The Relationship between Musical Sophistication, Executive Functions and Autistic Traits

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Contents

Abbreviations

ADEXI: Adult Executive Functioning Inventory

ADHD: Attention Deficit Hyperactivity Disorder

AQ: Autism Spectrum Quotient

ASC: Autism Spectrum Condition

CFA: Confirmatory Factor Analysis

CFI: Comparative Fit Index

DIF: Differential Item Functioning

EDA: Electrodermal Activity

EF: Executive Function

Gold-MSI: Goldsmiths Musical Sophistication Index

MUSIC: Mellow, Unpretentious, Sophisticated, Intense, Contemporary

OMSI: Ollen Musical Sophistication Index

PCA: Principal Component Analysis

PEBL: Psychology Experiment Building Language

PedsQL: Pediatric Quality of Life Inventory™

RMSEA: Root Mean Square Error of Approximation

SRMR: Standardised Root Mean Square Residual

TIPI: Ten Item Personality Inventory

TLI: Tucker-Lewis Index

Chapter 1: General Introduction

Music is ubiquitous. Whether you are having a meal in a café, driving a car, playing games, working out, working, or studying, music is likely to be part of the experience or in the background. However, with the current research evidence, it remains unclear whether and how music influences our cognition. Moreover, findings regarding the relationship between music and personality and psychological factors, such as autism traits, has been mixed and controversial.

Musical sophistication has gained attention in recent years. While an association has been established between musical training and better cognition, other dimensions that contribute to musical sophistication, such as perceptual abilities and active engagement of music, and how they relate to cognition, is underexplored. Therefore, the current thesis aims to examine the relationship between general and specific aspects of musical sophistication with cognition. Specifically, it focuses on the possible positive relationship between several aspects of musical sophistication and executive functions (EF), an umbrella term for interrelated neurocognitive processes that are involved in planning, regulating, and adapting our behaviour in response to the constantly changing environment (Jurado & Rosselli, 2007). Moreover, its relation to other factors such as personality, and psychological factors, such as autism traits, is explored.

EFs are important for everyday life (work, school, social interaction, quality of life), and are known to be related to psychiatric conditions. Autistic individuals tend to have poorer EFs, and elevated autistic traits are associated with poorer EF (Mason et al., 2021). However, autistic traits are related to *better* perceptual ability in processing music (e.g., pitch discrimination; Dohn et al., 2012). Hence, the current thesis is interested in exploring the relationship between musical sophistication, EF, and autistic traits. This chapter will first introduce the definition and concept of musical sophistication, EF. and autistic traits, then describe the theoretical potential relationship between musical sophistication, EF and autistic traits, and how this forms the basis for the subsequent chapters.

Musical sophistication

Research on music and cognition has mainly focused on how musical training, as defined by the duration of formal musical training or education, affects cognitive performance. For example, cognitive performances of musicians and non-musicians are often compared to elucidate its association with musical training (Amer et al., 2013; Meyer et al., 2020; Strong & Mast, 2019). While the duration of formal training is an important reflection of musical ability, it does not capture one's full musical experience. Skills such as appreciating music, a sense of rhythm, communicating through music, and engaging in music are considered defining one's musical ability by people from different age groups and different levels of musical expertise, whereas technical skills in music have been perceived to be less important (Hallam, 2010). This suggests that the level of musical ability should not be operationalised by musical training only.

To determine the multidimensionality of musical ability, Ollen (2006) proposed the concept of musical sophistication which incorporates not only musical skills obtained via musical training, but also musical skills obtained through active engagement of music in everyday life. In parallel with this proposal, Ollen (2006) developed a 10-item instrument called Ollen Musical Sophistication Index (OMSI) to categorise individuals as either more or less musically sophisticated. Müllensiefen et al. (2014) later expanded the concept of musical sophistication by integrating cognitive theories of expertise in other domains (e.g., wine and badminton) and developing a 39-item instrument (i.e., Goldsmiths Musical Sophistication Index; Gold-MSI) that could assess musical sophistication on a continuum. Moreover, the Gold-MSI defined an empirical model of musical sophistication with five distinct dimensions: Active Engagement, Perceptual Abilities, Musical Training, Singing Abilities, and Emotions. While each dimension measures a distinct ability, they could be combined to provide a score of general musical sophistication. While both OMSI and Gold-MSI both provide a measure of musical sophistication, the former was developed using data from musicians only and did not reflect various dimensions of musical abilities like the Gold-MSI. Despite that, some OMSI items best predicted musical sophistication (i.e., OMSI and Gold-MSI score), suggesting a correlation between two measures (Zhang & Schubert, 2019). Therefore, OMSI is used in Chapters 4 and 5 where a briefer measure was needed due to time constraints, and because musical sophistication is not the main interest. The Gold-MSI was used in Chapter 6 given that musical sophistication was the main interest, and it covers more facets of musical sophistication.

Executive functions

While musical training has been consistently shown to positively relate to EF (Benz et al., 2016; Bugos et al., 2007), less is known about how other dimensions of musical sophistication are related to EF. EF refers to a set of high-level cognitive processes that are involved in planning, regulating, and adapting behaviours in response to an unfamiliar and changing environment (Gilbert & Burgess, 2008). Three core EFs are working memory, cognitive flexibility, and inhibition (Miyake et al., 2000). Working memory contains multiple components involve in the manipulation and storage of information in mind in the absence of perceptual information (Cowan, 2008; Diamond, 2013); cognitive flexibility refers to the ability to adapt to one's perspective or behaviour in response to new rules or priorities; and inhibition refers to the ability to suppress one's urge and impulse, and act appropriately (Diamond, 2013). These neurocognitive processes are essential for nearly every aspect of life, such as academic achievement in school (Borella et al., 2010), job readiness (Bailey, 2007), physical health (Crescioni et al., 2011), and quality of life (Brown & Landgraf, 2010).

There has been evidence for a positive association between musical training, working memory and cognitive flexibility (Benz et al., 2016), with musicians consistently outperforming non-musicians on working memory and cognitive flexibility tasks (George & Coch, 2011; Meyer et al., 2020; Zuk et al., 2014). This is supported by a meta-analysis which concluded that musicians perform better than non-musicians on tonal and verbal working memory tasks with moderate-to-large effect size (Talamini et al., 2017). The impact of musical training on inhibition is however inconclusive, with some studies demonstrating a positive effect (Hennessy et al., 2019), while others find a null effect (D'Souza et al., 2018; Moore, 2018). While musical training appears to be positively associated with EF overall, it remains unclear whether musical sophistication and its dimensions, besides musical training, are associated with EF.

Difficulties in EF negatively affect daily functioning in normal populations. They are also commonly experienced in neurological conditions such as schizophrenia (Schaefer et al., 2013), attention deficit hyperactivity disorder (Corbett et al., 2009), and autism spectrum condition (ASC; Demetriou et al., 2018). For ASC, a condition characterised by social communication difficulties, and repetitive, restricted behaviour and interest (American Psychiatric Association, 2013), a prominent cognitive theory postulates that EF deficits underlie these symptoms (Hill, 2004). It has been suggested that individuals from the general population who possess elevated autistic traits may also experience EF difficulties (Mason et al., 2021).

Although autistic individuals experience social and EF difficulties, special isolated abilities are commonly reported among them (Kanner, 1943; Meilleur et al., 2015). One of the often reported special abilities in autism relates to music perception; autistic individuals are shown to have superior pitch discrimination performance compared to neurotypical individuals (Bonnel et al., 2010; Heaton et al., 1998, 2008). Musicians with absolute pitch display significantly higher levels of autistic traits than musicians without absolute pitch and non-musicians, and autistic traits correlate with pitch identification performance (Dohn et al., 2012). Moreover, among a general population-based sample, parents report that children with an islet of ability or special abilities, including abilities in music, possess more autistic traits (Vital et al., 2009). This suggests that autism and autistic traits in the general population might be associated with enhanced perceptual abilities (i.e., pitch discrimination), a subdomain of musical sophistication. However, the association between autistic traits and musical sophistication has not been studied yet. Furthermore, the potential superior musical abilities are in contrast with EF difficulties that are common for autistic individuals or individuals with elevated autistic traits, since EFs seem to be *positively* related to musical abilities. Thus, the current thesis is interested in disentangling how musical sophistication, EF and autistic traits are related.

Musical sophistication and executive functions

Debate about whether promoting musical training/sophistication causally improves EF is ongoing. There is a possibility that pre-existing differences (e.g., in EF, IQ or brain structures) determine who are more likely to take musical lessons/trainings. Cross-sectional comparisons of EF performance between musicians and non-musicians do suggest a positive association between musical training and EF (George & Coch, 2011; Meyer et al., 2020). Moreover, brain imaging studies suggest differences in the activation of several brain areas (e.g., supplementary motor area and ventrolateral prefrontal cortex) between musicians and non-musicians (Zuk et al., 2014). However, these findings cannot rule out the potential role of pre-existing differences in driving the discrepancies between musicians and non-musicians. Swaminathan et al. (2017) found that association between intelligence and musical training disappeared after controlling for musical aptitude, but the association between musical training and musical aptitude persisted even after accounting for musical training. This further supports the hypothesis that high-functioning individuals are more likely to take musical lessons/trainings.

In contrast, there are longitudinal findings supporting musical training induces changes in brain and behavioural performance. Hyde et al., (2009) found no difference in brain structures between children who received training and children who did not receive training at baseline, but enlargement of corpus callosum, as well as increased grey matter in auditory and motor cortex were observed after 15 months of piano training. Similarly, children who went through two years of musical training showed stronger activations in regions underlying inhibition than children who went through sports training and children without musical training (Habibi et al., 2018). Performance in inhibition improved among children who went through four years of training, whereas no such improvements were observed among children who went through sports training or no training (Hennessy et al., 2019). Conflicting results were also found where there was no impact of musical training on EF (Bowmer et al., 2018), though it could be due to a shorter training duration (i.e., eight weeks). Hence, there is mounting evidence for a positive effect of musical training on EF performance and its associated brain regions.

Despite the debate about the causes and consequences of musical training on EF, there is a clear association between musical training and EF. Therefore, the current thesis is interested in examining whether musical sophistication, a construct that goes beyond musical training, is associated with EF.

Autistic traits

The word ‘spectrum’ in ASC implies that there are substantial individual differences between people with an ASC diagnosis. Moreover, general populations could also possess autistic traits to a certain degree even though they do not fulfil the criteria for a diagnosis. To quantify the autistic traits, the Autism Spectrum Quotient (AQ), a 50-item questionnaire with five subscales (i.e., social skills, imagination, attention switching, attention to detail and communication), was developed (Baron-Cohen et al., 2001). Autistic traits appear to be normally distributed in the general population and the autistic population consistently scores higher than the neurotypical population (Ruzich et al., 2015). Further evidence suggests that the AQ measures the intended traits along the autistic spectrum (Murray et al., 2016), and autistic traits as measured by the AQ are associated with difficulties and strengths that are commonly observed in ASC such as EF difficulties (Christ et al., 2010), theory of mind difficulties (Gökçen et al., 2016), and superior pitch discrimination performance (Dohn et al., 2012) in the general population. Together, these findings corroborate the use of AQ in assessing autistic traits among the general population and suggest that studying autistic traits in the general population might provide important insights on the cognitive processes of ASC.

Research evaluating the validity of the AQ has been primarily conducted in Western cultures, and there are limited studies examining its validity in Eastern cultures. While the translated AQ measures autistic traits as intended and observes similar findings as the original findings, such as sex differences on the AQ score, in other cultures such as Japan (Wakabayashi et al., 2006), Korea (Ko et al., 2018), and China (Zhang et al., 2016), there are potential cultural biases that lead to differential responses and scores (Freeth et al., 2013). Freeth and colleagues (2013) reported that Malaysian students scored significantly higher than British students on the English AQ, and they delineate possible cultural differences. For example, Japanese participants were, on average, slightly more influenced by social contexts than American participants when processing facial emotions (Masuda et al., 2008). This may influence how participants from different cultures respond to items assessing social skills (e.g., Item 36: I find it easy to work out what someone is thinking or feeling just by looking at their face). Hence, there might be cultural differences in responses to such items, or more general, on measures of autistic traits.

Research evaluating the reliability and validity of the AQ is scarce in Malaysia, hence the AQ should be validated first before using it in Malaysia. While cultural differences in social conventions are undoubtedly contributors to differences in the AQ scores between cultures, I further expected an influence of language on how the questions were responded. For example, in the study showing differences between the UK and Malaysia in AQ scores, the English AQ was administered to all participants even though English is the second language of many Malaysian students (Freeth et al., 2013). Perhaps proficiency in English influenced how Malaysian participants responded to the AQ, and they might score differently when responding in their native language. In chapter 2, I report a study that addresses the question of whether language influences AQ scores and answering tendency, in highly multilingual Malaysia. Participants responded to the AQ in two languages (English and Mandarin or English and Bahasa Malaysia). People tend to provide responses in line with the cultural norms of presented language (Harzing, 2005), thus I expected that participants would score lower on the English than Mandarin or Bahasa Malaysia AQ as British students were found to score lower than Malaysian and Indian students (Freeth et al., 2013).

Besides, the underlying psychometric properties and factor structure of the AQ are likely to be affected by culture. It has been argued that the conceptualization of autistic traits in five dimensions in the original AQ is not ideal. Various alternative factor structures have been proposed (Austin, 2005; English et al., 2020; Hoekstra et al., 2008; Kloosterman et al., 2011; Russell-Smith et al., 2011), and every alternative factor structure recommends a shorter version of the AQ (i.e., only including a subset of the 50 items). An abridged hierarchical version of the AQ-50, the AQ-28, appears to be more reliable (Hoekstra et al., 2011). The AQ-28 performs similarly or even better than the AQ-50 (Agelink van Rentergem et al., 2019; Kuenssberg et al., 2014), and is widely used in research (Dewinter et al., 2017; Geurts et al., 2016; Huang et al., 2021). Although the AQ-28 is used in Western countries, such as the UK and the Netherlands, where it was originally and extensively studied, it is unclear whether it would fit similarly in southeast Asia, such as Malaysia. Chapter 3 focuses on the factor structure of the AQ, by evaluating its cross-cultural validity and psychometric properties among the general population in the Netherlands and Malaysia. I expected that the hierarchical structure of the AQ-28 will be replicated in the Netherlands, where the AQ-28 had been studied before. However, given the lack of studies on the AQ in Malaysia, the analyses in Malaysia were more explorative. Cross-cultural measurement invariance of the AQ-28 was additionally evaluated to verify if the autistic traits measured in the Netherlands and Malaysia are compatible and comparable. I expected that the AQ-28 would not achieve cross-cultural measurement invariance given the differential discriminatory properties in the United Kingdom, Japan and India (Carruthers et al., 2018). The mean scores on the AQ-28 of Dutch and Malaysian participants were compared and expected to align with the prior findings of Malaysian students scoring significantly higher than British students on the original AQ-50 (Freeth et al., 2013). Hence, it is predicted that Malaysian participants would score significantly higher than Dutch participants on the AQ-28.

Music preference and autistic traits

Although musical sophistication includes a broad reflection of musical abilities, it does not include specific music preferences. One is likely to actively engage in their preferred/favourite music in everyday life, and active engagement is a dimension of musical sophistication. There seems to be a link between autistic traits and music preference. Autistic traits are related to systemizing and empathizing (Wheelwright et al., 2006). Systemizing is the tendency to analyse systems and rules that underlie them, whereas empathizing is the tendency to respond appropriately to others' emotions and predict their behaviours (Baron-Cohen, 2009). Individuals who are high on systemizing or empathizing cognitive style prefer Intense (e.g., rock) and Mellow (e.g., R&B) music respectively (Greenberg et al., 2015). Hence, autistic traits are potentially associated with specific music preferences. A comparison of autistic and non-autistic children revealed that the former group shows a greater preference for perceptually demanding dissonant music than the latter (Masataka, 2017). This aligns with the notion that those who possess more autistic traits prefer to systemise and hence might prefer more complex and perceptually demanding music.

That said, to the best of my knowledge, no study has specifically examined the relationship between autistic traits and music preferences. To address this gap, I studied whether autistic traits as measured by the AQ-28 would predict a preference for a certain musical style (Chapter 4). The musical styles I studied can be broadly categorised into five empirically tested factors in the West (Rentfrow et al., 2011, 2012). The five factors are Mellow, Unpretentious, Sophisticated, Intense and Contemporary, or MUSIC in short. I first tested whether the MUSIC factors could be confirmed in Malaysia by using the musical excerpts from the original study (Rentfrow et al., 2011). I then examined whether autistic traits could predict music preference from the established music preference factors. I hypothesised that the MUSIC factors would be confirmed in Malaysia given the substantial support for its stability (Bonneville-Roussy et al., 2013) and considerable replication of the MUSIC factor in Singapore (Heng et al., 2018). Elevated autistic traits were hypothesised to be related to a greater preference for Sophisticated or Intense music.

Music listening, executive function and autistic traits

Music listening is a form of active music engagement. Listening to music before or during cognitive tasks appears to have a positive influence on task performance (Angel et al., 2010; Hallam et al., 2002; Rauscher et al., 1993; Schellenberg et al., 2007), though null (Giroux et al., 2020; Steele et al., 1997), and detrimental effects are also reported (Furnham & Strbac, 2002; Giannouli et al., 2019). While a wide range of cognitive abilities such as spatial-temporal, linguistic processing, reading comprehension and processing speed were investigated previously (Angel et al., 2010; Etaugh & Michals, 1975; Rauscher et al., 1993; Schellenberg et al., 2007), limited research has specifically examined the effects of music listening on EF. Out of the three core domains of EF, the effect of music listening on working memory is probably the most studied. Similar to the mixed findings on other cognitive abilities, positive and null effects of music listening on working memory are reported (Chew et al., 2016; Schellenberg et al., 2007; Steele et al., 1997). Less is known about the effects of music listening on cognitive flexibility and inhibition, though there are indications that music listening has no direct influence on inhibitory control (Mansouri et al., 2017). Therefore, chapter 5 examines the effects of music listening on the performance of these three EF domains.

Early research has coined the enhancement in cognitive performance in response to music the ‘Mozart effect’ since such enhancement has been observed following the exposure to Mozart music (Jaušovec et al., 2006; Rauscher et al., 1993), but there is little evidence for the Mozart effect (Pietschnig et al., 2010; Steele et al., 1999). Instead, some have argued that the enhancement in performance is the consequence of preference because the *preferred* condition/stimulation has a positive effect on mood and arousal (Husain et al., 2002; Thompson et al., 2001). Elevated electrodermal activity (EDA), an autonomic property sensitive to changes in sympathetic arousal, is commonly observed while listening to preferred music (Davis & Thaut, 1989; Rickard, 2004). Significant changes in psychophysiological arousal are only detected when participants find the musical excerpts pleasurable, whereas participants who report no pleasurable episodes show no changes in psychophysiological arousal, highlighting the pivotal role of preference (Salimpoor et al., 2009). The current thesis, therefore, intends to compare the performance on each EF domain while listening to preferred music, relaxing music and no music (i.e., silence) in Chapter 5.

Increased physiological response to preferred music is noticed among autistic individuals, and more so when compared to neurotypical individuals (Hillier et al., 2016). I examined whether listening to preferred music would lead to better EF performance and elevated physiological response, and whether autistic traits were associated with EF difficulties and elevated physiological response (Chapter 5). Participants completed the EF tasks while listening to preferred music, relaxing music and in silence (i.e., a repeated measure), and the physiological response was recorded throughout these three conditions. It was hypothesised that listening to preferred music would lead to better EF performance and elevated EDA. Moreover, EDA would positively predict EF performance, and autistic traits would be negatively associated with EF performance and positively associated with EDA.

Musical sophistication, autistic traits, executive function, and quality of life

While chapters 2-5 focus on different aspects of active engagement in music, Chapter 6 examines whether musical sophistication as conceptualised by Müllensiefen and colleagues (2014) is related to EF and autistic traits. Hardly any studies have examined whether musical sophistication is related to EF given that the concept of musical sophistication has only recently gained attention. However, musicians have been consistently shown to perform better than non-musicians on EF tasks (D'Souza et al., 2018; Meyer et al., 2020), and improvements in EF following musical training are reported (Bugos et al., 2007; Chen et al., 2021). Therefore, it seems likely that greater musical sophistication would be associated with lower EF difficulties.

Superior musical ability, especially perceptual ability, has been observed among autistic individuals (Bonnel et al., 2010), and autistic traits are positively associated with pitch discrimination performance (Dohn et al., 2012). On the other hand, EF difficulties are common among autistic individuals (Demetriou et al., 2018) and those with elevated autistic traits (Mason et al., 2021). Therefore, while autistic traits might be positively associated with musical sophistication, or specifically with perceptual ability, it contradicts with the found negative relationship between autistic traits and EF. The current thesis aims to address the paucity of research by investigating the relationship between musical sophistication, autistic traits and EF, and the seemingly contradictory associations.

Apart from the lack of research, why autistic traits specifically, but not other traits such as ADHD or schizophrenic traits, were examined in relation to musical sophistication was motivated by the overlap of genes associated with both musical aptitude and ASC. Several genes (e.g., AVPR1a, FCGR1C & DLGAP2) that are associated with musical aptitude and creativity are also linked to risk for ASC (Israel et al., 2008; Mariath et al., 2017; Ukkola-Vuoti et al., 2013). Importantly, a substantial portion of genetic influences are shared between a diagnosed ASC and autistic traits in the general population (Colvert et al., 2015). Given the shared genetic influences and overlap of genes associated with musical aptitude, it would be interesting to examine whether autistic traits in the general population are associated with musical sophistication, a construct that conceptualises musical ability in multiple dimensions.

