentively for 0-15 min / 15-30 min / 30-60 min / 60-90 min / 2 hrs / 2-3 hrs / 4 hrs or more per day.

39. The sport I am best at is _____