With the indication that EF is crucial for every aspect of life (Diamond, 2013), and that musical training improves EF (Benz et al., 2016), one might expect that musical sophistication and EF would be positively associated with quality of life. Quality of life is conceptualised as subjective well-being in multiple dimensions such as social, physical, and emotional well-being (Gill et al., 2013). There are indications that regularly engaging in music activities (e.g., music listening) has a positive effect on quality of life (Ashley, 2002; Särkämö et al., 2014). Given that musical sophistication refers to the engagement and contribution of different musical activities to overall musical ability, greater musical sophistication might be associated with a better quality of life. In addition, a greater level of autistic traits is associated with poorer quality of life, with potential mediators such as loneliness, social anxiety and coping strategy (Pisula et al., 2015; Reed et al., 2016). It is unclear if EF mediates the relationship between autistic traits and quality of life, in which this thesis will explore by examining whether musical sophistication, EF, and autistic traits are related to quality of life in Chapter 6. I hypothesised that musical sophistication would be positively associated with autistic traits and quality of life, and negatively associated with EF difficulties. Autistic traits would be positively associated with EF difficulties and negatively associated with quality of life. EF difficulties would be negatively associated with quality of life, and potentially mediate the relationship between autistic traits and quality of life.

Overview of the current thesis

The overarching goal of this thesis is to examine how musical sophistication and/or specific dimension of musical sophistication are related to autistic traits, EF and quality of life in the general population. Chapters 2 and 3 focus on validating the AQ as the AQ was used throughout the studies of the thesis. In Chapter 2, I investigated whether language influences the response to the AQ among multilingual Malaysians. Specifically, participants' responses to the AQ in their native language and English were compared. In Chapter 3, I evaluated the psychometric properties of an abridged version of the AQ (i.e., AQ-28) in the Dutch and Malaysian general population, and whether the autistic traits as measured by the AQ-28 are comparable between Dutch and Malaysian participants. In Chapter 4, I examined if autistic traits would be associated with certain music preferences after controlling for other factors (e.g., age, gender, personality traits and musical ability) that are known to influence music preferences. In Chapter 5, I investigated if listening to preferred music would improve the performance on EF tasks compared to relaxing music and silence and whether autistic traits and EDA are associated with the performance on EF tasks. The relationship between autistic traits, musical sophistication, EF, and quality of life was explored in Chapter 6.

Chapter 2: Language Matters: The Autism-Spectrum Quotient in English, Mandarin and Bahasa Malaysia

The autism-spectrum quotient (AQ) measures autistic traits and has been studied in different countries, sometimes with the English version, and sometimes with translated versions. However, the language of the questionnaire might influence non-native English speakers' answering tendency. In the current study, I compared the responses to the AQ of multilingual Malaysians (96 participants filled out the AQ in English and Mandarin, and 79 participants filled out English and Bahasa Malaysia). Participants scored higher on the English AQ compared to the Mandarin AQ, whereas there was no difference between the English and Bahasa Malaysia AQ score. Analysis of the response style suggests that the same person might display discrepant response styles in different languages, which seems to be related to language proficiency.

Based on:

Chee, Z. J., & de Vries, M. (2021). Language Matters: The Autism-Spectrum Quotient in English, Mandarin and Bahasa Malaysia. *Journal of Autism and Developmental Disorders*, 1-11.

An autism spectrum condition (ASC) is a neurodevelopmental condition characterised by social impairments and the presence of repetitive behaviour and/or restricted interests (American Psychiatric Association, 2013). However, people who are not on the spectrum could also have certain levels of autistic traits. For example, relatives of someone with an autism diagnosis tend to have relatively more autistic traits (Bishop et al., 2006). Autistic traits are seen within the general populations across different cultures (Baron-Cohen et al., 2001; Pisula et al., 2013; Wakabayashi et al., 2006), and there are different instruments designed to measure autistic traits in the autistic and general population. However, these instruments might not be equally reliable in different cultures, or when administered in different languages.

One of the most used instruments to measure autistic traits is the Autism Spectrum Quotient (AQ). Although this is not a diagnostic or screening tool, individuals with an ASC tend to score significantly higher than the neurotypical population (Baron-Cohen et al., 2001; Ruzich et al., 2015). The AQ has been translated into numerous languages and some of the translated versions of AQ have been validated in their respective countries (e.g., the Netherlands; Hoekstra et al., 2008; Poland; Pisula et al., 2013; Japan; Wakabayashi et al., 2006; China; Zhang et al., 2016). Despite the validation of the translated AQ in some countries, other studies show that people from different countries might score differently on the AQ. For example, Malaysian students and Indian students scored significantly higher than British students on the English AQ (Freeth et al., 2013). The authors proposed that this difference could be attributed to the differences in expressing or interpreting autistic traits between cultures. This might indeed partially explain the difference. For instance, it was suggested that people from an Eastern society like Malaysia would respond differently to certain items assessing social skills because the norm behaviour that the AQ refers to is derived from Western societies and might not be directly applicable to Eastern cultures (Freeth et al., 2013). For example, there may be a modest average difference between East Asians and Americans in the extent to which contextual variables affect processing of facial emotions with the former group affected slightly more by social context (Masuda et al., 2008). This might influence the answer on AQ item 36 (“I find it easy to work out what someone is thinking or feeling just by looking at their face”). East Asians might more likely disagree with this statement, given the relatively larger focus on context, while Americans might endorse this statement more often. Recent evidence using the AQ-Child (Auyeung et al., 2008), which is similar to the original self-reported AQ but reported by parents, supported that expression or interpretation of several AQ items may differ between cultures (Carruthers et al., 2018). Hence, differences in AQ scores between cultures can (partly) be explained by cultural differences in beliefs and behaviours.

Language, cultural accommodation, and ethnic affirmation

The language of a questionnaire can also influence the answering tendency of respondents. Two theories that aim to explain this phenomenon will be discussed, 1) the cultural accommodation theory, including the Sapir-Whorf hypothesis that aims to explain this theory, and 2) the ethnic affirmation theory. The *cultural accommodation* theory poses that using a certain language will activate the cultural values associated with that language, triggering a response that is consistent with the culture associated with that language (Harzing, 2005). For example, bilinguals from Hong Kong who completed an English version of the Schwartz Value Survey (SVS), which measures how important a cultural value is to the respondent, scored higher on ‘Western’ culturally important values (e.g., individualism), whereas those who completed the Chinese SVS scored higher on ‘Eastern’ values (Ralston et al., 1995). Similar differences between native and second language responses were found on questionnaires measuring elective choice and ideal job, which participants filled in *either* in English or their native language (except for British participants who only completed the questionnaire in English) in eight (Harzing et al., 2002), and 24 countries (Harzing, 2005). The scores of non-native English speakers on English questionnaires were closer to the British means than the scores of the primary language of the respondents. Reporting cultural values hence seems to be affected by language.

Cultural accommodation is also found in personality measures. Spanish-English bilinguals reported themselves to be more extraverted, agreeable and conscientious when responding in English than when responding in Spanish (Ramírez-Esparza et al., 2006). This is consistent with the idea that native English speakers are more extraverted, agreeable and conscientious than native Spanish speakers (Ramírez-Esparza et al., 2006). Likewise, Mandarin-English bilinguals who responded in English scored higher on global trait emotional intelligence than those who responded in Mandarin (Gökçen et al., 2014). Again, this corresponded with the idea that overall British respondents scored higher on trait emotional intelligence than Chinese respondents. Besides supporting the cultural accommodation theory, these findings suggest that cultural accommodation may even apply to relatively stable and non-cultural constructs like personality.

The Sapir-Whorf hypothesis (i.e., linguistic relativity hypothesis) suggests that the language we use influences our cognition (Lucy, 2015), activating the pre-existing cultural settings that the language is associated with (Patrão, 2018). This might explain cultural accommodation. Participants from mainland China and Taiwan who were instructed in Mandarin displayed a greater tendency to group objects based on relationship (i.e., consistent with the collectivistic view) than participants who were instructed in English (Ji et al., 2004). Moreover, Mandarin-English bilinguals displayed more dialectical thinking when responding in Mandarin (Chen et al., 2014), which aligns with East Asians' enhanced dialectical thinking style compared to Westerners (Boucher & O'Dowd, 2011). This suggests that possibly cultural accommodation happens because language triggers the user to temporarily display cognitions congruent with the culture associated with that language.

It seems that cultural accommodation can apply to cultural values, and personality, and might be explained by cognition. The effect is found in different experimental designs (i.e., between- and within-subject) and in both written and spoken language (Chen et al., 2014). This implies that cross-cultural differences might be lost when English questionnaires are administered in different countries for cross-national comparison. Therefore, it warrants research to investigate whether cultural accommodation would apply to autism characteristics as measured with the AQ.

An alternative, and opposing, theory is *ethnic affirmation*, suggesting that respondents are more likely to display responses consistent with one's own ethnic/culture when responding in their *second* language (Yang & Bond, 1980). Mandarin-English bilinguals showed more identification with Chinese culture when responding in English than when responding in Mandarin on two out of three questionnaires (Bond & Yang, 1982). However, item analyses revealed cultural accommodation on some items as well. Bond and Yang (1982) suggested that ethnic affirmation is more likely to happen than cultural accommodation when an item is more important to the participant's ethnic identity/culture. However, a later study found cultural accommodation rather than ethnic affirmation when explicitly measuring the importance of cultural values to the participants (Ralston et al., 1995). Therefore, it seems that cultural accommodation is a more robust finding.

Established cultural differences are a prerequisite for possible language effects (e.g., Ramírez-Esparza et al., 2006). Although it is unclear whether autistic traits are influenced by culture, the AQ measures deviant behaviour according to British standards, and what is considered deviant might be influenced by culture. Moreover, Malaysian students score higher on the AQ than British students, suggesting cultural differences (Freeth et al., 2013). Besides previously mentioned facial emotion processing, interpretation of pretend play (included in the AQ) might be influenced by culture. On the Western instrument The Child-Initiated Pretend Play Assessment, 75% of neurotypical Malaysian children were reported as showing atypical pretend play suggests that there might be cultural bias (Vetrayan et al., 2016), and hence language effects when measuring autistic traits with the AQ. According to the cultural accommodation theory, Malaysians might score lower on the AQ when answering in English, reflecting typical Western behaviour, compared to answering the AQ in their primary language.

Response style

Besides language effects, response styles (RS) vary between cultures. RS is defined as the tendency to produce systematic responses independent of the underlying construct that the questionnaire is designed to measure (Baumgartner & Steenkamp, 2001). Two types of response styles that might be at play are extreme RS versus middle RS (the tendency to use extreme or middle responses on a Likert/rating scale), and acquiescence RS versus disacquiescence RS (the tendency to agree or disagree with a statement regardless of the content) (Harzing, 2006). East Asians seem to display more middle RS compared to Westerners, who display more extreme RS (Chen et al., 1995; Harzing et al., 2012). Greek respondents displayed more acquiescence and extreme RS in comparison to respondents from Italy, Spain, France, Germany and the United Kingdom (Van Herk et al., 2004). RS can also vary between ethnicities from the same country. In the United States, Hispanics consistently exhibited a more extreme RS than non-Hispanics (Culpepper & Zimmerman, 2006;

Hui & Triandis, 1989). In Israel, Arabs display a more extreme RS than Jewish participants (Baron-Epel et al., 2010). In Malaysia, Malays tend to demonstrate a more acquiescence RS and a positive extreme RS (i.e., the higher end of a rating scale) than Chinese Malaysians (Harzing, 2006). The variation of RS according to ethnic background appears to be robust even after controlling for sex, parents' educational background and academic achievement (Bachman & O' Malley, 1984). Taken together, there are differences in RS between and within countries which could introduce artefacts not pertinent to the content of the questionnaire.

Apart from nationality and ethnic background, language is one of the most influential determinants of RS. More extreme RS is observed when one responds in their native language compared to a non-native language (Harzing, 2006). Additionally, on English questionnaires, it appears that English proficiency is positively associated with extreme RS (Messner, 2017). Generally, one is more likely to use extreme responses when answering in one's native language, or when one's English proficiency is high when answering in English. With respect to acquiescence RS and disacquiescence RS, the findings are not entirely clear.

The current study

Malaysia is a multilingual and multi-ethnic country in which each ethnic group retains their mother tongue (Albury, 2017) and cultural values, yet English proficiency in Malaysia is relatively good (Education First, 2019), especially in urban areas and at international universities. Therefore, I employed a within-subject design to study language effects on the AQ at a British university in Malaysia where the admission requirements necessitate English proficiency. A within-subject design makes it possible to directly compare individual language tendencies, which is not possible in between-subject designs (Harzing, 2005; Harzing et al., 2002).

The main aim of this study was to investigate whether Malaysians differ in their responses to the AQ when answering in English, and in their primary language (Mandarin or Bahasa Malaysia). Firstly, I hypothesised that cultural accommodation would be observed on the AQ, where participants would score lower on the English than on the Mandarin/Bahasa Malaysia AQ. Previous studies showed that Westerners score lower on the AQ than Asians (Freeth et al., 2013; Wakabayashi et al., 2006), which suggests that Western values are associated with lower scores on the AQ (a low

AQ score reflects ‘typical’ behaviour according to Western values). According to the cultural accommodation theory, Malaysians are expected to display a more Western response to the English AQ, than when they respond in their primary languages. Secondly, I predicted that participants would display a more extreme RS in their primary language, i.e., the language that they are most proficient in, their mother tongue. Finally, although acquiescence RS varies across countries and ethnicities, there is no clear pattern to how it varies according to language. I hence expect a difference, but no specific direction is predicted.

Method

Participants

Mandarin/English Sample. The English and Mandarin AQ were completed by 96 participants (64 females and 32 males; response rate on follow up questionnaire = 64.4%). The participants were all Chinese Malaysians, between the age of 18-26 (M = 19.9, SD = 1.77).

Bahasa Malaysia/English Sample. The English and Bahasa Malaysia AQ were completed by 79 participants (53 females and 26 males; response rate on follow up questionnaire = 64.8%). The ethnicity of participants who completed the English and Bahasa Malaysia AQ were more diverse (see Table 2.1) with an age range of 18-29 years (M = 20.1, SD = 2.11).

Participants rated their proficiency in English, Mandarin and Bahasa Malaysia using a 7-point Likert scale (*non-user*, *not very good*, *some basic knowledge*, *basic communication skills*, *competent, fluent* and *native speaker*; see Table 2.1). Only participants who reported to have some basic knowledge or higher in both English and Mandarin or Bahasa Malaysia were included. Moreover, I used this measure to determine the participants’ native language. However, some participants (in both groups) did not report that they were a native speaker in any of the languages. In the Mandarin/English sample, most participants rated themselves higher in Mandarin than English proficiency (n = 62), some participants rated themselves equally in Mandarin and English proficiency (n = 21), and some higher in English than Mandarin proficiency (n = 13). For the Bahasa Malaysia/English sample, 35 participants rated themselves higher in Bahasa Malaysia than English proficiency, 23 rated themselves equally in Bahasa Malaysia and English proficiency, and 21 rated themselves higher in English than Bahasa Malaysia proficiency.

Table 2.1

Demographics of the participants

	Sample	
Characteristic	English vs Mandarin (*N* = 96)	English vs Bahasa Malaysia (*N* = 79)
Sex		
Males	32 (33.3%)	26 (32.9%)
Females	64 (66.7%)	53 (67.1%)
Age (in years)		
$M \pm SD$	19.9 ± 1.77	20.1 ± 2.11
Ethnicity		
Malay	-	28 (35.4%)
Chinese	96 (100%)	40 (50.6%)
Indian	-	8 (10.1%)
Others	-	3 (3.8%)
Proficiency (Median)		
English	5 (Range = 3-7)	6 (Range = 3-7)
Mandarin	7 (Range = 4-7)	-
Bahasa Malaysia	-	6 (Range = 4-7)
p	$< .001^{**}$	.06

Note. $^*p < .05$, $^{**}p < .01$

Measures

The original English AQ (Baron-Cohen et al., 2001) and the Singapore Mandarin version of AQ (Autism Research Centre, n.d.) were used (see Appendix I for the original English AQ). There was a minor correction to the Singapore Mandarin AQ (the meaning of items 13 and 24 in Singapore Mandarin AQ were opposite to the original AQ). Additionally, the AQ was translated to Bahasa Malaysia, using translation-back-translation according to recommendation (Tsang et al., 2017). The ordinal alpha was reported as recommended by Zumbo et al. (2007) to estimate the internal reliability of Likert scales. The internal reliability of the English AQ (α = .85; Mandarin/English, α = .88; Bahasa Malaysia/English), Mandarin AQ (α = .86), and Malay AQ (α = .87) were good.

Instead of using the original scoring (i.e., 0 for *definitely agree* and *slightly agree* and 1 for *definitely disagree* and *slightly disagree*, or vice versa), I used the scoring of 1 – 4 (200 was the maximum score), given the reported more reliable range (Murray et al., 2016) and higher internal consistency and test-retest reliability (Stevenson & Hart, 2017). Half of the AQ items are reversely structured, thus half of the items would score 4 and 3 points for definitely agree and slightly agree, and another half of the items would score 4 and 3 points for definitely disagree and slightly disagree (Baron-Cohen et al., 2001). Given that the subscales of AQ have not shown consistency (Murray et al., 2017), I only studied the total AQ score.

The total extreme and middle RS were calculated by giving a scoring of one for items that were scored as *definitely agree* or *definitely disagree* (extreme), and zero for items that were scored as *slightly agree* or *slightly disagree* (middle). The acquiescence RS was calculated by dividing the number of items that were scored as definitely agree and slightly agree, by the total items in AQ. The calculation of extreme RS and acquiescence RS followed a previous study (Harzing, 2006), and they were calculated while ignoring the reverse scoring of the AQ, which would give an estimate of how likely a participant would display an RS regardless of the content.

Procedure

This study was approved by the Science and Engineering Research Ethics Committee of the university (Ethics Identification Number: OF220119). The participants were recruited through the faculty's study participation recruitment email. After obtaining consent from participants, participants were asked to provide some basic demographic information (e.g., ethnicity, gender, field of study and age), and rate their fluency in English, Mandarin and Bahasa Malaysia. The order of the AQ language was counterbalanced such that approximately half of the participants completed the English AQ first, and the other half completed the Bahasa Malaysia/Mandarin AQ first.

The follow-up questionnaire in English, Bahasa Malaysia or Mandarin was sent to the participants approximately one week after they completed the first questionnaire. If the participants did not respond to the follow-up questionnaire, a reminder email was sent after roughly a week of the follow-up email (*N* days between questionnaires: Mandarin; $M = 10$, $SD = 5$; Bahasa Malaysia; $M = 12$, $SD = 11$). Students received study credits or compensation for their participation.

Results

Planned analysis

The independent variable of the current study was a repeated measure (i.e., language). Hence, a one-way repeated-measures ANOVA was used to determine if the participant scored differently on the AQ in different languages. The normality of data was checked before conducting the analyses. Given that the independent variable only had two levels (i.e., Mandarin vs English or Malay vs English), a sphericity test was unnecessary (Field, 2018). Non-parametric tests were used if the assumptions for normality were violated, or when the data were count (e.g., extreme and acquiescence RS). All analyses were conducted with SPSS v25 (IBM Corp., 2017).

Mandarin vs English

A one-way repeated measures ANOVA revealed that there was a significant difference between the total score on the English and Mandarin AQ, $F(1, 95) = 12.6$, $MSE = 26.9$, $p < .001$, $\eta p^2 = .12$. The participants scored higher on the English AQ compared to the Mandarin AQ (see Table 2.2).

A non-parametric Friedman's test (M. Friedman, 1937) was conducted and revealed a significant difference between total extreme RS on the English and Mandarin AQ, $\chi^2_F(1) = 4.15$, $p = .042$. The participants displayed a more extreme RS on the Mandarin AQ than on the English AQ (see Table 2.2).

A Friedman's test revealed that there was no significant difference in acquiescence RS between the Mandarin and English AQ (see Table 2.2), $\chi^2_F(1) = .42$, $p = .59$.

Bahasa Malaysia vs English

After the removal of two outliers, the normality assumption was met ($n = 77$). A one-way repeated measures ANOVA revealed no significant difference between the total score on the English and Bahasa Malaysia AQ, $F(1, 76) = .48$, $MSE = 19.4$, $p =$

.49, ηp^2 = .006[1]. Given the cultural heterogeneity of the sample, I analysed the Malay participants' data separately (n = 28). The one-way repeated measures ANOVA revealed again no significant difference between the total score on the English and Bahasa Malaysia AQ, $F(1, 27) = .52$, $MSE = 21.3$, $p = .48$, $\eta p^2 = .02$.

A Friedman's test was conducted. There was a significant difference between the total extreme RS on the English and Bahasa Malaysia AQ, χ^2_F (1) = 34.7, $p <$ .001. The participants were more likely to display an extreme RS on the English AQ than on the Bahasa Malaysia AQ (see Table 2.2). Analysis with only the Malay subsample revealed a similar result, $\chi^2_F(1) = 20.57$, $p < .001$.

A Friedman's test revealed that there was a significant difference in acquiescence RS between the Bahasa Malaysia and English AQ, χ^2_F (1) = 5.56 p = .02. The participants displayed a more acquiescence RS on the English than on the Bahasa Malaysia AQ (see Table 2.2). Repeating the analysis with only Malay participants revealed a similar result, $\chi^2_F(1) = 9.00$, $p = .004$.

Table 2.2

The mean (standard deviation) of total AQ score, median of total extreme RS and median of acquiescence RS on English, Bahasa Malaysia and Mandarin AQ.

	Language					
	English	Mandarin	p	English	Bahasa Malaysia	p
Total AQ						
Mean	120	117	$< .01^{**}$	117	117	.49
(*SD*)	(11.5)	(11.9)		(9.45)	(8.26)	
Extreme RS						
Median	12	15	$.04^{*}$	14	8	$< .01^{**}$
Range	0-46	0-40		1-36	0-34	
Acquiescence						
Median	.58	.56	.59	.60	.58	$.02^{*}$
Range	.30-.84	.32-.84		.30-.88	.32-.82	

[1] Analyses including the outliers showed similar results, $F(1, 78) = .94$, $MSE = 19.6$, $p = .34$, ηp^2 = .012.

Note. *$p < .05$, **$p < .01$

Language proficiency

Because of the variability in first and second language distribution, and English language proficiency (particularly in the Bahasa Malaysia sample), I additionally explored with a correlational analysis whether English language proficiency was related to the total AQ scores, extreme RS and acquiescence RS. I conducted Pearson correlations although the data were ordinal or count because it was demonstrated that Pearson correlation is robust against violations and could produce similar results as Spearman correlation (Norman, 2010). English proficiency was negatively correlated with total AQ scores in the Mandarin/English sample, $r(94) = -.22$, $p = .03$, and positively correlated with extreme RS in the Bahasa Malaysia/English sample, $r(77) = .26$, $p = .02$ (See Table 2.3).

Table 2.3

Correlations between language proficiency and the outcome variables in the corresponding language.

	Sample			
	Mandarin/English (*N* = 96)		Bahasa Malaysia/English (*N* = 79)	
	Mandarin Proficiency	English Proficiency	Bahasa Malaysia Proficiency	English Proficiency
Total AQ Scores	.01	-.22*	.03	-.13
Extreme RS	-.02	.19	.14	.26*
Acquiescence RS	-.02	.14	.05	.18

Note. *$p < .05$, **$p < .01$

Discussion

The main aim of the current study was to investigate whether Malaysians who speak more than one language would respond differently to the English and Mandarin/Bahasa Malaysia AQ. In contrast to the hypothesis, the Mandarin/English sample scored higher on the English than on the Mandarin AQ. There was no significant difference between the English and Bahasa Malaysia AQ. In line with the hypotheses, a more extreme RS was seen on the Mandarin AQ compared to the English AQ. In contrast, a more extreme RS was seen on the English than on the Bahasa Malaysia AQ. Moreover, while no differences were found in acquiescence RS in the Mandarin/English sample, the Bahasa Malaysia/English sample displayed a more acquiescence RS on the English than on the Bahasa Malaysia AQ. Explorative analyses showed that English proficiency was negatively correlated with total English AQ scores in the Mandarin/English sample, and positively correlated with extreme RS in the Bahasa Malaysia/English sample.

Mandarin vs English

The results did not support the hypothesis that the score on the Mandarin AQ would be higher (i.e., cultural accommodation theory) than on the English AQ. In fact, I found the opposite. A possible explanation might be that ethnic affirmation took place (Yang & Bond, 1980). This is surprising given the lack of consistent support for this theory, and if supported, it occurs in the context of culturally important content (Bond & Yang, 1982), which is not expected with the AQ. Regardless, the current findings demonstrate that Chinese Malaysians are likely to display elevated scores on English AQ, which might not accurately reflect their autistic traits. The elevated English AQ found in the current study could partly explain previous findings (Freeth et al., 2013), where Malaysian students scored relatively high on the English AQ. However, the average scores on the Mandarin AQ in the current study were still higher than the scores of the British students in the study by Freeth and colleagues (2013), hence it might not explain the full picture. Moreover, Japanese also score higher than British even when responding in their native language (Wakabayashi et al., 2006). Since English proficiency was negatively correlated with English AQ scores, better English proficiency might lead to lower English AQ scores and diminish the currently found language differences. The current findings hence suggest that the Mandarin AQ scores reflect a more reliable range given the possible contamination of proficiency on the English AQ.

In line with previous findings (Harzing, 2006), participants displayed a more extreme RS in Mandarin, in which their proficiency was higher than in English, and they were more likely to display middle RS in English. This is consistent with findings demonstrating more a middle RS when responding in English compared to one's native language (Harzing, 2006). Moreover, my study showed that this effect is even present within the same person. This implies that participants might be more confident to use explicit and strong answers in their native language, and it might be more reliable to administer a questionnaire in someone's native language.

There was no difference in acquiescence RS between the Mandarin and English AQ, where previous studies showed differences between nationalities and ethnicities (Harzing, 2006). However, previous studies did not explicitly test whether acquiescence RS would differ between languages (Harzing, 2006). The current findings suggest that the tendency to agree or disagree with an item might not differ between the Mandarin and English AQ.

Bahasa Malaysia vs English

There were no differences between the Bahasa Malaysia and English AQ scores, implying that cultural accommodation did not take place within the whole sample nor the Malay-only sample. However, the results are challenging to interpret given the diversity of the sample. For the Chinese Malaysians, both English and Bahasa Malaysia were not their first language, and for the Malay, on average, their English language proficiency was higher than their Bahasa Malaysia proficiency. In short, Bahasa Malaysia was not the primary language for the majority of this sample. Previous findings of language effects were based on a comparison between primary/native and second languages (Gökçen et al., 2014; Ramírez-Esparza et al., 2006; Zavala-Rojas, 2018). The current findings suggest that cultural accommodation might not be detected when not directly comparing one's primary and secondary language.

In contrast to the expectation that participants would show a more extreme RS in Bahasa Malaysia (which I assumed to be their native language), the Bahasa Malaysia/English sample were more likely to display an extreme RS on the English AQ than on the Bahasa Malaysia AQ. This, however, might not be surprising in light of the observed positive correlation between English proficiency and extreme RS in the Bahasa Malaysia/English sample (Table 2.3), and corroborates previous findings that showed that a more extreme RS was related to higher English proficiency (Harzing, 2006). Such a correlation was not found in the Mandarin/English sample where the proficiency in Mandarin was significantly higher than in English. This suggests that when the proficiency of both languages (native vs English) is comparable, one is more likely to display an extreme RS in English. The current findings are, therefore, in line with findings showing a higher tendency to use extreme responses in English than Kannada when the proficiency of both languages is similar (Messner, 2017). Moreover, since Bahasa Malaysia was not the primary language of most participants, the findings suggest that participants might have shown a more middle RS in their non-primary language, Bahasa Malaysia.

The Bahasa Malaysia/English sample displayed a more acquiescence RS on the English than on the Bahasa Malaysia AQ, whereas no such difference was observed between the English and Mandarin AQ. However, given the diversity of the sample (ethnicity and language proficiency), these findings are difficult to interpret. To get a clearer picture, future research could recruit explicitly native Bahasa Malaysia speakers who speak English as a second language. The results do suggest that when administering an English questionnaire to multilinguals, extreme and acquiescence RS irrelevant to the content might occur.

General discussion

The current results show that language might influence AQ scores and RS, but the differences and direction might result from several factors.

Firstly, language proficiency might partly explain the discrepancy in the findings. In the Mandarin/English sample, better English language proficiency (predominantly their second language) might lead to lower (and possibly more accurate) English AQ scores. In the Bahasa Malaysia/English sample, the difference in AQ scores was possibly not found because their English and Bahasa Malaysia language proficiency was similar. When the proficiency of both languages is similar, there might be no differences when responding in different languages. Notably, although there was some spread in English proficiency in the current sample, all participants were considered *fluent* in English (i.e., they all follow a fully English study for which they need to have a proven minimal English level). Furthermore, even with a basic measure, English proficiency correlated with the AQ scores and RS. The proficiency in one's non-primary language hence appears to play an important role even when the bilinguals/multilinguals are fluent in this language.

Secondly, the specific language might play a role. Certain information/words might be interpreted differently in different languages. It has been suggested that language might influence the interpretation of certain items (e.g., item 34; ‘Enjoy doing things spontaneously’) in Japanese, Bengali and Hindi, leading to some items showing excellent discriminant properties in some countries but not in others (Carruthers et al., 2018). Possibly, there are more ambiguous words in Mandarin than in Bahasa Malaysia when compared to the English AQ, which might explain the differences between the Mandarin and English AQ but not the Bahasa Malaysia and English AQ. Although beyond the scope of the current study, item analyses in larger-scale studies could give insight into which specific items might vary between languages/cultures. Certain items, for example touching upon pretend play, or spontaneity (Carruthers et al., 2018) might be interesting to focus on in future studies. I used back-translation versions of the AQ. The existing Mandarin AQ was translated with back-translation, and I wanted the Bahasa Malaysia AQ to be translated similarly for comparability. Although widely used, this might have led to inadequacy in the translation (Barger et al., 2010; Harkness et al., 2004). Differences in AQ scores between languages could possibly arise due to semantic or conceptual differences. However, although both the Mandarin and Bahasa Malaysia AQ were translated similarly, there were only differences observed between Mandarin and English AQ.

Thirdly, cultural dimensions such as individualism and collectivism might play a role. Individualism emphasises the independency of the self and on personal goals (Triandis, 1993), and it is linked to the inclination to attend to focal objects independent of the context (Nisbett & Miyamoto, 2005). Collectivism emphasises the interdependent self and strives to maintain harmonious relationship between individuals (Triandis, 1993), and is linked to the inclination to attend to objects in relation to the context (Nisbett & Miyamoto, 2005). Western societies and English-speaking countries are commonly associated with individualism (Triandis, 2015). This might have influenced the current findings in two ways. 1) Individualistic tendencies might influence scoring on the *attention to details* subscale of AQ. Although this could explain the higher scores on the English AQ as compared to the Mandarin AQ due to cultural accommodation, I did not find this effect on the Bahasa Malaysia AQ. Moreover, this contrasts previous consistent findings of lower AQ scores among Westerners compared to Asians/East Asians (Freeth et al., 2013; Wakabayashi et al., 2006). 2) Individualism has been linked to less acquiescence RS

(Harzing, 2006), and more extreme RS (Marshall & Lee, 1998), but see (Harzing, 2006; Johnson et al., 2005). Although Malaysians are suggested to be less individualistic than British (Hofstede Insights, n.d.), I did not explicitly measure individualism/collectivism. In addition to the inconsistency in the literature, this makes interpretations on the relationship between individualism/collectivism and AQ scores and response styles speculative, though of interest for future studies.

Limitations and implications

The study has some limitations. Firstly, language proficiency was evaluated relatively basic to check whether participants were fluent enough to fill in the questionnaires in Mandarin and Bahasa Malaysia. We did not anticipate a direct influence of fluency on the scores and response styles. Some participants did not state that they were a native speaker in any of the languages. This is, however, reflective of Malaysia, which is a highly multilingual country, where many people speak different languages from an early age on (sometimes even combined in one conversation), and the difference between primary and secondary language might not always be completely clear. Therefore, it was unclear whether the differences on the AQ score could be attributable to the discrepancy between native and second language, especially for the participants who completed the Bahasa Malaysia and English AQ. Moreover, the Bahasa Malaysia/English sample was heterogeneous with respect to ethnicity and language background. Therefore, the findings on the comparison of Bahasa Malaysia and English AQ should be interpreted with caution. Future studies could recruit explicitly native Bahasa Malaysia speakers who are fluent in English to get a clearer picture. Secondly, RS might confound with autistic traits (Bolt & Johnson, 2009), i.e., people with high autistic traits might be identified as displaying more extreme or acquiescence RS. A solution would have been to measure RS independently, for example with a short and unrelated scale (Greenleaf, 1992), or as a latent variable using the multidimensional nominal response model (Bolt & Johnson, 2009). However, the within-subject, counterbalanced design probably has minimised this possible bias. Autistic traits are relatively stable across time (Whitehouse et al., 2011), hence it is unlikely that the AQ score differences between languages emerged from the fluctuation of autistic traits a week apart.

Although the AQ is a widely used measure of autistic traits, the factor structure, the interpretability (English et al., 2020), and the scoring of the AQ (i.e., binary or Likert; Stevenson & Hart, 2017) are under debate. Though there might be more similarities than differences in social norms across cultures, all AQ items are, by definition, bounded by Western social norms because the AQ was developed in a Western country. Therefore, non-Western participants' responses to items describing social behaviours that vary across cultures are likely to differ. Conversely, there is a possibility that due to cultural differences, ASC itself differs across cultures. However, even if ASC is different in different cultures, the AQ is biased towards "Western ASC", and the current findings highlight how the use of languages associated with distinct social norms might lead to differential responses. Thus, a locally developed measurement of autistic traits could be an important future direction to capture the culturally unique social behaviours given that a growing body of research has indicated that the accuracy of screening tools such as AQ could be compromised due to cultural or ethnic differences (de Leeuw et al., 2020).

The current findings suggest that even within the same person, the language can influence the way one responds to a questionnaire, tendency to agree or use extreme answer options, although it might be dependent on the presented language. Given the likelihood of having this contamination from language, some solutions have been proposed in previous studies to reduce the language effect, such as using a 7-point Likert scale or ranking (Harzing et al., 2009), or letting the participants choose which language they prefer to answer in. However, changing the answer scale might have other disadvantages, such as reducing comparability with previous studies. Moreover, letting participants choose the language may potentially intensify the language effect (Richard & Toffoli, 2009). Since RS varies between nationalities, ethnicities or even languages, failure to take that into account might confound the cross-cultural comparisons. Various methods and statistical controls could potentially control for RS, but each method is associated with specific disadvantages (Van Vaerenbergh & Thomas, 2013). For example, adding representative indicators for response styles (RIRS) was recommended (i.e., adding additional items irrelevant to the content of the questionnaire to capture response styles, and include the calculated response styles as covariates in subsequent analyses), but researchers may not always have the choice to include additional items (e.g., working on secondary data) or risk a drop in participation rate due to lengthy questionnaires. Therefore, it appears that an optimal solution would be to administer the AQ in the native language of the participants because it offers the most straightforward control for possible contamination from the differences between languages or cultures, and participants would better qualify their responses on rating scales (Van Vaerenbergh & Thomas, 2013). Moreover, before using a questionnaire in a different language or country, it is important to validate a questionnaire for that specific population and culture.

Conclusion

The current study shows that, with a within-subject design, responses on the AQ might be influenced by language when comparing someone’s primary and secondary language. However, these results might be weaker, or absent for participants who are highly proficient in English. Moreover, language might influence the response style, where participants might respond more extreme or agreeable in their primary/most proficient language. Cross-cultural comparison of AQ scores may thus be contaminated by the language of the AQ, and RS could additionally introduce artefacts. Importantly, the observed difference on the AQ score between the Mandarin and English AQ was small (a 3 points difference) and might hence be of limited clinical relevance. Nonetheless, it might be important to consider when applying the norm/cut-off scores derived from one culture to another or making cross-cultural comparisons.

In conclusion, it seems best to administer questionnaires in a participants’ native language. If that is not possible, researchers should take the non-primary language proficiency and cross-cultural differences in RS into account or exercise caution in interpreting the results when the English AQ is used for non-English speaking people. Moreover, these effects could reduce the reliability/validity of Western/English developed diagnostic tools in Malaysia, hence the questionnaires/diagnostic tools should be validated in the country’s languages separately before implementing them.

Chapter 3: The Factor Structure and Measurement Invariance of the Autism Spectrum Quotient-28: A Cross-Cultural Comparison between Malaysia and the Netherlands

Despite several psychometric advantages over the 50-item Autism Spectrum Quotient (AQ-50), an instrument used to measure autistic traits, the abridged AQ-28 and its cross-cultural validity have not been examined as extensively. Therefore, the current study aimed to examine the factor structure and measurement invariance of the AQ-28 in 818 Dutch (M_{age} = 37.4, 581 females, 233 males, 4 others) and 437 Malaysian (M_{age} = 23.0, 328 females, 99 males, 10 others) participants from the general population. The hierarchical structure of the AQ-28 showed fair and good fit in Malaysia and in the Netherlands respectively. A multi-group invariance analysis supported that the AQ-28 is cross-culturally invariant. Malaysians (*M* = 68.63, *SD* = 8.33) scored significantly higher than Dutch participants (*M* = 51.48, *SD* = 10.30) on the AQ-28 while gender was controlled for. While the measurement invariance suggests that the AQ-28 functions similarly in Malaysia and the Netherlands in terms of structure and concept, exploratory analyses showed eleven items with differential item functioning (DIF). Hence, while the AQ-28 possesses a stable factor structure and appears to measure the same latent traits in Malaysia and the Netherlands, some items potentially display cultural bias which, in turn, might explain the differences in AQ scores.

Based on:

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The Autism Spectrum Quotient (AQ) is a 50-item self-report questionnaire developed in the United Kingdom (UK) to measure autistic traits in the general population (Baron-Cohen et al., 2001). An Autism Spectrum Condition (ASC) is characterised by social difficulties and repetitive/restricted behaviour and interests (American Psychiatric Association, 2013). The AQ-50 has five subscales (Social Skills, Imagination, Communication, Attention Switching, Attention to Detail; 10 items per subscale) that were formulated to reflect traits that are associated with ASC. While the AQ is widely used, its factor structure has not been consistently confirmed, with various factor structures proposed across studies (Austin, 2005; Hurst et al., 2007; Kloosterman et al., 2011). Moreover, the cross-cultural validity of the AQ remains underexplored (but see Carruthers et al., 2018; Freeth et al., 2013), hindering cross-cultural comparisons. In light of this, the current study aims to compare the factor structure of an abridged version of the AQ, the AQ-28 (Hoekstra et al., 2011), in Malaysia and the Netherlands and examine cross-cultural measurement invariance.

The originally proposed five-factor structure of the AQ-50 is under debate, as it was not supported across various studies using principal components analysis (PCA) and confirmatory factor analysis (CFA; Austin, 2005; Hoekstra et al., 2008; Hurst et al., 2007; Kloosterman et al., 2011). Numerous alternative factor structures with a reduced number of items have been proposed (Austin, 2005; Hoekstra et al., 2008; Kloosterman et al., 2011; Lau et al., 2013; Russell-Smith et al., 2011). This clearly indicates that some of the original items could be dropped without losing explanatory power and this might even improve the consistency of the scale. In light of that, the AQ-28 was developed and validated in both a Dutch and a British sample (Hoekstra et al., 2011). The AQ-28 has a hierarchical structure similar to an earlier factor model proposed by Hoekstra et al. (2008) with four lower-order factors 'Social skills', 'Routine', 'Switching' and 'Imagination' subsumed under a higher-order factor 'Social behaviour' and another separate higher-order factor 'Numbers/patterns'. The AQ-28 is highly correlated with the AQ-50 (r = .93-.95) and, similar to the AQ-50, males score higher than females on the AQ-28 (Hoekstra et al., 2011). The factor structure of the AQ-28 was replicated in autistic samples from the UK and the Netherlands (Grove et al., 2017, 2021; Kuenssberg et al., 2014). The AQ-28 appears to measure similar traits in both the general and autistic population (Murray et al., 2014), and in males and females in the autistic population (Grove et al., 2017).

Differential item functioning (DIF) analysis on the AQ-50 suggested the AQ-28 may be more appropriate for comparison between autistic and non-autistic groups given that eight items that perform differently in both groups were not included in the AQ-28 (Agelink van Rentergem et al., 2019). The findings overall suggest that AQ-28 is a reliable alternative to the AQ-50.

The cross-cultural validity of the AQ-28 is underexplored, even though the AQ-50 is used and has been studied in non-Western populations. For example, in a Taiwanese population, PCA supported a five-factor structure similar to the original proposed structure with reduced items (Lau et al., 2013), and sex differences were replicated. This suggests that the AQ-50 may consistently capture autistic traits across different cultures. However, other studies found that some items of the AQ-50 may display cultural bias (Carruthers et al., 2018; Freeth et al., 2013). For instance, people from different cultures might respond differently to the AQ item assessing the ability to understand others' emotions based on faces (item 36 in the AQ-50), because East Asians, on average, are slightly more likely to be influenced by social context than Americans when evaluating facial emotions (Masuda et al., 2008). So far, studies on cultural bias used the self-report AQ-50, parent-report AQ-50 (the parent-report version consists of the same items, but the child's traits are reported by their parents), and parent-report AQ-28 (Liu et al., 2021). To the best of my knowledge, no study to date has specifically investigated the factor structure of the self-report AQ-28 in a non-Western general population sample. Moreover, even though the factor structure of the AQ-28 has been consistently confirmed among autistic samples (Grove et al., 2017, 2021), less is known about its replicability in the general population. Therefore, the current study addressed these issues using the AQ-28 in a Dutch and a Malaysian general population sample.

Apart from the factor structure, measurement invariance of the AQ-28 across cultures has not been confirmed. Meaningful cross-cultural comparisons necessitate measurement invariance (Boer et al., 2018), that is, true cross-cultural differences in a trait can only be revealed if the measure assesses the same trait in both cultures. For example, Malaysian students were found to score significantly higher than British students on the AQ-50 (Freeth et al., 2013). The authors suggest that the score differences might reflect cultural differences in the expression of autistic traits. Alternatively, the score differences could stem from measurement non-invariance, which was not tested. Therefore, the current study further investigated whether previous cross-cultural score differences on the AQ-50 (Freeth et al., 2013) could be replicated with the AQ-28, and whether cross-cultural measurement non-invariance could explain these differences.

The main objective of the current study was to examine the factor structure of the AQ-28 with CFA in Dutch and Malaysian general population samples. I hypothesised that the hierarchical structure of the AQ-28 would display a good fit in the Dutch sample since it was initially studied in the Netherlands. Given the dearth of studies examining the hierarchical structure of AQ-28 in a non-Western context, I formulated no specific hypothesis concerning the factor structure in the Malaysian sample. The current study also aimed to test cross-cultural measurement invariance of the AQ-28 and compare the total score on the AQ-28 between Dutch and Malaysian adults. Given that several items of the AQ-50 showed differential discriminatory power across cultures (Carruthers et al., 2018), I hypothesised that the AQ-28 would show cross-culturally measurement non-invariance. Moreover, given that Malaysian students scored higher than British students on the AQ-50 (Freeth et al., 2013), I hypothesised that Malaysians from the general population would score higher on the AQ-28 than Dutch people from the general population. I additionally explored which items of the AQ-28 function differently in Malaysia and the Netherlands with differential item functioning (DIF) analysis.

Method

Participants

Malaysian sample. Ethical approval was obtained from the Science and Engineering Research Ethics Committee of the University of Nottingham Malaysia (Ethics Identification Number: CZJ160719). The AQ-28 data of 537 Malaysian participants was the same sample recruited in Chapter 4. Exclusion criteria for the analyses were: 1) taking less than 15 minutes to complete all questionnaires (*n* = 74), 2) taking the survey twice (*n* = 10), 3) being under the age of 18 (*n* = 1), 4) not being Malaysian (*n* = 9), and 5) filled in the Bahasa Malaysia version of the AQ-28 (*n* = 6). After applying those filters, 437 (81%) responses were retained. The age of the Malaysian participants (328 females, 99 males and 10 preferred not to say) ranged from 18 to 69 (*M* = 23.0, *SD* = 5.9). The participants were 264 (60.4%) Chinese

Malaysians, 120 (27.4%) Malay, 30 (6.9%) Indian Malaysians and 23 (5.3%) of other ethnicities.

Dutch sample. The AQ-28 data of 831 Dutch non-autistic participants were collected by the Netherlands Autism Register (NAR), and the data collection was approved by the ethics committee of Vrije Universiteit Amsterdam (VCWE2020-041R1). The NAR collects data about autistic and non-autistic individuals. For the purpose of this study an ASC diagnosis is an exclusion criterion and only data of the non-autistic sample was used. Participation was voluntary and participants were informed that their data would be used for scientific research. I excluded participants under 18 years (n = 13), resulting in 818 participants, including 581 females, 233 males and 4 “other”, included in the analyses. The age of the Dutch participants ranged from 18 to 80 (M = 37.4, SD = 15.1). 736 (90%) of the participants self-identified Dutch as their ethnicity, whereas Moroccan, Turkish, Surinamese, Antilleans/Arubans and Indonesian made up 5.7% of the rest of the sample. The remaining 4.3% (n = 35) were of other ethnicities.

A Welch independent t-test revealed that the mean age of the Dutch sample (M = 37.36, SD = 15.09) was significantly higher than the mean age of the Malaysian sample (M = 22.97, SD = 5.90), $t(1172) = -24.04$, $p < .001$, Cohen’s d = 1.26.

Materials

The AQ-28 has two correlated higher-order factors that measure ‘Social behaviour’ and ‘Numbers/Patterns’, with four lower-order factors ‘Social Skills’, ‘Routine’, ‘Switching’ and ‘Imagination’ subsumed under the ‘Social behaviour’ factor (Hoekstra et al., 2011). The factors and their items can be found in the Supplementary Material (Supplementary Table 3.1). Each item of the AQ-28 is rated on a 4-point Likert scale (*definitely agree*, *slightly agree*, *slightly disagree*, *definitely disagree*). I adopted the scoring of 1 – 4 rather than using the binary scoring system, as it was shown to reflect a more reliable range (Murray et al., 2016). Approximately half of the items are reversed scored. A higher score indicates higher autistic traits.

Procedure

Malaysian participants were, for an overarching study, presented with musical excerpts and several questionnaires, including the AQ-28, upon consenting to participate in the online study.

Dutch participants in this study completed the AQ-28 along with the Sensory Perception Quotient-Short online (Tavassoli et al., 2014).

Statistical analyses

CFA based on the polychoric correlations between the AQ-28 items and DWLS was done using the lavaan package (0.6-9; Rosseel, 2012) in R (R Core Team, 2021; version 4.1.1). The fit of the models was assessed with χ^2 and its associated *p* value. As χ^2 is highly sensitive to sample size, the Root Mean Square Error of Approximation (RMSEA), Standardised Root Mean Square Residual (SRMR), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were used as well to assess the fit of the model because these are relatively independent of sample size (Schermelleh-Engel et al., 2003). A model is considered a 'good' fit by value of ≥ .95 or fair fit if > .90 for TLI and CFI, and a good fit by a value of ≤ .06 or fair fit if < .08 for RMSEA and SRMR (Hu & Bentler, 1999). Two models were tested with CFA: a) all items load onto one latent variable (i.e., autistic traits) and b) item loadings correspond with the hierarchical model reported by Hoekstra et al. (2011).

The internal reliability of the total AQ-28 scale and subscales in both samples was assessed with ordinal alpha (Gadermann et al., 2012), computed with the psych package (Revelle, 2021) in R (R Core Team, 2021).

A multi-group invariance analysis was also conducted using the lavaan package in R to test whether the hierarchical model of AQ-28 differs between the Netherlands and Malaysia. In general, configural, metric (fixed loadings) and scalar (fixed intercepts) invariance have to be fulfilled to ensure meaningful comparisons of scores between cultures (Fischer & Karl, 2019). A change of < -.010 in CFI, a change of > .015 in RMSEA, and a change of > .030 or > .010 in SRMR indicate that there is no metric and scalar measurement invariance respectively (Chen, 2007). A partial invariance model was conducted whenever the change in fit indices exceeded the recommended cut-off. This was done by first identifying parameters that had a significant impact on model fit by using the ccpsyc package in R (Karl, 2021), and freeing the constraints of those identified parameters (Fischer & Karl, 2019).

Finally, we explored which AQ-28 items function differently in Malaysia and the Netherlands by differential item functioning (DIF) analysis. The DIF procedure for ordinal data conducted was based on the adjacent category logit regression model implemented within the difNLR package in R (Hladká & Martinková, 2020). Bonferroni correction was applied to account for multiple comparisons.

Community involvement

Autistic community members were not involved in the current study, but autistic community stakeholders such as the Dutch Association for Autism (NVA) are involved in the annual survey conducted by the NAR.

Results

Confirmatory factor analysis and internal reliability

The CFA showed that both Malaysian and Dutch data fitted poorly on the one-factor model (see Table 3.1). The hierarchical model in Malaysian data showed a fair fit despite the fact that TLI and CFI were below .90, because TLI and CFI are affected by model complexity (Cheung & Rensvold, 2002), and both RMSEA and SRMR were within the acceptable range. As predicted, the hierarchical model showed a good fit in the Dutch data (see Table 3.1). Notably, the Numbers/Patterns factor was negatively correlated (r = -.20) with the Social Behavior factor in the Malaysian data, but positively correlated (r = .32) with the Social Behavior factor in the Dutch data.

Table 3.1

Fit indices of one-factor and hierarchical model for Malaysian and Dutch data.

	One-Factor		Hierarchical	
	Malaysia	Netherlands	Malaysia	Netherlands
Chi-square[a]	1650.87	5094.64	1056.43	1646.55
df	350	350	345	345
RMSEA	.092	.129	.069	.068
(90% CI)	(.088 - .097)	(.126 - .132)	(.064 - .074)	(.065 - .071)
SRMR	.096	.128	.079	.077
TLI	.798	.791	.888	.942
CFI	.813	.807	.897	.947

Note. [a]All models returned a chi-squared value with p value < .001.

The total AQ-28 scale showed good internal reliability for the Malaysian data (α = .75) and excellent internal reliability for the Dutch data (α = .89). The higher-order Social Behaviour factor and lower-order Social Skills factor showed good internal reliability in both the Malaysian and Dutch samples (α's ranging from .81 to .88). The rest of the factors (i.e., Numbers/Patterns, Routine, Switching and Imagination) had poor internal reliability in the Malaysian sample (α's ranging from .50 to .67), but good internal reliability in the Dutch sample (α's ranging from .72 to .85). Some items from the Numbers/Patterns factor correlated negatively with the total scale (i.e., item 5, 7 and 16; see Table 3.3) in the Malaysian data (in line with the negative correlation between the factors Numbers/Patterns and Social Behavior), but no negative correlations were detected in the Dutch data.

Cross-cultural measurement invariance and differential item functioning

While the SRMR values exceeded the cut-off slightly in the metric and partial metric invariance model, the CFI and RMSEA values of all tested models were within the acceptable range, indicating an overall fair fit. As shown in Table 3.2, the metric invariance model (M2) showed a considerable drop in CFI that exceeded the recommended cut-off compared to the configural invariance model (M1), but the change in RMSEA and SRMR were within the recommended cut-off. Although I decided to tentatively accept M2, a partial metric invariance model (M3) was explored. M3 was constructed by letting the loadings of Social Skills, Routine, Switching and Imagination factor freely load onto the higher-order Social Behavior factor for Malaysian and Dutch data, as these parameters were identified as having the most impact on the model fit. M3 improved such that the change in CFI, RMSEA and SRMR compared to M1 were within the recommended cut-off (see Table 3.2). The scalar invariance model (M4) was constructed based on M3, and the change in CFI, RMSEA and SRMR were within the recommended cut-off (see Table 3.2).

Table 3.2

Comparisons of invariance models as a function of country (Malaysia and the Netherlands).

Model[a]	χ^2	*df*	CFI	RMSEA (90% CI)	SRMR	$\Delta\chi^2$	Δdf	ΔCFI	ΔRMSEA	ΔSRMR	Decision
M1: Configural Invariance	2703	690	.936	.068 (.066-.071)	.078	-	-	-	-	-	
M2: Metric Invariance	3382	717	.915	.077 (.074-.080)	.086	151.78	27	-.021	.009	.008	Tentatively Accept
M3: Partial Metric Invariance	3041	713	.926	.072 (.070-.075)	.082	91.28	23	-.010	.004	.004	Accept
M4: Scalar Invariance	3401	763	.916	.074 (.072-.077)	.080	325.09	50	-.010	.002	-.002	Accept

Note. [a]All models returned a chi-squared value with p value < .001.

Table 3.3

The Chi-Square and Corrected Item Whole Correlation of items that showed DIF.

	Corrected Item Whole Correlation		χ^2 (DIF)
Items	MY	NL	
4. I frequently get so strongly absorbed in one thing that I lose sight of other things	.12	.44	35.38^{***}
5. I usually notice car number plates or similar strings of information	*-.02*	*.49*	*71.51****
6. When I'm reading a story, I can easily imagine what the characters might look like	.30	.36	14.98^{*}
7. I am fascinated by dates	*-.02*	*.51*	*59.81****
8. In a social group, I can easily keep track of several different people's conversations	.51	.48	55.61^{***}
9. I find social situations easy	.74	.67	33.87^{***}
13. I am fascinated by numbers	.19	.47	13.02^{*}
15. I find it hard to make new friends	.65	.57	69.49^{***}
16. I notice patterns in things all the time	*-.11*	*.40*	*53.60****
23. I find it difficult to imagine what it would be like to be someone else	.33	.35	25.58^{***}
26. New situations make me anxious	.45	.50	67.05^{***}

Note. $^{*}p < .05$, $^{***}p < .001$. Significant chi-squared value indicates DIF. MY: Malaysia; NL: Netherland. Items that were negatively correlated with the total scale in the Malaysian data are in italics.

Although the loadings of four factors were unequal for Malaysian and Dutch samples (i.e., M3), the impact of unequal loadings on mean-comparing statistics was minimal (Steinmetz, 2013). Therefore, the findings overall support cross-cultural measurement invariance of the AQ-28, indicating that the total AQ-28 score can be meaningfully compared between Malaysia and the Netherlands.

The DIF analysis suggested that eleven items, including the items that were negatively correlated with the total scale in the Malaysian data, showed differential functioning in Malaysia and the Netherlands (see Table 3.3). The DIF indicates that these items potentially display cultural bias.

Total AQ-28 score comparison

AQ scores do not seem to vary across age groups (Lodi-Smith et al., 2021), but consistently differ between males and females among the general population (Ruzich et al., 2015). Therefore, gender but not age was included as a covariate in the following ANCOVA. Those who did not reveal their gender (10 Malaysian and 4 Dutch participants) were excluded from the following ANCOVA. Given that the scalar invariance model was accepted, I proceeded to compare the mean scores on the full AQ-28 scale between Malaysian and Dutch participants. A one-way between-subjects ANCOVA with gender (two levels) as a covariate revealed a significant main effect of country, $F(1, 1238) = 900.49$, $p < .001$, $\eta p^2 = .42$, with Malaysians (M = 68.63, SD = 8.33) scoring significantly higher than Dutch participants (M = 51.48, SD = 10.30) on the AQ-28.

The previously reported negative correlations between items from the Numbers/Patterns subscale and the total scale in the Malaysian data suggest that greater endorsement of these items is considered less rather than more “autistic” in Malaysia, which may result in a higher AQ-28 score in a general population sample. Therefore, I repeated the ANCOVA on total AQ-28 score excluding the items from the Numbers/Patterns subscale. Again, the one-way between-subjects ANCOVA with gender as a covariate revealed a significant main effect of country, $F(1, 1238) = 692.77$, $p < .001$, $\eta p^2 = .36$, with Malaysians (M = 55.96, SD = 8.24) scoring significantly higher than Dutch participants (M = 42.48, SD = 8.78) on the AQ-28. AQ-28 scores after excluding Numbers/Patterns items were highly correlated with total AQ-28 scores in both countries (*r’s* > .90).

Discussion

As expected, the hierarchical structure of the AQ-28 displayed a good fit in a Dutch general population sample. Moreover, while no specific prediction was made for the Malaysian sample, the hierarchical structure of the AQ-28 displayed a fair fit as well. Against the hypothesis, cross-cultural measurement invariance of the AQ-28 was supported. However, exploratory analysis did identify eleven DIF items. The mean AQ-28 score of the Malaysian participants was significantly higher than that of the Dutch participants, confirming the hypothesis and extending previous findings on the AQ-50. The findings overall suggest that while the AQ-28 possesses a stable factor structure and measures the same latent traits in Malaysia and the Netherlands, some items, particularly from the Numbers/Patterns factor, potentially display cultural bias.

Previous research replicated the hierarchical AQ-28 structure among self-reporting British and Dutch autistic samples (Grove et al., 2017, 2021; Kuenssberg et al., 2014), and the current findings further confirm the hierarchical structure in self-reporting Malaysian and Dutch general population samples. The stable hierarchical structure of the AQ-28 in the general population of Malaysia and the Netherlands suggests that autistic traits may be structurally and conceptually comparable in both cultures. In contrast, no support was found for the hierarchical structure in China and the Netherlands on the parent-report AQ-28 (Liu et al., 2021), suggesting that the psychometric properties of the parent- and self-report AQ-28 might differ.

Although the current results of the measurement invariance suggest that scores on the AQ-28 can be compared meaningfully between the general populations of Malaysia and the Netherlands, the DIF analysis show that a high number of items (39%) function differently. Moreover, surprisingly, the DIF items do not align with the items identified by Carruthers et al. (2018) as showing potential cultural differences (Japan and India compared to UK; items 19 and 24 in the current study). Moreover, Carruthers et al. (2018) showed cross-cultural differences in the predictive value of parent-report AQ-50 items of an ASC diagnosis. Self- and parent-report AQ might hence function differently, and although the current measurement invariance results suggesting that the self-report AQ-28 can be used for cross-cultural comparisons, the DIF results contradict this, and the measurement invariance results might not generalise to other versions (parent-report) of the AQ.

Some factors demonstrated poor internal reliability in Malaysia but better reliability in the Netherlands. Notably, the Numbers/Patterns factor negatively correlated with the Social Behavior factor and some items from the Numbers/Patterns factor correlated negatively with the total scale in the Malaysian sample but positively in the Dutch sample. While the poor internal reliability suggests that Numbers/Patterns items may not be a good measure of autistic traits in Malaysia, the negative correlations also suggest that endorsement of Numbers/Patterns items might in fact indicate *lower* autistic traits in Malaysia. Moreover, all but one item (item 22) from the Numbers/Patterns factor were identified as showing DIF, further confirming that these items function differently in the Netherlands and Malaysia. This coincides with recent findings of negative correlations between the ‘attention to details’ subscale and other subscales of the AQ-50 in China, but not in the UK (Ward et al., 2021). Ward and colleagues (2021) suggested that cross-cultural differences underlie the negative correlations, and I concur with their notion. Given that a majority (60%) of the Malaysian participants are Chinese Malaysian, the negative correlations of the Numbers/Patterns factor and items with the Social Behavior factor and total AQ score might be explained by the meaning of and emphasis on numbers in the Chinese culture. There are numerous superstitions involving numbers in the Chinese culture. For instance, number 8 is considered a lucky number and number 4 is considered an unlucky number. These superstitions have a profound influence on behaviour such that one would intentionally seek or avoid certain digits in everyday life, such as birth dates, price endings and car plates (Almond et al., 2015; Simmons & Schindler, 2003; Wong et al., 2019). Though there are also superstitious beliefs about numbers in the West (e.g., “13”), the effects of such superstitions on behaviour are possibly milder than in the Chinese culture. Moreover, while autistic children performed significantly better in detecting embedded figures than non-autistic children in the UK, no such difference was found between autistic and non-autistic children in Singapore (Koh & Milne, 2012). Together these findings suggest that noticing patterns, numbers or details may not be a universal indicator of ASC across cultures. Therefore, a high score on the Numbers/Patterns scale might not reflect “autistic” traits per se, but instead socially appropriate behaviours or preferences in Malaysian and Chinese cultures. This, in turn, might partly explain the significantly higher AQ-28 scores of Malaysians compared to Dutch participants. Yet, even after excluding the Number/Patterns items, Malaysians still scored higher on the AQ-28 than the Dutch participants.

The higher AQ-28 scores among Malaysians compared to Dutch adults is consistent with previous findings of higher AQ-50 scores of Malaysians compared to British adults (Freeth et al., 2013). With the current study, I could rule out measurement non-invariance as a potential explanation. Differences in AQ-28 scores between Malaysian and Dutch adults may originate from true differences in subclinical autistic traits and/or cultural differences in the interpretation or reporting of autistic traits (de Leeuw et al., 2020). I tend to favour the latter explanation, as eleven items showed DIF and possibly display cultural bias (Table 3.3). The AQ was developed based on Western social norms, but what is considered a norm in the West might not apply to other cultures. For instance, using a Western assessment tool for pretend play, the Child-Initiated Pretend Play Assessment, 75% of typically developing Malaysian children were identified as showing abnormal play style (Vetrayan et al., 2016). Furthermore, parents from collectivistic cultures, where social relatedness and collective goals are highly valued, are less likely to emphasise imagination as a socialization goal than parents from individualistic cultures, where independence of self and personal goals are valued more (Mone et al., 2016). Cultural differences in play styles and emphasis on imagination might evoke different responses of Dutch and Malaysian participants on items concerning pretend play, imagination, and numbers, causing these items to show DIF, and possibly explaining the higher AQ scores among Malaysian participants.

The higher AQ scores among Malaysians do imply that the AQ cut-off scores should be adjusted to reflect these cross-cultural differences. In the current study, the mean score of Malaysian participants is above the recommended cut-off of 65 or slightly below the strict cut-off of 70 (Hoekstra et al., 2011), suggesting that generalisation of cut-off scores from one culture to another is likely to result in false positives. Therefore, instead of generalising the cut-off score of the AQ-28 from one culture to another, the cut-off should be derived from the target culture, by studying autistic samples in addition to general population samples.

The language in which the AQ-28 was administered to Malaysian and Dutch participants might also explain the higher AQ-28 score of Malaysians and items that showed DIF. Dutch participants filled in the Dutch AQ-28, which is likely their native language, while Malaysian participants filled in the English AQ-28, which is likely their second language. Although Malaysians, especially a sample mainly recruited via the university, are generally very fluent in English, English proficiency might still influence the interpretation of AQ-28 items and thus contribute to some items showing DIF. Additionally, Malaysian Chinese scored significantly higher on the English AQ-50 than on the Mandarin AQ-50 (refer to Chapter 1), and similar patterns were observed in Chinese from China (Ward et al., 2021). This might partly explain the exaggerated differences in AQ-28 scores between Malaysian and Dutch participants in the current study, but I conjecture that this would only explain the results partly, given that the differences between languages in previous studies were smaller (a 3-point difference on the AQ-50; refer to Chapter 2 and Ward et al., 2021) than in the current study. Future research could compare the AQ-28 in the native language of participants to inspect whether the score differences remain and whether the same items would show DIF.

Limitations and implications

Although the current findings provide support for a hierarchical factor structure and measurement invariance of the AQ-28 in the general population of Malaysia and the Netherlands, it is unclear if the findings can be generalised to clinical samples. To do so, cross-cultural comparison of AQ-28 scores among clinical populations should be made.

Given that I did not inquire about an ASC diagnosis in the Malaysian sample, there is a possibility that the Malaysian sample contained autistic participants. This could potentially explain the elevated AQ-28 scores among Malaysian as compared to Dutch sample. However, among a recent survey of 2732 Malaysian university students, only 8 students reported an ASC diagnosis while another 68 suspected themselves to have an ASC (Low et al., 2021). Enquiring about the diagnosis might have only partly solved this issue, as many adults with autism in Malaysia remain undiagnosed. Therefore, it is probable that the current Malaysian sample contained a very low number of participants with an actual autism diagnosis, with minimal expected effects on the results. Furthermore, the elevated AQ scores among Asian participants as compared to Western participants are consistently observed across studies (Freeth et al., 2013; Wakabayashi et al., 2006). This suggests that cross-cultural differences in the interpretation, report and/or expression of autistic traits are a more likely explanation for the score differences between Malaysian and Dutch participants.

The DIF analysis was exploratory in nature. While it is useful in offering preliminary insights into which items are likely to be culturally sensitive, reasons for DIF are not straightforward. Future research should consider conducting the DIF analyses with hypotheses grounded in a cultural framework that provides a basis to why some items might be interpreted differently in specific cultures.

Conclusions

The current results demonstrated that the factor structure of the AQ-28 is stable in Malaysia and the Netherlands. With the evidence for cross-cultural measurement invariance, I corroborate and extend previous findings by showing that Malaysians scored significantly higher on the AQ-28 than Dutch adults from the general population. I also identified eleven items potentially showing DIF. These findings together suggest that the AQ-28 has some cultural biases. Therefore, in line with the recent call to incorporate cultural factors in understanding ASC (de Leeuw et al., 2020), future research should validate or develop culturally appropriate screening and diagnostic tools, and cut-off scores. Nonetheless, the AQ-28 might still be a useful instrument in quantifying and comparing autistic traits cross-culturally, given the evidence for its factor structure and cross-cultural measurement invariance in Malaysia and the Netherlands, though the potential differential functioning of some items, particularly those of the Numbers/Patterns scale, deserve further examination.

Chapter 4: Replication of the Music Preference (MUSIC) Model and Evaluation of its Association with Personality and Autistic Traits

Music preferences have, in the West, consistently been found to follow a five-factor structure (i.e., Mellow, Unpretentious, Sophisticated, Intense and Contemporary, in short MUSIC). These Factors, in turn, are associated with the Big-Five personality traits. However, the stability of the music preference factor structure and its association with personality in non-Western cultures are underexplored. Moreover, besides personality traits, other behavioural traits might relate to music preferences. High systemizing traits, as often seen in autism, tend to be associated with a preference for Intense music. However, whether this generalises to autistic traits in the general population remains unclear. Therefore, the current study attempted to examine the five-factor MUSIC model and test its association with Big-Five personality traits and autistic traits among Malaysians through an online study. 444 participants (332 females, 101 males and 10 preferred not to say) rated their preference for 50 brief musical excerpts and completed the Ollen Musical Sophistication Index, the Ten Item Personality Inventory, and the Autism-spectrum Quotient-28. The original MUSIC model was partly replicated with virtually identical Sophisticated and Intense factors. However, most of the previously reported associations between Big-Five personality traits and music preferences were not found after controlling for age, gender and musical sophistication. Instead of an expected positive association between autistic traits and Intense music, a negative association was found between autistic traits and Contemporary music. These findings partially support the validity of the MUSIC model in Malaysia and highlight the importance of music preference research in a non-Western context.

Based on:

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It is well-supported that there are individual differences in music preferences. These differences might be driven by various factors such as social factors (e.g., culture and social identity; Boer & Fischer, 2012; North et al., 2000), personal factors (e.g., personality; Rentfrow & Gosling, 2003), physiological factors (e.g., arousal; McNamara & Ballad, 1999) and basic demographic factors (e.g., age and gender; LeBlanc et al., 1999). Early research on music preferences tended to use genre labels (e.g., rock, pop, indie, etc) to separate music preferences into meaningful categories. However, there was little consensus on how many or which genre labels to study, with some including 11 (Colley, 2008) and others including 30 (George et al., 2007) genre labels. Rentfrow and Gosling (2003) proposed a four-factor music preference model with the consideration of 14 music genres. Despite the differences in the number and naming of the identified factors from various numbers of music genres (e.g., five; Colley, 2008); six; Dunn et al., 2012; Schäfer & Sedlmeier, 2009); and nine; George et al., 2007), there is substantial overlap in the models from these studies. Three distinct factors are repeatedly found across studies, and they are defined by the same set of music genres. For instance, rock and heavy metal music, classical and jazz music, and rap and hip-hop music often cluster together to form a factor respectively. Moreover, one factor consisting mainly of country music emerged whenever singer-songwriter music was examined by a study. Together, the findings corroborate that there are at least four distinct factors of music preference.

Motivated to bridge the findings, Rentfrow et al. (2011) proposed a five-factor music preferences model developed through a series of studies. 26 genres and subgenres were mentioned most often by 5600 participants. Subsequently, 706 participants rated their liking for two musical excerpts of each genre, revealing a five-factor music preferences model with the factors Mellow (soft rock & soul), Urban (rap & electronica), Sophisticated (classical & jazz), Intense (rock & heavy metal) and Campestral (pop & country), or MUSIC in short. Finally, the five-factor music preferences model was replicated in two independent samples using two different sets of musical excerpts. The study of Rentfrow et al. (2011) showed that in addition to music genres, preferences for sonic (e.g., loud, fast, distorted) and psychological (e.g., sad, relaxing, complex) attributes explained a significant amount of variance in the MUSIC factors. In sum, the validity of the five-factor model and the factors were confirmed to some extent and could be interpreted in terms of preferences for certain sonic and psychological attributes of music (Rentfrow et al., 2011).

The MUSIC model was further replicated using a subset of 50 musical excerpts from Rentfrow et al. (2011), with the Urban and Campestral factor renamed into Contemporary and Unpretentious respectively (Rentfrow et al., 2012). The MUSIC model emerged even when a set of jazz- or rock-only music excerpts were examined, thus corroborating that the MUSIC model is not only based on classification of genres, but also the preferences for certain combinations of sonic and psychological attributes of music (Rentfrow et al., 2012). For example, the Intense factor was positively associated with loud, dense, percussive, yelling, aggressive, and animated affect, and negatively associated with warm, sensual, and dreamy affect. The robustness of the MUSIC model was confirmed in a large study with over 250,000 (mostly Western) participants, and the MUSIC model appeared to be invariant across age groups (Bonneville-Roussy et al., 2013). The empirical examination of the MUSIC model thus far has focused on Western samples, but the replicability of the MUSIC model in a non-Western sample remains underexplored. Culture may affect the replicability of the MUSIC model since music perception is highly influenced by culture. For instance, individuals from different cultures may perceive different emotions from the same musical excerpts (Lee & Hu, 2014), though features of music that express basic emotions appeared to be universal cross-culturally (Sievers et al., 2013). Given that psychological attributes of music explain unique variance in the MUSIC model, cross-cultural differences in perceiving psychological attributes may affect the replicability of the MUSIC model. The MUSIC model has been confirmed in a Southeast Asian (i.e., Singaporean) population (Heng et al., 2018), though with a relatively small sample (N = 83). Therefore, the objective of the current study was to evaluate the replicability of the MUSIC model with a larger, Malaysian sample.

Associations between musical preferences and Big-Five personality traits were commonly observed across different studies. Positive associations have been found of Openness with preference for reflective and complex music (i.e., Mellow, Sophisticated and Intense); Extraversion with energetic music (i.e., Contemporary); and Agreeableness and Conscientiousness with gentle sounding music (i.e., Unpretentious). Conscientiousness was negatively associated with loud and distorted music (i.e., Intense; see Table 4.1 for a summary; Bonneville-Roussy et al., 2013; Delsing et al., 2008; Rentfrow & Gosling, 2003; Zweigenhaft, 2008). The magnitude of these associations is small but consistent across studies and persist after controlling for demographic variables (Bonneville-Roussy et al., 2013; Greenberg et al., 2016), such as age and gender which are known to influence music preferences (Bonneville-Roussy et al., 2013; Colley, 2008).

Links between music preference and personality are studied extensively. Moreover, it is known that music preferences differ between individuals with and without musical training (Ginocchio, 2009; Gürgen, 2016). However, the role of musical sophistication, a broader construct of musical ability, including musical training and receptive skills (Ollen, 2006) on the relationship between music preference and personality is unclear. Receptive skills such as engagement in music, ability to appreciate music and perceive emotions likely influence one's music preference. Hence, it might be important to consider musical sophistication when examining the associations between music preferences and personality traits.

Table 4.1

Hypothesised relationships between MUSIC and Big-Five personality traits

	Mellow	Unpretentious	Sophisticated	Intense	Contemporary
Extraversion					+
Conscientiousness		+		–	
Openness	+		+	+	
Agreeableness		+			
Emotional Stability					
Autistic Traits			+	+	

Besides the Big-Five personality traits, autistic traits might be associated with certain music preferences. Autistic traits are traits reflecting the symptoms of Autism Spectrum Conditions (ASC; American Psychiatric Association, 2013), such as social communication difficulties and repetitive behaviours. Although there are no clear indications that autistic traits are related to music preferences, cognitive styles related to autism, systemizing and empathizing (Wheelwright et al., 2006), have been linked to specific music preferences. Empathizing refers to identifying and responding appropriately to others' emotions and predict their behaviours (Baron-Cohen & Wheelwright, 2004) and is negatively related to autistic traits, whereas systemizing refers to analysing systems and their underlying rules (Baron-Cohen et al., 2003) and is positively related to autistic traits. People who are highly empathizing seem to prefer Mellow music and highly systemizing individuals prefer Intense music (Greenberg et al., 2015). I want to study whether the findings from systemizing and empathizing could be generalised to autistic traits.

Apart from the lack of music preference research in relation to personality traits and autistic traits in non-Western contexts, cross-cultural differences in the conceptualisation of music genres, personality traits and autistic traits also motivate the current chapter. For example, if music genres are based on acoustic features, it is likely that the MUSIC model would be invariant across cultures. Hence, studying whether the MUSIC model is reliable in Malaysia could possibly inform how music genres are conceptualised cross-culturally. Similarly, perception and expression of personality traits and autistic traits likely differ across cultures (de Leeuw et al., 2020; Lui et al., 2020). Given these cross-cultural differences, it would be important to examine the patterns of relationship with music preferences in another culture rather than generalising findings from one culture to another. The current chapter attempts to study if the associations between music preferences and personality traits would be confirmed in an Asian population while taking age, gender and musical sophistication into account and has three aims; 1) to confirm the MUSIC model in a Malaysian general population sample; 2) to examine the associations of music preferences with Big-Five personality traits and 3) to examine the associations of music preference with autistic traits. Firstly, I hypothesised that the MUSIC model would be confirmed, specifically the Mellow, Sophisticated, Intense and Contemporary factors (Heng et al., 2018). Secondly, I explored whether the previously found relationship between music preference and Big-Five personality (see Table 4.1) would be found in a Malaysian sample. Lastly, I hypothesised that autistic traits would be positively associated with Intense and Sophisticated music (Greenberg et al., 2015).

Method

Participants

Ethical approval for this online study was obtained from the Science and Engineering Research Ethics Committee of the University of Nottingham Malaysia (Ethics Identification Number: CZJ160719). Participants were recruited through the university recruitment email and social media. 939 responses were recorded. It would take at least 15 minutes to listen to all excerpts and finish all questionnaires. Therefore, participants were excluded if they (a) took less than 15 minutes to complete the survey where most of the responses were empty or incomplete (n = 409), (b) did not confirm not having participated in the pilot (n = 67), (c) responded to the survey more than once (n = 10), and (d) were not Malaysian (n = 9). The final sample consisted of 444 participants (332 females, 101 males and 10 prefer not to say) with an age range of 17 to 69 (M = 23.0, SD = 6.0).

Materials

Musical Excerpts. All 94 unreleased professionally made musical excerpts used in the original study were acquired from the authors (Rentfrow et al., 2011). In line with Rentfrow et al. (2012), I used 50 musical excerpts. Three of the original 50 musical excerpts were not available ("Through the Years" by The O'Neill Brothers, "Sweet 5" by Kush, and "Electro" by Leo the Lionheart). I selected three musical excerpts of the same genres from the remaining musical excerpts ("Falling Down" by Ezekiel Honig, "And What You Hear" by Twelve 20 Six, and "Feed Your Head" by Phaedra) to include a total of 50 musical excerpts. Each musical excerpt was around 15s long. A pilot study (n = 23) confirmed that all musical excerpts were unfamiliar to Malaysians. In the main study, participants had to rate each musical excerpt on a rating scale of 1 (*Extremely Dislike*) to 9 (*Extremely Like*).

Musical Sophistication. The Ollen Musical Sophistication Index (OMSI) was used to estimate musical sophistication (Ollen, 2006). Musical sophistication includes the duration of musical training and receptive abilities (e.g., frequency that one engages in musical activity). The OMSI (see Appendix II for the full questionnaire) comprises of nine items. Six items assess experience in musical training and education (e.g., How many years of private music lessons have you received?) and three items assess the personal experience in musical activities (e.g., Which option best describes your experience at composing music?). The OMSI was originally scored binary (less vs more musically sophisticated), but I used the continuous scores to control for musical sophistication. OMSI has an acceptable internal reliability (α = .74; Ollen, 2006).

Big-Five Personality Traits. The Ten Item Personality Inventory (TIPI) is a 10-item questionnaire that measures the Big-Five personality traits (Gosling et al., 2003). Each personality trait is measured by two items, one of which is reverse scored (see Appendix III for the full questionnaire). One has to rate how much they agree or disagree with each item on a 7-point Likert scale (1 = *disagree strongly*, 7 = *agree strongly*). The TIPI has adequate test-retest reliability, converges with the standard instruments, and showed predicted associations with external correlates such as political view and depressive traits when the Big-Five personality traits were measured with a different instrument (Gosling et al., 2003). Moreover, Big-Five personality as measured with the TIPI has been linked to musical preferences in previous research (Bonneville-Roussy et al., 2013).

Autistic Traits. The Autism-Spectrum Quotient 28 (AQ-28) was used to measure autistic traits. Please see the Materials and Results section of Chapter 3 for details about the AQ-28.

Procedure

Before the start of the online survey, participants could choose to respond in either English or Malay. After consenting to participate in the study, the 50 musical excerpts were randomly presented to the participants. Participants had to rate how much they liked each musical excerpt. After this, the OMSI, TIPI, and AQ-28, were administered in random order. At the end of the survey, participants were informed of the purpose of the research. All participants were given information on their likely musical preference and its link to personality traits according to previous research (Rentfrow et al., 2012). Psychology students from the University of Nottingham Malaysia were additionally given study credits.

Results

Confirmation of the MUSIC Model

The following analyses were conducted using SPSS v25, AMOS v25 and R. The dataset was randomly split to be able to conduct principal component analysis (PCA) in half of the data and confirmatory factor analysis (CFA) in the second half of the data.

PCA with varimax rotation was conducted on the first half of the data (n = 222). Both Kaiser-Meyer-Olkin Measure (.89) and Bartlett's Test (p < .001) indicated that PCA was appropriate to conduct on the data. The PCA produced a first factor that accounted for 24% of the variance. The scree plot suggested an "elbow" around five factors. The first five eigenvalues were also suggested to be greater than chance in explaining the variance according to parallel analysis of Monte Carlo simulations. Successive PCAs were then conducted for one-factor through six-factor solutions and the sixth factor was found to explain a relatively small proportion of the variance (3%). The analyses together suggested no more than five factors should be retained.

I also examined whether the factors extracted above were invariant across different extraction methods such as maximum likelihood and principal axis. Principal axis and maximum likelihood with varimax rotation were conducted for the five-factor solution. Next, regression factor scores of each solution from PCA, principal axis and maximum likelihood were correlated. The factors appeared to be invariant across the three extraction methods, with correlations averaging above .98 between the PCA and maximum likelihood factors, .99 between the PCA and principal axis factors, and .99 between the maximum likelihood and principal axis factors. The results suggest that regardless of the extraction methods used, the same solutions would be obtained. Therefore, I reported the solutions derived from the PCA in the current study.

The five-factor solution with a factor loading cut-off of > .4 appeared to be fairly consistent with the MUSIC model found in the Western samples (Rentfrow et al., 2012). The first and third factor confirmed the Intense and Sophisticated factor (see Table 4.2). The second factor comprised all of the Mellow factor excerpts from the original MUSIC model, but three excerpts from the Unpretentious factor also loaded onto the second factor. The fourth factor confirmed the Contemporary factor, but two original excerpts did not load onto this fourth factor. The fifth factor consisted of mainly excerpts from the Unpretentious factor, with three excerpts that were previously loaded onto the Contemporary factor.

Tucker’s congruence coefficient was computed with the psych R package (Revelle, 2021) to determine the similarity of factors the current and Rentfrow et al.'s (2012) study (see Table 4.3). A value between .85-.94 indicates a fair similarity, and a value above .95 suggests identical factors (Lorenzo-Seva & ten Berge, 2006). The Sophisticated and Intense factors were fairly identical between the current and Rentfrow and colleauges' (2012) study. The congruence coefficient for Contemporary and Mellow factor dipped below the cut-off range (factor congruence coefficient = .80 and .72 respectively), indicating potential dissimilarity. The Unpretentious factor found in the current study was found to be dissimilar to the Unpretentious factor found in the previous study (factor congruence coefficient = .56).

CFA was conducted with SPSS Amos v25 on the second half of the sample (*n* = 222). I compared the original MUSIC model with the model obtained from the PCA above. As shown in Table 4.4, both models showed poor fit to the data with fit indices falling below the acceptable values (CFI & TLI > .95, RMSEA < .06; (Hu & Bentler, 1999). The original MUSIC model (Rentfrow et al., 2012) demonstrated an overall slightly better fit. Hence, the original MUSIC model was used in the subsequent analyses of music preferences.

Table 4.2

Factor loadings on the MUSIC dimensions between the current study and Rentfrow et al. (2012).

			Factors									
			M		**U**		**S**		**I**		**C**	
Artist	**Piece**	**Genre**	MY	RF	MY	RF	MY	RF	MY	RF	MY	RF
Human Signals	Birth	Soft Rock	***.63***	***.67***	-.04	.08	.19	.27	-.13	-.03	.17	.16
Bruce Smith	Children of Spring	Adult contemporary	***.59***	***.65***	-.03	.14	.39	.38	-.12	-.05	-.06	.01
Lisa McCormick	Let's Love	Adult contemporary	.31	.30	.14	.29	.38	***.51***	-.05	.02	.36	.16
Taryn Murphy	Love Along The Way	Soft Rock	***.59***	***.50***	.26	**.43**	.02	-.02	.07	.11	.23	.16
Frank Josephs	Mountain Trek	R&B/soul	***.68***	***.72***	.00	.18	.19	.17	-.02	-.05	.16	.14
Walter Rodriguez	Safety	Electronica	***.55***	***.59***	.03	.01	.09	.13	-.02	.02	.37	**.45**
Language Room	She Walks	Soft Rock	***.61***	***.54***	-.00	.24	.07	.06	.12	.19	.11	.08
Curtis	Carrots and Grapes	Rock 'n' Roll	.19	-.05	***.54***	***.69***	.36	.29	.30	.14	.03	.02
Laura Hawthorne	Famous Right Where I am	Mainstream country	***.69***	**.46**	.24	***.62***	-.01	-.12	.12	.01	.03	.10
James E. Burns	I'm Already Over You	New Country	***.68***	.30	**.50**	***.79***	.03	.08	-.03	-.04	-.00	.03
Five Foot Nine	Lana Marie	Country-rock	***.66***	.34	.33	***.71***	.15	.10	-.07	-.05	.05	.03
Anglea Motter	Mama I'm Afraid To Go There	Bluegrass	.25	-.11	***.70***	***.65***	.18	.35	.14	.14	-.01	.06
Babe Gurr	Newsreel Paranoia	Bluegrass	**.51**	.13	***.65***	***.76***	.18	.18	.06	-.04	-.12	.03
Bob Delevante	Penny Black	New Country	***.71***	.25	.38	***.75***	-.02	.13	-.01	.01	-.10	.05
Carey Sims	Praying for Time	Mainstream country	***.73***	**.47**	-.04	***.65***	.11	-.02	.08	.05	.05	.08
Ali Handal	Sweet Scene	Soft Rock	***.64***	***.52***	.01	.38	.15	.31	-.10	.03	-.03	.01

			Factors									
			M		**U**		**S**		**I**		**C**	
Artist	**Piece**	**Genre**	MY	RF	MY	RF	MY	RF	MY	RF	MY	RF
Hillbilly Hellcats	That's Not Rockabillity	Rock 'n' Roll	.11	-.11	***.64***	***.64***	.20	.27	.15	.03	-.02	-.02
Antonio Vivaldi	Concerto in C	Classical	.18	.21	.07	.05	***.76***	***.75***	.09	.00	-.13	-.06
Lisa McCormick	Fernando Esta Feliz	Latin	.07	.06	.35	.27	***.53***	***.63***	.15	-.03	**.44**	.25
Daniel Nahmod	I Was Wrong	Traditional jazz	.34	.34	-.06	.13	***.59***	***.64***	.07	-.04	.20	.23
Various artists	La Trapera	Latin	.11	-.01	.37	.19	***.59***	***.75***	.07	-.04	.29	.15
DNA	La Wally	Classical	.03	.18	.16	.06	***.71***	***.69***	.08	.07	.09	.00
Moh Alileche	North Africa's Destiny	World beat	-.01	.06	**.42**	.20	***.50***	***.67***	.04	.01	.27	.07
Laurent Martin	Scriabin Etude Opus 65 No 3	Avant-garde classical	.16	.03	.10	.00	***.71***	***.76***	.02	.05	.06	-.02
Ljova	Seltzer, do I drink too much?	Avant-garde classical	.16	.04	.19	.11	***.69***	***.82***	.12	.06	.16	.07
Bruce Smith	Sonata A Major	Classical	**.53**	.31	.03	.08	***.64***	***.70***	-.05	-.04	-.10	-.03
Paul Serrato & Co.	Who are You?	Traditional jazz	.06	.07	.20	.10	***.53***	***.68***	.08	.02	**.42**	.25
Five Finger Death Punch	Death Before Dishonor	Heavy Metal	-.03	.08	.05	-.12	.02	-.02	***.83***	***.80***	.05	-.01
Cougars	Dick Dater	Classic rock	-.06	-.15	.15	.21	.09	.08	***.73***	***.76***	.21	.08
Bankrupt	Face the Failure	Punk	.02	-.05	.04	.00	.06	-.01	***.85***	***.85***	.05	-.02
Exit 303	Falling Down 2	Classic rock	.11	.15	-.14	.05	.02	-.01	***.78***	***.82***	.15	-.01
The Stand In	Frequency of a Heartbeat	Punk	.07	.10	.11	.09	.05	.01	***.77***	***.75***	.06	.07
The Tomatoes	Johnny Fly	Classic rock	-.08	-.06	.12	.14	.06	.04	***.83***	***.79***	.11	.01
Squint	Michigan	Punk	-.05	-.04	.07	.03	.03	-.02	***.87***	***.83***	.00	-.06

			Factors									
			M		**U**		**S**		**I**		**C**	
Artist	**Piece**	**Genre**	MY	RF	MY	RF	MY	RF	MY	RF	MY	RF
Dawn Over Zero	Out of Lies	Heavy Metal	-.01	.14	.11	-.10	.11	-.03	***.78***	***.72***	.11	.10
Straight Outta Junior High	Over now	Punk	.06	-.06	.18	.11	.09	.05	***.81***	***.82***	.03	.00
Five Finger Death Punch	White Knuckles	Heavy Metal	-.23	-.11	.14	-.12	.01	-.05	***.74***	***.74***	.15	.01
Ciph	Brooklyn Swagger	Rap	-.02	-.10	.00	.15	.08	-.05	.20	.07	***.67***	***.75***
Sammy Smash	Get the Party Started	Rap	.02	-.02	-.10	.13	-.01	-.09	.16	.06	***.70***	***.76***
The Cruxshadows	Go Away	Europop	.06	.30	***.45***	-.21	.10	.25	.18	.08	.34	***.50***
Mykill Miers	Immaculate	Rap	.07	.08	.12	.03	.07	.10	.08	.08	***.71***	***.75***
Preston Middleton	Latin 4	R&B/soul	.07	.16	.06	.04	.16	.23	.11	-.01	***.65***	***.73***
Benjamin Chan	MATRIX	Electronica	-.02	.04	***.53***	-.23	.15	.15	.31	.34	.29	***.46***
AB+	Recess	Electronica	.05	**.40**	.13	-.01	.50	***.54***	.10	-.04	***.53***	.34
Robert LaRow	Sexy	Europop	.10	.05	.32	.13	.01	.13	.24	-.06	***.64***	***.72***
DJ Come Of Age	Thankful	R&B/soul	.29	.23	-.07	.22	.14	.03	-.08	-.11	***.64***	***.62***
Magic Dingus Box	The Way It Goes	Electronica	.13	.35	***.53***	-.13	.15	.18	.13	.04	**.43**	***.52***

Note. This table excludes the three musical excerpts that I selected and not included in Rentfrow et al. (2012). The largest loading for each musical excerpt is in italics, and the factor loadings equal or above .40 are in bold. MY: Malaysian sample; RF: factor loadings obtained from Rentfrow et al. (2012). M = Mellow, U = Unpretentious, S = Sophisticated, I = Intense, C = Contemporary.

Table 4.3

Tucker's congruence coefficients between current study and Rentfrow et al. (2012).

	Rentfrow et al. (2012)				
Current Study	Mellow	Unpretentious	Sophisticated	Intense	Contemporary
Mellow	.72	.79	.41	.03	.28
Unpretentious	.34	.56	.54	.20	.41
Sophisticated	.48	.35	**.88**	.26	.35
Intense	.06	.17	.18	**.88**	.19
Contemporary	.43	.08	.35	.26	.80

Note. Congruence coefficients above .85 are in bold.

Table 4.4

Fit indices of the original MUSIC model and the explored model.

	Model	
	Original MUSIC	Explored Model
Model fit indices		
χ^2	2671.49	2848.82
df	1034	1034
p	< .001	< .001
CFI	.728	.699
TLI	.716	.685
RMSEA	.085	.089
(90% CI)	(.081 - .089)	(.085 - .093)
AIC	2953.49	3130.82

Note. Both models dipped below the recommended fit indices

Music preferences, personality and autistic traits

The weighted preference for each of the five MUSIC dimensions was calculated using a previously reported formula (Greenberg et al., 2015). This weighted preference of each MUSIC dimension takes participants' preference rating of each excerpt and the factor loadings of that excerpt on each dimension into account. I used the factor loadings found in the current study in this formula.

Given the influence of age, gender and musical sophistication on music preferences (Bonneville-Roussy et al., 2013; Gürgen, 2016; Soares-Quadros Júnior et al., 2019), hierarchical multiple linear regressions were conducted to examine the predictability of Big-Five personality traits and autistic traits on the MUSIC dimensions beyond age, gender and musical sophistication. No issues of multicolinearity, normality, and influential points were detected. However, there was a potential issue with homogeneity of variance across all models. Hence, hierarchical multiple linear regressions with weighted least squares estimation were conducted. Age, gender, and musical sophistication were entered as control variables in Step 1 and Big-Five personality traits and autistic traits were entered in Step 2 for each model. The results of the multiple linear regressions with age, gender, and musical sophistication as control variables are reported in Table 4.5. In line with previous research (Bonneville-Roussy et al., 2013), age negatively predicted a preference for Intense music. Females showed a greater preference for Mellow and Sophisticated music in comparison to males, and males showed a greater preference for Unpretentious and Intense music. These gender differences were also consistent with studies showing a greater preference for music with emotional content among females and a greater preference for folk, rock and heavy rock music among males (Colley, 2008; Soares-Quadros Júnior et al., 2019). Extraversion positively predicted a preference for Mellow music. Agreeableness positively predicted a preference for Mellow and Unpretentious music, and negatively predicted a preference for Intense music. Openness positively predicted a preference for Intense music. Autistic traits negatively predicted a preference for Contemporary music.

Table 4.5

Standardised beta coefficients of autistic traits and Big-Five personality traits on the MUSIC dimensions.

	Mellow		Unpretentious		Sophisticated		Intense		Contemporary	
Step 1:	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*	*β*	*t*
Age	.03	.71	-.03	-.67	.01	.10	-.11	-2.32*	.06	1.24
Gender	.27	5.71***	-.15	-3.13**	.12	2.44*	-.20	-4.05***	-.04	-.80
Musical Sophistication	-.09	-2.04*	.02	.37	.10	2.05*	.06	1.23	-.05	-.97
Step 2:										
Autistic Traits	.10	1.63	-.05	-.79	.01	.16	.01	.15	-.14	-2.10*
Extraversion	.13	2.30*	.06	1.07	-.03	-.42	-.06	-.98	.01	.21
Agreeableness	.12	2.43*	.11	2.16*	.04	.77	-.13	-2.55*	-.05	-.97
Conscientiousness	.03	.51	.02	.42	.09	1.69	-.07	-1.41	.04	.78
Emotional Stability	.02	.30	.01	.15	-.05	-.93	.00	.05	.02	.34
Openness	-.08	-1.65	-.10	-1.91	-.04	-.81	.12	2.26*	-.01	-.22

Note. $^{*}p < .05$. Gender is dummy-coded (male = 0, female = 1).

Discussion

The current study attempted to confirm the MUSIC model and examine the associations of Big-Five personality and autistic traits with musical preferences. In line with my hypothesis and preliminary findings, the MUSIC model was partly confirmed among a Malaysian sample. In particular, the Intense and Sophisticated factors were similar. The associations between musical preferences and Big-Five personality traits found in the current study were somewhat inconsistent with previous findings after accounting for age, gender and musical sophistication. Moreover, inconsistent with my hypothesis, autistic traits were not associated with a preference for Sophisticated or Intense music, but a negative association was found with Contemporary music.

The MUSIC model

The MUSIC model was partly confirmed with two emerging factors corresponding to the previously reported factors Intense and Sophisticated from Rentfrow et al. (2012). This echoes the previous findings among Singaporeans which demonstrated that the MUSIC model was not perfectly replicated (Heng et al., 2018), though their study also showed that the Intense and Sophisticated music factors were fairly similar to the original reported factors (Rentfrow et al., 2012). Broad genres such as heavy metal (i.e., Intense) were ranked similarly across 47 countries (Schedl, 2017). While Malaysia was not included in the study by Schedl (2017), the emergence of these two factors that comprise popular and broad genres suggests that Malaysians are substantially exposed to these genres. The confirmation of Intense and Sophisticated music among Malaysians suggests that Malaysians have a high familiarity with these factors.

The Mellow and Contemporary factors in the current study are somewhat different from Rentfrow et al. (2012), and some excerpts failed to load onto the original factors. Cultural differences in music-evoked emotions might explain the discrepancy given that perceived psychological attributes of music explain unique variance in the MUSIC model (Rentfrow et al., 2012). Emotional reactions to music were found to differ across cultures (North & Davidson, 2013). Emotions such as surprise, spirituality, astonishment, anxiety, happiness, love, pride and interest are more prevalent in collectivistic cultures than in individualistic cultures (Juslin et al., 2016). The perceived mood from the same set of musical excerpts differed between Korean, Chinese and Americans (Lee & Hu, 2014). Moreover, the perceived extra musical associations with genres (e.g., perceived higher intelligence of fans of classical music) might differ across cultures. Certain stereotypes are associated with fans of certain music genres (Rentfrow et al., 2009; Rentfrow & Gosling, 2007), but the pattern of associations might differ across cultures. For instance, Americans associate ethnic minorities more with hip-hop than with other genres, while Germans do not associate ethnic minorities with specific genres (Kristen & Shevy, 2013). It is not argued that these findings can be generalized to Malaysia given the continuous nature of collectivism-individualism construct and limited numbers of nations included in these previous studies. The findings merely demonstrate that there are subtle cultural differences, and a combination of these cross-cultural differences might hence drive the slight inconsistency between studies.

The Unpretentious factor differs greatly between the current study and (Rentfrow et al., 2012). A similar pattern emerged in the Singaporean sample (Heng et al., 2018), where Unpretentious was the only factor that did not reach the threshold for factor congruence. While the aforementioned reasons (cultural differences in music-evoked emotions and general associations with genres) likely also explain the lack of replication of the Unpretentious factor, there might be other reasons that this factor is unstable across cultures. One of the potential reasons is familiarity, as highlighted by Heng et al. (2018). Given that Malaysia is geographically and culturally similar to Singapore, the level of exposure to country and folk music (genres that make up the Unpretentious factor) might be similarly low. Familiarity has been consistently shown to influence and explain a substantial portion of variance in music preference (Fung, 1996; Teo et al., 2008). For example, among the predictors investigated (e.g., personality and demographic), familiarity was found to be the strongest predictor of music preferences for South Koreans and Americans (Yoo et al., 2018), and familiarity plays a key role in listeners' emotional engagement in music (Pereira et al., 2011). More importantly, familiarity probably stands out among the cross-cultural differences in perceived musical emotions and extra musical associations because it was suggested that there are more similarities than differences across cultures (Juslin et al., 2016; Kristen & Shevy, 2013). Low familiarity with the music implies limited knowledge about the genre of the music, which in turn, might lead to difficulty in recognising different music excerpts belonging to similar genres. Therefore, familiarity might be the main driving force behind not replicating the Unpretentious factor.

The argument on why some of the MUSIC factors were not confirmed in the current study so far is based upon the potential cross-cultural differences in perceived psychological attributes of musical excerpts. Considering that each MUSIC factor is a cluster of similar music genres, how music genres itself are conceptualised in various cultures would likely affect the cross-cultural reliability of the MUSIC model. There is evidence indirectly suggesting that music genres are, at least, partially dependent on social context. For instance, people tend to have clear stereotypes about the fans of various music genres, and these music-genre stereotypes reflect truth to a certain extent (Rentfrow & Gosling, 2007). The findings suggest that music genres are usually tagged with social contents (i.e., stereotypes), and cultural differences in the perception of these stereotypes (Kristen & Shevy, 2013) might lead to failing to replicate the MUSIC factors. On the other hand, acoustic features define music genres too; music under the same genre clearly shares similar acoustic features. Moreover, as highlighted by Rentfrow et al. (2012), both psychological and acoustic features shape the formation of the MUSIC factors. In a similar vein, if music genres are viewed as different MUSIC factors, conceptualisation of music genres are probably drive by a combination of psychological and acoustic features as well. Therefore, while the formation of the MUSIC model is not based solely on music genres, subtle cross-cultural differences in the social contents associated with certain music genres likely also contribute to why some MUSIC factors are not confirmed in the current study.

In a recent study, the MUSIC model was reported to be invariant across 53 countries, including Malaysia and Singapore (Greenberg et al., 2022). The seemingly contradictory findings between the current study and Greenberg et al. (2022) are reconcilable. Firstly, although the MUSIC model was not fully replicated, the original MUSIC model (Rentfrow et al., 2012) showed a better fit in the current data than the model based on EFA. This aligns with its invariance across countries. Secondly, despite the invariance of the MUSIC model across countries, there were variations in how the music preference model is constructed based on geographical location (Greenberg et al., 2022). Specifically, when examining similarities on the formation of the MUSIC model across countries, three major clusters were found with one cluster consisting primarily of Asian countries. This suggests that cross-cultural differences in music cognition and familiarity with the presented music described above might underlie the emergence of the clusters. Thus, while both mine and the recent findings (Greenberg et al., 2022) provide some evidence that the MUSIC model is useful across countries, the current findings specify where the MUSIC model might differ between countries and plausible explanations for the variations.

Music preferences and personality

The current study replicated the relation between Agreeableness and Openness with the Unpretentious and Intense music/factors respectively. However, other associations between MUSIC preferences and Big-Five personality traits were not replicated. Several explanations might account for this inconsistency. Firstly, the current study took musical sophistication into account in addition to age and gender while examining the association between music preferences and personality, while only the latter two were commonly considered in prior research (Greenberg et al., 2016; Nave et al., 2018; Vella & Mills, 2017). Extended musical training has been shown to associate with certain music preferences; participants with more than five years of training tend to give higher preference ratings regardless of the genres compared to those with less training (Ginocchio, 2009). Moreover, individuals with more musical training appeared to use music differently than those with less training which, in turn, contributed to an increased preference for certain music (e.g., complex music such as classical and jazz; Getz et al., 2014). However, in the current study, regression models without musical sophistication as a control variable did not change the results. It seems that while musical sophistication was positively associated with preference for Mellow and Sophisticated music, accounting for this relation did not reveal any previously found associations of personality traits with Mellow and Sophisticated music. Therefore, the current findings suggest that generalization of these associations from one culture to another should be exercised with caution.

Secondly, while the Big-Five personality dimensions were found to be relatively stable across 56 countries (Schmitt et al., 2007), and associations with music preferences were fairly consistent across 53 countries (Greenberg et al., 2022), a closer inspection of the Big-Five constructs among Malaysian or non-WEIRD (western, educated, industrialised, rich and democratic) populations showed low validity (Hee, 2014; Laajaj et al., 2019). The failure to detect the previously found associations might hence stem from low validity of the TIPI, or Big-Five in Malaysia. However, the TIPI is a frequently used instrument in the music preference literature (e.g., Greenberg et al., 2022). Moreover, the replication of the associations of Agreeableness and Openness with Unpretentious and Intense respectively provides partial support that the TIPI is reliable in capturing these personality traits. However, the significant positive association between Extraversion and Mellow shows that the proposition that extraverts would prefer energetic and upbeat music (Vella & Mills, 2017) does not apply in Malaysia. This aligns with previous findings that traits associated with Extraversion differ between Asian and Euro Americans; assertiveness and activity are linked to Extraversion for Euro Americans but not for Asian Americans (Lui et al., 2020). The current results that Extraversion is positively associated with Mellow music in Malaysia supports the notion that the relationships between personality traits and music preferences might not be universal.

Another notable difference between the current study and prior research is the relationship of Agreeableness with Mellow and Intense music, which was not commonly observed previously. However, these relations support the hypothesis that individuals who are high in Agreeableness would prefer warm, calming and inoffensive music (Bonneville-Roussy et al., 2013). While these findings provide support for the reliability of the TIPI and its use in the current study, the inconsistent results might be due to the dissimilarity of the MUSIC factors between the current and previous study (Rentfrow et al., 2012). Agreeableness was positively associated with a preference for Unpretentious music (Bonneville-Roussy et al., 2013). Given that the Unpretentious factor was not replicated in the current study, it is also unlikely to find the previously observed association with Agreeableness. Therefore, it appears that the cross-cultural differences mentioned in the previous section that led to non-success in replicating the MUSIC factors might explain the inconsistent findings.

Music preferences and autistic traits

Although the expected positive association between autistic traits and Intense music was not found, I did find a negative association with Contemporary music. The hypothesis was extrapolated from the findings among individuals who are high in systemizing (Greenberg et al., 2015), hence the hypothesis was not based on autistic traits, which might explain the inconsistent results. While systemizing is related to autistic traits (Wheelwright et al., 2006), it is only a small part of the picture. The AQ measures autistic traits more broadly, including items measuring social and communication traits. While systemizing might be positively associated with a preference for Intense music, this does not seem to generalise to autistic traits.

The hypothesised positive association between autistic traits and Sophisticated music was not supported, which was based on the enhanced perceptual functioning theory in ASC (Mottron et al., 2006). According to this theory, autistic individuals prefer and appreciate Sophisticated/complex music more, given their enhanced lower-level auditory perception. Although the AQ-28 has been shown to measure the same latent traits, though with notable bias, among autistic and non-autistic individuals (Murray et al., 2014), there might be qualitative differences between those who are clinically diagnosed and those who score higher on the AQ. Moreover, heterogeneity is apparent within the autism spectrum. For example, only some autistic individuals display superior musical ability (Heaton et al., 2008), who might represent a genetically distinct subgroup (Nurmi et al., 2003). Therefore, it is probable that preference for Sophisticated music applies exclusively to this subgroup which displays enhanced perceptual functioning, and future research could explicitly investigate this by comparing within and between clinical and non-clinical populations.

The negative association between autistic traits and Contemporary music was not hypothesised. This association can be explained by the sociable and danceable function component of contemporary music (Bonneville-Roussy et al., 2013; Rentfrow et al., 2012). Autistic traits align with more social difficulties. A decreased preference for Contemporary music might hence result from the social component of this factor. The findings suggest that autistic traits among general populations relate to less preference for Contemporary music after accounting for age, gender and musical sophistication.

Limitations and future directions

Firstly, in this online study, there was a risk of self-selection bias. Individuals who are interested in music might be more likely to participate in the current study. Moreover, most of the participants are young adults and university students who consume more music and consider music more important than older adults (Bonneville-Roussy et al., 2013). Hence, I might have included participants with relatively high musical engagement which might lead to different (higher) preferences. Therefore, one should exercise caution when generalizing the current findings to the wider general population, and future studies could consider including a more representative sample to test the replicability of the current findings. Secondly, the current study design called for a brief measure of personality and music sophistication. Although both personality traits and musical sophistication significantly predicted preference for certain music even with these brief instruments, inclusion of more extensive instruments (e.g., Big Five Inventory and Goldsmiths Musical Sophistication Index; John & Srivastava, 1999; Müllensiefen et al., 2014) in future research could further delineate the relationship of musical sophistication and personality with music preference, especially in a non-Western context. Thirdly, an attempt to empirically confirm the MUSIC model necessitated the use of the same set of musical excerpts. Nonetheless, a more comprehensive study is needed to examine the effects of including a wider range of genres that Malaysians are exposed to (e.g., Malay, Mandarin and Korean pop music) on the formation of a music preference model.

Conclusion

The main objective of the current study was to test whether the MUSIC model and its association with Big-Five personality traits could be confirmed in Malaysia. The current results, to the best of my knowledge, are among the first to investigate the replicability of the MUSIC model among a relatively large Southeast Asian sample. The MUSIC model was partly confirmed among Malaysians with the Sophisticated and Intense factors being virtually identical with prior research. In line with previous findings, a preference for Unpretentious and Intense music were significantly associated with Agreeableness and Openness respectively even when musical sophistication was accounted for. Agreeableness was positively associated with a preference for Mellow music and negatively associated with a preference for Intense music. Autistic traits were associated with a reduced preference for Contemporary music. Overall, while the current findings provide partial support for the MUSIC model in Malaysia, it also highlights the importance of studying music preference in a non-Western context given the potential cross-cultural differences in music preferences and its association with listeners' characteristics.

Chapter 5: The Effects of Listening to Preferred Music on Executive Function Performance and Electrodermal Activity in relation to Autistic Traits

Listening to self-selected or preferred music has been suggested to increase arousal and subsequently improve cognitive performance. However, less is known about the effects of music listening on executive function (EF), and whether this effect is mediated by electrodermal activity (EDA), a physiological measure of arousal. While autistic traits are associated with poorer EF, people with autism show more elevated EDA in response to self-preferred music compared to the neurotypical population. This study aimed to investigate whether listening to preferred music would elevate EDA, and consequently enhance performance in EF tasks, and whether the effect of preferred music on EDA and EF is moderated by autistic traits. Twenty-eight (21 females, 7 males, M_{age} = 22.9) university students completed the Corsi Block Test, Trail Making Test and Go-NoGo Task while listening to preferred music, relaxing music and in silence. Their EDA was measured throughout all conditions. They also completed the Autism-Spectrum Quotient-28 (AQ-28). Listening to preferred music did not lead to elevated EDA nor to better EF performance compared to relaxing music and silence. Autistic traits did not predict EF performance, nor EDA. The findings suggest that the effects of music listening on cognitive performance might not be directly applicable to EFs, and self-selected background music might not elicit autonomic responses, nor influence EF.

Music listening has been linked to cognitive performance for decades. For example, the ‘Mozart effect’ refers to the enhancement in cognitive performance following exposure to Mozart music, and it received attention following the report of improvements in spatial task performance after listening to Mozart (Rauscher et al., 1993). Since then, many studies have shown improvements in cognitive performance following exposure to music (Hallam et al., 2002; Mammarella et al., 2007; Schellenberg et al., 2007), though null effects (Steele et al., 1999), and negative effects are also reported (Giannouli et al., 2019). Nonetheless, it is speculated that the positive effects might result from music listening activating the neuronal cortical networks that underlie cognition and attention. Using an electroencephalogram, Verrusio et al. (2015) found an elevation of the alpha-band and median frequency index of background alpha rhythm activity, where such activity is linked to memory and cognition, in both healthy adults and in elderly after listening to Mozart compared to Beethoven. Therefore, it is hypothesised that music may prime the neuronal networks that are responsible for cognition and attention, which in turn, would lead to enhanced performance on cognitive tasks that are served by these networks.

The reported effects in the prior paragraph all refer to listening to music *before* performing cognitive tasks. However, people often play music in the background while performing tasks in everyday life (Lonsdale & North, 2011). Evidence for the effects of background music on cognitive performance is mixed (Angel et al., 2010; Furnham & Strbac, 2002; Jäncke & Sandmann, 2010). Considering that listening to music while performing tasks is a more probable scenario in everyday life, the current study focused on the effect of background music on cognitive performance.

While it is intriguing that mere listening to music might lead to temporary cognitive enhancement, understanding the mechanism of how music affects cognitive performance might not be straightforward. A meta-analysis suggests that there is little evidence for the Mozart effect (Pietschnig et al., 2010). Rather, the Mozart effect might result from one’s preference for one condition over another. Nantais and Schellenberg (1999) showed that people did not perform better on a spatial-temporal task when listening to Mozart per se, but people who preferred listening to Mozart performed better when listening to Mozart while those who preferred a narrated story performed better when listening to a narrated story. Although there was no measure of mood and arousal, the authors postulated that one’s preferences for one condition increased the level of mood and arousal in that condition, which in turn, led to better performance.

Changes in mood and arousal have long been associated with changes in autonomic responses (Rickard, 2004; Silvestrini & Gendolla, 2007). The autonomic nervous system includes the sympathetic (i.e., predominates during emergency "fight-or-flight" reactions and physical activity) and the parasympathetic (i.e., predominates during quiet, resting conditions) nervous system. Electrodermal activity (EDA) is one of the autonomic properties most sensitive to changes in sympathetic arousal, reflecting emotional and cognitive states (Braithwaite et al., 2013). Most importantly, it might be the only autonomic variable that is not influenced by parasympathetic activity. Listening to music, especially preferred music, could lead to elevated EDA, which indicates increased arousal (Davis & Thaut, 1989; Harrer & Harrer, 1977; Rickard, 2004; Salimpoor et al., 2009; Schäfer & Sedlmeier, 2011).

If cognitive performance is enhanced by elevated arousal, listening to preferred music may lead to the same result due to its influence on arousal. According to the Yerkes-Dodson law, there is an inverted-U-shaped function between arousal and behavioural performance (Cohen, 2011; Yerkes & Dodson, 1908). The inverted-U-shaped function suggests that an optimal performance would be observed when reaching an optimal level of arousal, whereas under- or over-arousal would lead to poorer performance. However, different music may lead to different levels of arousal. For example, music with a slow tempo and in minor mode, which is usually indicative of sad music, may not increase arousal (Verrusio et al., 2015), and highly arousing music (e.g., loud and fast) has been shown to disrupt cognitive performance (Cassidy & MacDonald, 2007; Thompson et al., 2012). Nevertheless, regardless of the genre of music or whether the music contains lyrics, *preferred* music reliably activates the brain network that encompasses the default mode network (a network of brain regions that have measurable activity even when the brain is not actively engaged in goal-directed activities or commonly considered as at "rest") and the hippocampus (Wilkins et al., 2014). A major subdivision of the default mode network, the ventral medial prefrontal cortex, is involved in the regulation of physiological arousal (Raichle, 2015; Zhang et al., 2014). This suggests that preferred music would enhance arousal. Furthermore, a recent review indicates that there is a positive correlation between cognitive function and functional connectivity of the default mode network

(Mak et al., 2017). Possibly, the brain regions that pertain to cognitive functioning (default mode network in this case) and physiological arousal are modulated by music listening, which in turn leads to better behavioural performance (Ferreri et al., 2014). Moreover, people might prefer listening to music that modulates their arousal level to an optimal state so that it would not disrupt their performance during work/study. Hence, listening to preferred music likely leads to optimal changes in physiological responses, which in turn, might lead to enhanced behavioural performance according to Yerkes-Dodson law.

Besides EDA, subjective arousal (i.e., self-reported arousal) tends to increase after listening to music and this increase is accompanied by enhanced cognitive performance (Schellenberg et al., 2007). Subjective arousal is a person's perception of his/her own arousal, and it is usually measured using a rating scale from very calm to very aroused/excited. An increase in subjective arousal in response to music has been consistently observed (Gomez & Danuser, 2004; Rickard, 2004; Schellenberg et al., 2007), but not all music induces similar levels of subjective arousal. For example, a Mozart excerpt with fast and major mode induced an increase in subjective arousal, but an Albinoni excerpt with slow and minor mode did not (Thompson et al., 2001), which coincides with the idea that music with a slow tempo and minor mode might not enhance arousal. Furthermore, higher subjective arousal appears to be positively correlated with objective arousal (Gomez & Danuser, 2004). To get a holistic view of a person's arousal, both a subjective and objective measure of arousal should be used.

While different aspects of cognitive abilities such as linguistic processing, spatial-temporal and processing speed have been tested while listening to music, there is little research examining the effect of music listening on executive functioning (EF) specifically (Diamond, 2013). Except for working memory, where both positive (Chew et al., 2016) and null (Schellenberg et al., 2007; Steele et al., 1997) effects were reported following exposure to music, limited research has focused on cognitive flexibility and inhibition. Despite the mixed findings of music listening on working memory, I expect that performance on all EF domains might transiently be improved from listening to preferred music, based on the evidence of heightened arousal from such process.

Autistic individuals show a stronger increase in physiological responses to preferred music compared to neurotypical individuals (Hillier et al., 2016). Autonomic dysregulation is commonly reported among autistic individuals but depending on the branch of the investigated autonomic nervous system, hyper- and hypo-arousal are observed (Arora et al., 2021). That said, there is little research investigating whether autistic traits in the general population are also associated with increased or decreased physiological arousal. Besides, elevated autistic traits are associated with more EF difficulties (Christ et al., 2010). This study examined whether autistic traits are associated with physiological arousal, and whether elevated arousal would alleviate EF difficulties associated with autistic traits.

In the current study, I investigated if music listening *while* performing EF tasks had a positive impact on EF, after controlling for musical sophistication, as musical sophistication is known to positively relate to EFs (Meyer et al., 2020). I hypothesised that listening to preferred music would elevate arousal (both subjective and objective), which in turn would enhance performance on EF tasks. I also hypothesised that higher autistic traits would worsen EF performance. While a relationship between autistic traits and EDA is expected, the direction is unclear since both hypo- and hyper-arousal were reported.

Method

Participants

This study was approved by the Science and Engineering Research Ethics Committee of the University of Nottingham Malaysia (Identification Number: CZJ261219). Twenty-eight (21 females, 7 males) university students aged between 18 to 32 (M = 22.9, SD = 3.5) were recruited through the university recruitment email. 17 participants (60.7%) self-identified as Chinese Malaysian, 2 (7.1%) self-identified as Malay, 2 (7.1%) self-identified as Indian Malaysian, and 7 self-identified (25.1%) with other ethnicities.

Measures

Music. Preferred music was selected by participants prior to the experimental session. Songs from diverse genres, ranging from Western pop, rock, indie, classical, instrumental to Kpop, Mandopop and Indi-pop were provided by participants. Instrumental relaxing music was selected by the experimenter, based on previous literature, where it was shown to induce a relaxed state. Example pieces of relaxing music are Pachelbel's Canon in D major (Knight & Rickard, 2001), Satie's Gymnopedie no. 1 (Rickard et al., 2012), and Albinoni's Adagio (Bringman et al., 2009). These musical pieces have been shown to relieve or decrease subjective anxiety and subjective and objective measures of arousal.

Autistic traits. To measure autistic traits the AQ-28 was used. Refer to Materials and Results section of Chapter 3 for details.

Executive function. All EF tasks were implemented with open-source software called Psychology Experiment Building Language (PEBL; Mueller & Piper, 2014).

Working memory was assessed with an adapted version of the Corsi Blocks Test (Kessels et al., 2000). Nine blocks were shown on the screen in each trial and would light up in a particular sequence. Participants had to click on the blocks in the sequence that they lit up (see Supplementary Figure 5.1 for a visual representation). In the first trial two blocks lit up and the length would gradually increase. Kessels' version of the Corsi Blocks Test would require the nine blocks to remain at the same location on the screen across trials. However, given the possible practice effect from repeated testing, the locations of the nine blocks were randomised to appear differently across trials in the current study. Three practice trials were given before the experimental trials and the task terminated if participants failed to reproduce two trials of the same length. Memory span (the longest completed trial) was computed as an indication of working memory performance.

Cognitive flexibility was assessed with an adapted version of the Trail Making Test (Bowie & Harvey, 2006). The Trail Making Test consists of two parts. Part A requires participants to connect dots numbered 1 to 26 shown on the screen (see Supplementary Figure 5.2a), and it is usually used to test visual search and motor speed skills. Part B also requires participants to connect dots but in alternating sequence of numbers and letters (i.e., 1-A-2-B and so forth; see Supplementary Figure 5.2b), and it is suggested to tap into higher-order cognitive ability such as cognitive flexibility. Given the evidence of practice effects on the Trail Making Test (Buck et al., 2008), the location of dots was randomly generated in each trial. There were four trials each for Part A and B, and a short practice trial was provided prior to each experimental trial. The total time spent to connect the dots in Part A and B was computed to be used as the dependent variable in the current study.

Inhibition was measured with the Go-NoGo Task as described by Bezdjian et al. (2009). Participants had to respond to target letters as quickly as possible and refrain from responding to non-target letters (see Supplementary Figure 5.4). The Go-NoGo Task consisted of two conditions: P-Go and R-Go. In the P-Go condition, participants had to respond to the letter 'P' and refrain from responding to the letter 'R', and vice versa for the R-Go condition. A 2 x 2 square array was presented on the middle of the screen throughout the experiment, and either P or R would randomly appear in one of the arrays for 500 milliseconds. The next letter appeared in one of the arrays after 1500 milliseconds (i.e., the inter-stimulus interval) regardless of whether participants made a response. There were 160 trials for each condition with the ratio of targets to non-targets was 80:20 for both the P-Go and the R-Go condition. A brief practice trial was provided before the start of each condition. Errors of commission (i.e., responding to non-targets) and reaction to Go targets in P-Go and R-Go conditions were the primary interested variable of the current study as high error rates and shorter reaction time are indicators of impulsivity (or poor inhibition).

Musical sophistication. Musical sophistication was estimated using the Ollen Musical Sophistication Index (Ollen, 2006). For details about the OMSI, please refer to the Material section of Chapter 4.

Electrodermal activity. EDA was measured with Neulog Galvanic Skin Response logger sensor (NUL-217; https://neulog.com/gsr/). Given the relatively lengthy experiment (approximately 15-20 minutes for three EF tasks repeating 3 times), a sampling rate of 10/s was used in the current study. Two electrodes with Velcro finger connectors of the Neulog Galvanic Skin Response logger sensor were fit on the distal phalanges of the index and middle finger of participants' non-dominant hand. The readings of EDA were visualised and recorded using the Neulog application for Windows (https://neulog.com/software/) while connecting to the laptop with USB. Temperature and humidity were recorded given their possible influence on EDA (Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures et al., 2012).

Procedure

Prior to the experimental session, with informed consent, participants completed an online questionnaire that contained the AQ-28 and the OMSI. Participants were also asked to provide basic demographic information and a list of preferred music (at least 5) that they usually listen to while working/studying.

During the offline experimental session, participants' index and middle finger of their non-dominant hand were cleaned with alcohol to ensure better conductivity before the electrodes were attached securely. Participants were reminded to move their non-dominant hand as little as possible throughout the experiment, and the experiment started after the readings stabilised. All participants completed the Corsi Blocks Test, Go-NoGo Task and Trail Making Test three times while their EDA was recorded; 1) listening to their preferred music, 2) listening to relaxing music and 3) in silence. The EF tasks were presented on a laptop and the order of conditions and presentation of the three EF tasks were randomised. Baseline EDA was measured for two minutes immediately after completing the three EF tasks in each condition. The choice of measuring EDA after instead of before tasks was to avoid unstable electrodermal readings, especially at the very beginning of the experiment (Figner & Murphy, 2011). Sennheiser HD280 Pro Headphones were worn by participants throughout the experiment. The volume was set by participants to their comfort level prior to the start of the experimental session. Participants rated the familiarity, pleasantness, and arousal in each condition on a Likert scale of 1-7 (very unfamiliar/unpleasant/calm to very familiar/pleasant/aroused) at the end of the experiment session. Each experimental session lasted around 1.5 hours and participants were compensated with RM15.

Results

Data analysis

Data of 1 participant were excluded from analysis due to an error in the data collection procedure. The following results were therefore based on the data of 27 participants.

Considering the relatively small sample size and the within-subject design, mixed-effects models were used to analyse the data. Conventional methods such as repeated-measures ANOVA and linear regression do not allow the modelling of within-person correlations and could result in biased and less ideal estimates (Muth et al., 2016). Mixed-effects models were conducted with the R package ‘lme4’ (Bates et al., 2015) implemented in R (R Core Team, 2021; 4.1.1). Given the possible suboptimal performance of likelihood ratio test for small sample sizes (Halekoh & Højsgaard, 2014), I opted to estimate fixed effects with the Satterthwaite's method using the ‘lmerTest’ (Kuznetsova et al., 2017).

I used mixed-effects models to test whether (1) participants performed better on each EF task in the preferred music condition than in the other conditions, (2) EDA was higher in the preferred music condition than other conditions, (3) whether EDA positively predicted the performance on EF tasks, and (4) autistic traits either positively or negatively predicted EDA and negatively predicted EF performance. Fixed effects were centred and standardised where necessary. Condition was coded with deviation coding since I was interested in the main effects of Condition.

Following the recommendation of Barr et al. (2013), maximal random effects structure justified by design was modelled except when there were convergence issues which could not be resolved by optimization or increasing the number of iterations. Simplification of the random effects structure was a last resort since convergence issues would produce unreliable estimates and models (Brown, 2021). The random effects of each model are reported below. Given that I was interested in multiple fixed effects in a model, the ‘mixed’ function from the ‘afex’ package (Singmann et al., 2021) was implemented on the full model to assess the fixed effects. This is recommended instead of constructing and comparing nested models (with and without the target fixed effect) one by one, to avoid choosing models a posteriori (Brown, 2021). Final models chosen and reported below were also informed by theories and previous findings.

To answer my research questions of whether listening to preferred music, elevated EDA, and lower autistic traits were associated with better EF performance, three models (i.e., Model 1 Working Memory, Model 2 Cognitive Flexibility, and Model 3 Inhibition) were constructed. A fourth model (Model 4) was constructed to answer my research question of whether listening to preferred music and higher autistic traits were associated with elevated EDA. The raw EDA data (in μS) were square root transformed because they were positively skewed. The analyses below focused on the EDA during the first two minutes of each experimental condition for three reasons: 1) to match the duration of baseline measurement. 2) More noises are likely to be introduced in the EDA readings as the duration increases because EDA is very sensitive to changes in the environment. 3) With a sampling rate of 10/s over a long period of time (around 15-20 minutes per condition), it would be computationally expensive to analyse such enormous amount of EDA readings. However, I also repeated and reported the analyses on the full-length EDA of each experimental condition to check for possible differences in results.

Manipulation check: Comparisons of self-rated arousal, pleasantness, and familiarity between conditions

To test whether self-rated arousal, pleasantness and familiarity of the music differed between conditions, Friedman tests were conducted. Self-rated arousal differed between conditions, $\chi^2(2) = 29.78$, $p < .001$. Post hoc Wilcoxon signed-rank tests with a Bonferroni correction ($p < .017$) showed that self-rated arousal was significantly higher in the preferred (*Mdn* = 6) than relaxing music condition (*Mdn* = 3), $Z = -4.08$, $p < .001$, and silence condition (*Mdn* = 3), $Z = -4.07$, $p < .001$. There was no significant difference between the relaxing music and silence condition, $Z = -.10$, $p = .92$.

Self-rated pleasantness of the music differed between conditions, $\chi^2(2) = 20.06$, $p < .001$. Post hoc Wilcoxon signed-rank tests with a Bonferroni correction ($p < .017$) showed that there was no significant difference in self-rated pleasantness between preferred (*Mdn* = 6) and relaxing music condition (*Mdn* = 6), $Z = -2.34$, $p = .02$. The self-rated pleasantness was significantly higher in the preferred music condition than in the silence condition (*Mdn* = 4), $Z = -3.70$, $p < .001$. The self-rated pleasantness was also significantly higher in the relaxing music condition than in the silence condition, $Z = -3.19$, $p = .001$.

Given that the relaxing musical excerpts are quite well known, and familiarity influences the effects of music on cognition (Chew et al., 2016), I checked whether familiarity differs between self-selected and relaxing music. A Wilcoxon signed-rank test showed that participants were significantly more familiar with their preferred music (*Mdn* = 7) than the relaxing music (*Mdn* = 5) chosen by experimenter, $Z = -3.52$, $p < .001$.

Model 1: The effects of condition, autistic traits, self-rated arousal, and changes in EDA on working memory performance

Working memory performance was operationalised as memory span, which is one value per condition for each participant. Hence, the maximal random effects structure justified by design of Model 1 included only random intercepts of participants. It is expected that participants would perform better on the Corsi Blocks Test in the preferred music condition than in the other conditions, that autistic traits would negatively predict working memory, and that self-rated arousal and a positive change in EDA (increased EDA in comparison to baseline) would positively predict working memory. The change in EDA was computed by calculating the difference in the area under the graph between the experimental (first two minutes) and baseline sessions. Moreover, I hypothesised that those with a positive change in EDA during the preferred condition would predict better performance on the Corsi Block Test. Therefore, Model 1 assessed the main effects of Condition, autistic traits, self-rated arousal, change in EDA, and interaction between Condition and change in EDA while controlling for potential influence of musical sophistication on working memory.

As shown in Table 5.1 and Figure 5.1, memory span did not differ between the preferred music, relaxing music and silence conditions. Autistic traits, self-rated arousal and changes in EDA did not significantly predict memory span. Furthermore, there was no significant interaction between Condition and changes in EDA on memory span. Repeating analyses with changes in EDA over the full length of each experimental condition showed similar results: no significant relation of condition and memory span, and no significant interactions.

Table 5.1

*Model 1: memory span as a function of fixed effects and random effects. Model 1 = memory span ~ (Condition * changes in EDA + autistic traits + self-rated arousal + musical sophistication + random intercepts of participants).*

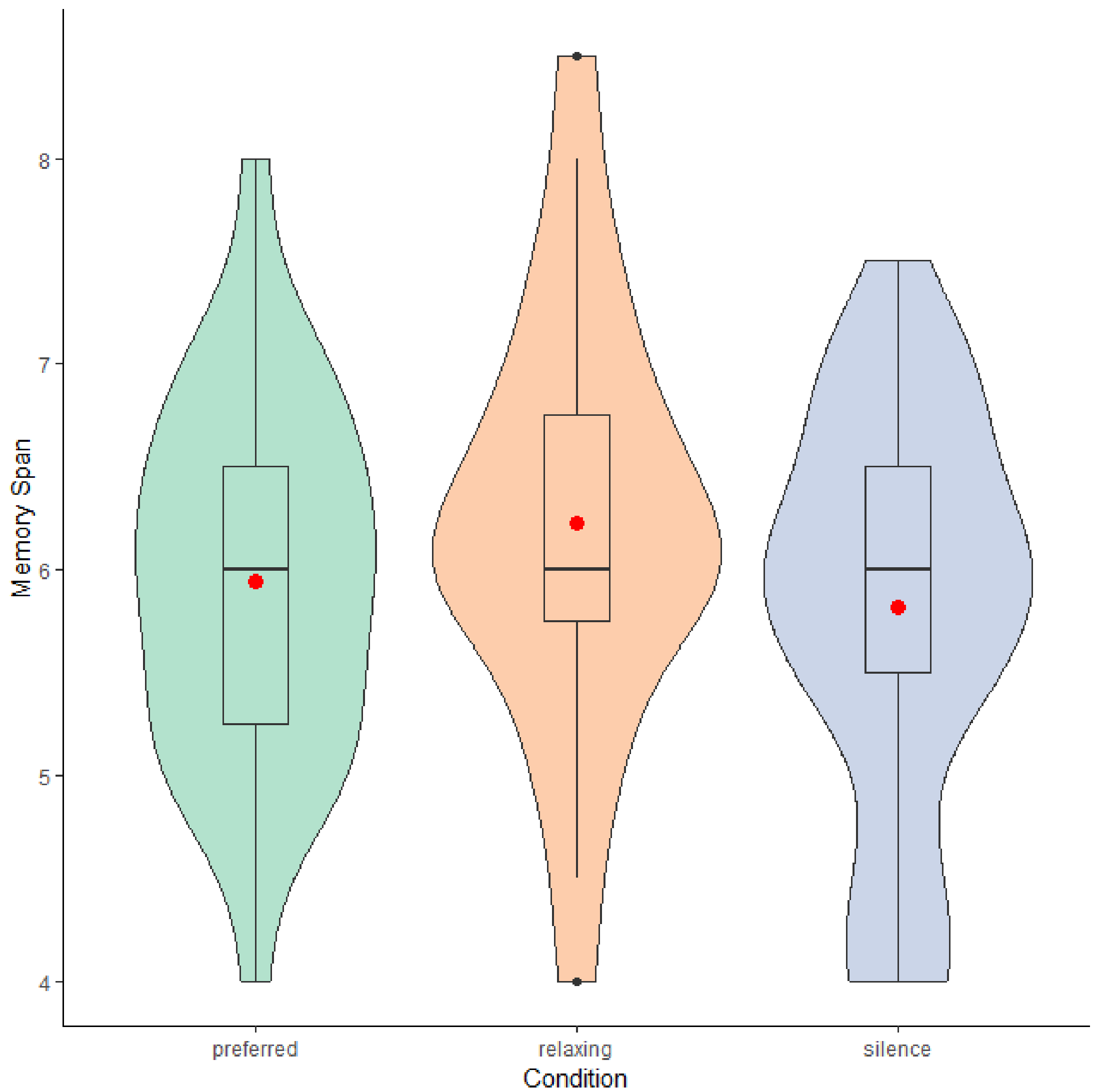
Random effects:		Variance
Participants	(Intercept)	.55
Residual		.39

Fixed effects:		Estimate	Standard error (SE)	*t* value
(Intercept)		6.01	.16	37.82***
Autistic traits		.16	.16	.97
Self-rated arousal		.02	.11	.21
Condition	Relax Vs Preferred	.25	.23	1.06
	Silence Vs Preferred	-.16	.23	-.69
Musical Sophistication		.12	.16	.72
Changes in EDA		-.12	.08	-1.49
Condition-Changes in EDA interaction	Relax Vs Preferred	.18	.19	.96
	Silence Vs Preferred	.26	.22	1.22
R^2		Marginal .08	Conditional .62	

Note. $^{***}p < .001$

Figure 5.1

Memory span in preferred music, relaxing music, and silence condition



Note. Red dot indicates mean memory span.

Model 2: The effects of condition, autistic traits, self-rated arousal, and changes in EDA on cognitive flexibility performance

The operationalisation of cognitive flexibility is the total time spent on Part B minus total time spent on Part A to control for motor speed (in milliseconds). I hypothesised that participants would perform better on the Trail Making Test in the preferred music condition than in the other conditions, that autistic traits would negatively predict cognitive flexibility, and that self-rated arousal and a positive change in EDA (increased EDA in comparison to baseline) would positively predict performance on the Trail Making Test. Moreover, I hypothesised that a positive change in EDA during the preferred condition would predict better performance on the Trail Making Test. Model 2 assessed the main effects of Condition, autistic traits, change in EDA, and interaction between Condition and change in EDA while controlling for potential influence of musical sophistication and motor speed on cognitive flexibility (total time spent on Part B minus Part A).

As shown in Table 5.2 and Figure 5.2, the Trail Making Test performance did not differ between the preferred music, relaxing music and silence conditions. Autistic traits, self-rated arousal and changes in EDA did not significantly predict Trail Making Test performance. Furthermore, there was no significant interaction between Condition and changes in EDA on Trail Making Test performance. Repeating analyses with changes in EDA over the full length of each experimental condition also did not significantly predict Trail Making Test performance, and there was no significant interaction with Condition.

Table 5.2

*Model 2: Trail Making Test performance as a function of fixed effects and random effects. Model 2 = Trail Making Test performance ~ (Condition * changes in EDA + autistic traits + self-rated arousal + musical sophistication + random intercepts of participants).*

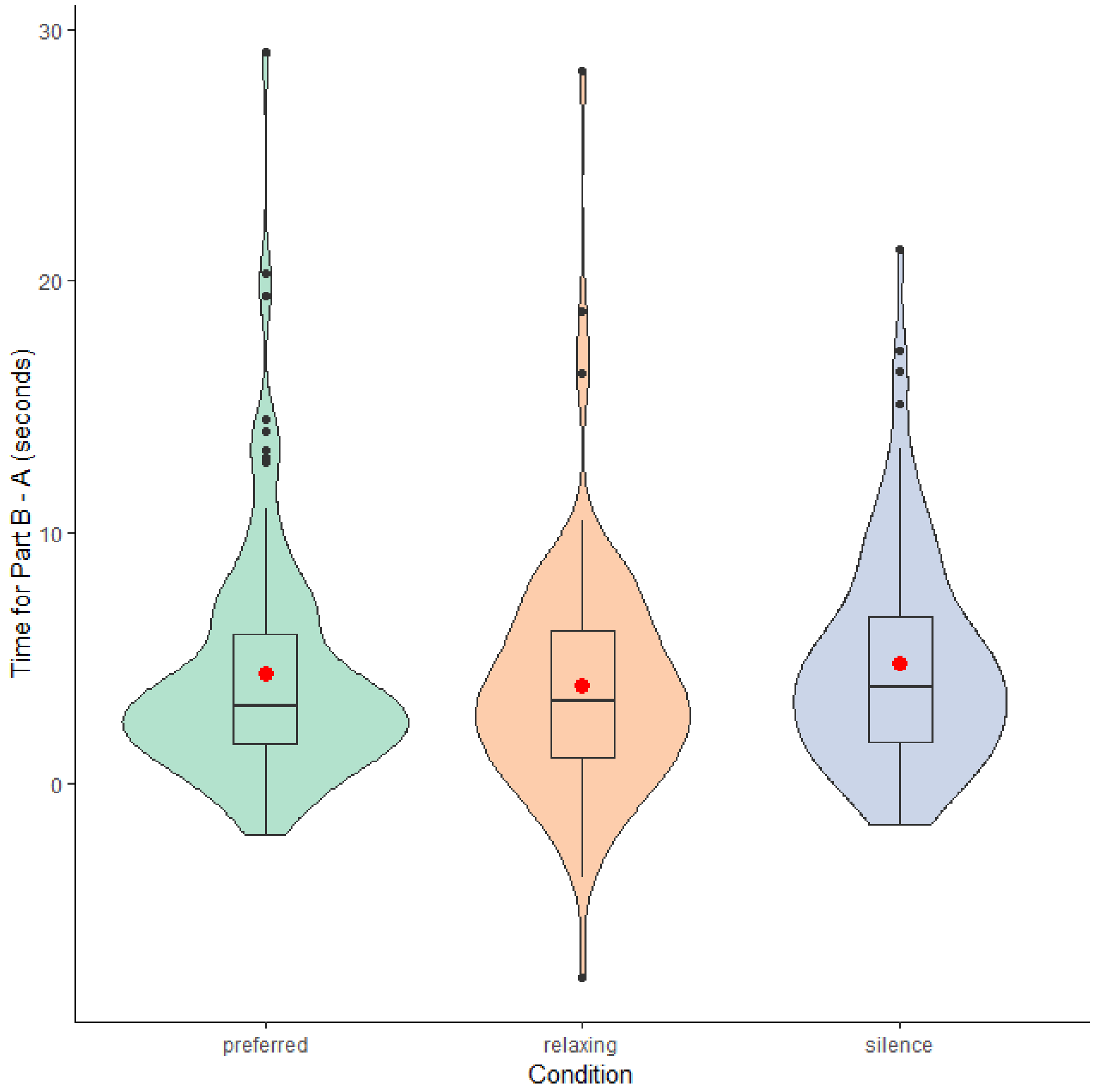
Random effects:			Variance	Correlation
Participants	(Intercept)		4.21	
Residual			16.79	
Fixed effects:		Estimate	Standard error (SE)	*t* value
(Intercept)		4.32	.46	9.45^{***}
Autistic traits		-.60	.47	-1.26
Self-rated arousal		-.19	.36	-.53
Condition	Relax Vs Preferred	-.63	.76	-.83
	Silence Vs Preferred	.29	.75	.39
Musical Sophistication		-.40	.46	-.87
Changes in EDA		.37	.27	1.38

Condition-Differences in EDA interaction	Relax Vs Preferred	-.14	.62	-.22
	Silence Vs Preferred	-.14	.70	-.20
R^2		Marginal .03	Conditional .22	

Note. $^{***}p < .001$

Figure 5.2

Trail Making Test performance in preferred music, relaxing music, and silence condition



Note. Red dot indicates mean time

Model 3: The effects of condition, autistic traits, self-rated arousal and changes in EDA on inhibition performance

Inhibition variables were the average reaction time on Go trials and commission errors on the Go-NoGo Task. While reaction time is a continuous variable, errors of commission are discrete outcomes that follow a binomial distribution (0 = correct, 1 = incorrect). Hence, a generalised form of mixed-effects model was constructed for the errors of commission. I hypothesised that participants would make fewer errors and show longer reaction times on the Go-NoGo Task in the preferred music condition than in the other conditions, autistic traits would negatively predict inhibition, and self-rated arousal and a positive change in EDA (increased EDA in comparison to baseline) would positively predict performance on the Go-NoGo Task. Moreover, I hypothesised that those with a positive change in EDA during the preferred condition would predict fewer errors and longer reaction times on the Go-NoGo Task. Therefore, Model 3a and 3b assessed the main effects of Condition, autistic traits, self-rated arousal, change in EDA, and interaction between Condition and change in EDA while controlling for the potential influence of musical sophistication on errors of commission and Go reaction time respectively. Gender was also controlled for as sex differences in error rates and Go reaction time were demonstrated previously (Bezdjian et al., 2009).

As shown in Table 5.3 and Figure 5.3, errors of commission did not differ between the preferred music, relaxing music, and silence condition. Autistic traits, self-rated arousal and changes in EDA did not significantly predict errors of commission. Furthermore, there was no significant interaction between Condition and changes in EDA on errors of commission. Repeating analyses with changes in EDA over the full length of each experimental condition also did not significantly predict errors of commission, and no significant interaction with Condition. Model 3b yielded similar results (see Table 5.4 and Figure 5.4); Go reaction time did not differ between the preferred music, relaxing music and silence conditions. Autistic traits, self-rated arousal and changes in EDA did not significantly predict Go reaction time. There was also no significant interaction between Condition and changes in EDA on Go reaction time. Repeating analyses with changes in EDA over the full length of each experimental condition showed that EDA positively predicted Go reaction time (standardised estimate = 6.05, *SE* = 2.76, $t(50) = 2.19$, $p = .03$, 95% CI = [.78, 11.38]), but no significant interaction with Condition. It is probable that EDA over the period of experimental condition would be more accurate in predicting performance in Go-NoGo Task since it was the longest task among the three.

Table 5.3

*Model 3a: errors of commission as a function of fixed effects and random effects. Model 3a = errors of commission ~ (Condition * changes in EDA + autistic traits + self-rated arousal + musical sophistication + gender + random intercepts of participants and trial type).*

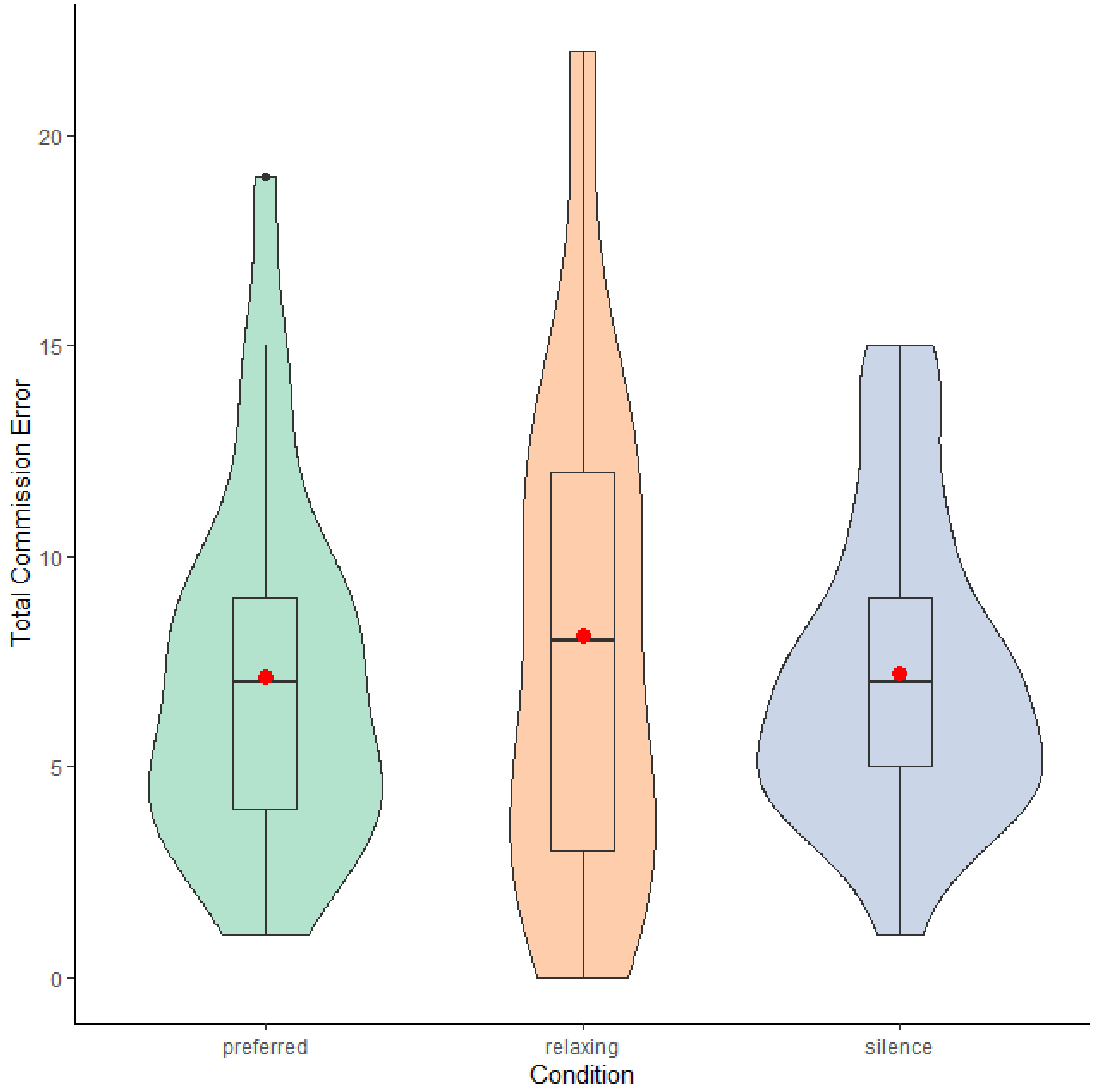
Random effects:			Variance	
Participants	(Intercept)		.31	
Trial Type	(Intercept)		1.45	
Fixed effects:		Estimate	Standard error (SE)	*z* value
(Intercept)		-4.51	.86	-5.25^{***}
Autistic traits		.12	.12	1.02
Self-rated arousal		.05	.07	.74
Condition	Relax vs Preferred	.19	.14	1.37
	Silence vs Preferred	.12	.14	.88
Gender		.11	.27	.40
OMSI		-.12	.12	-.96
Changes in EDA		.03	.05	.59
Condition-Changes in EDA interaction	Relax vs Preferred	-.07	.11	-.64
	Silence vs Preferred	.24	.13	1.83

R^2	Marginal	Conditional
	.01	.35

Note. $^{***}p < .001$

Figure 5.3

Commission error in preferred music, relaxing music, and silence condition



Note. Red dot indicates mean commission error.

Table 5.4

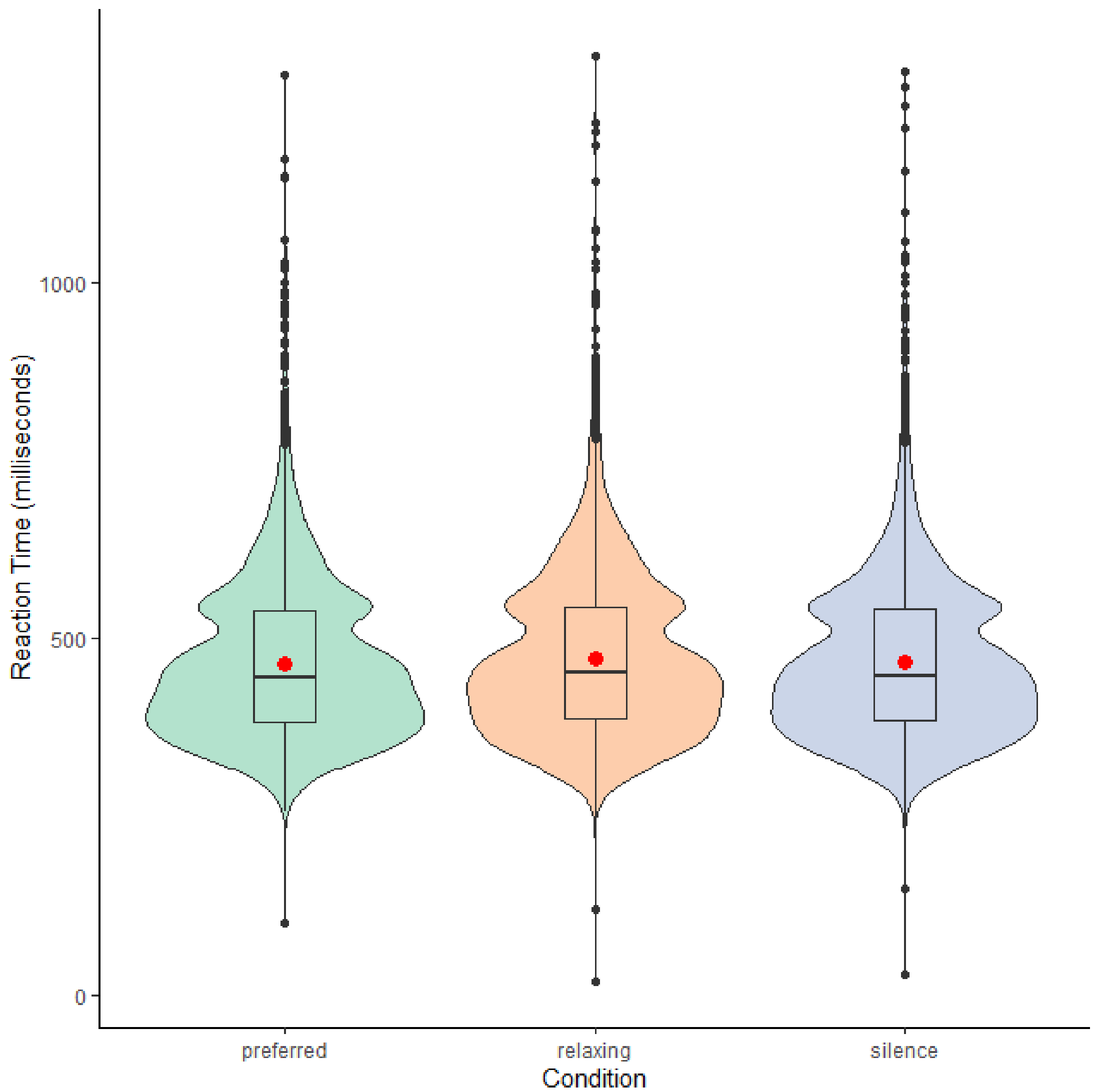
*Model 3b: Go reaction time (in milliseconds) as a function of fixed effects and random effects. Model 3b = Go reaction time ~ (Condition * changes in EDA + autistic traits + self-rated arousal + musical sophistication + gender + random intercepts and slopes of participants and random intercepts of trial type).*

Random effects:			Variance	Correlation	
Participants	(Intercept)		2486.4		
	Relax vs Preferred		1130.5	-.09	
	Silence vs Preferred		381.6	-.44	.56
Trial Type	(Intercept)		4552.5		
Residual			8745.4		
Fixed effects:		Estimate	Standard error (SE)	*t* value	
(Intercept)		481.87	51.00	9.45*	
Autistic traits		-13.28	8.95	-1.48	
Self-rated arousal		-5.21	3.02	-1.73	
Condition	Relax vs Preferred	-.05	8.01	-.01	
	Silence vs Preferred	-5.56	5.98	-.93	
Gender		21.48	20.51	1.05	
OMSI		-5.63	8.98	-.63	
Changes in EDA		2.90	2.47	1.17	
Condition-Changes in EDA interaction	Relax vs Preferred	.48	6.90	.07	
	Silence vs Preferred	-2.30	5.82	-.40	
R^2		Marginal .02	Conditional .47		

Note. $^{***}p < .001$

Figure 5.4

Go reaction time in preferred music, relaxing music, and silence condition



Note. Red dot indicates mean reaction time.

Model 4: The effects of condition and autistic traits on EDA

I hypothesised that EDA would be higher in the preferred music condition in comparison to relaxing music and silence condition and positively associated with autistic traits and self-rated arousal. Moreover, I hypothesised that autistic traits would positively influence EDA in the preferred music condition. Hence, Model 4 assessed the main effects of Condition, self-rated arousal and autistic traits, and interaction between Condition and autistic traits while controlling for the potential influence of temperature and humidity on EDA. Temperature and humidity were only included in this model because of their potential influence on EDA, but not on EF performance.

As shown in Table 5.5, EDA did not differ between the preferred music, relaxing music and silence condition, and autistic traits and self-rated arousal did not significantly predict EDA. Furthermore, there was no significant interaction between Condition and autistic traits on EDA.

Table 5.5

*Model 4: square root EDA as a function of fixed effects and random effects. Model 4 = sqrt EDA ~ (Condition * autistic traits + self-rated arousal + temperature + humidity + random intercepts and slopes of participants).*

Random effects:			Variance	Correlation	
Participants	(Intercept)		.30		
	Relax vs Preferred		.08	-.12	
	Silence vs Preferred		.09	-.16	.61
Residual			.01		
Fixed effects:		Estimate	Standard error (SE)	*t* value	
(Intercept)		1.65	.10	15.85***	
Autistic traits		-.05	.11	-.46	
Self-rated arousal		.02	.04	.65	
Condition	Relax vs Preferred	-.01	.08	-.11	
	Silence vs Preferred	-.03	.08	-.42	
Temperature		-.02	.10	-.19	
Humidity		.04	.07	.53	
Condition-Autistic traits interaction	Relax vs Preferred	.01	.05	.22	
	Silence vs Preferred	-.05	.06	-.82	

R^2	Marginal	Conditional
	.02	.97

Note. $^{***}p < .001$

Discussion

The current study aimed to examine the effects of listening to preferred music on EF. Against my hypotheses, listening to preferred music had no influence on working memory, cognitive flexibility, and inhibition task performance. Listening to preferred music also had no significant effects on arousal as measured by EDA in comparison to relaxing music and silence. EDA did not significantly predict working memory, cognitive flexibility, and inhibition performance. Moreover, both autistic traits and self-rated arousal did not significantly predict EDA and performance in each EF domain. Overall, I found no evidence that listening to preferred music would enhance performance on EF tasks which was accompanied by a lack of elevated autonomic responses.

The current findings are in line with research that showed no influence of music listening on EF, specifically on working memory (Giroux et al., 2020; Schellenberg et al., 2007). Moreover, the current study extended these findings to inhibition and cognitive flexibility. However, the current findings are in conflict with findings that showed positive effects of music listening on various cognitive tasks (Angel et al., 2010; Chraif et al., 2014; Schellenberg et al., 2007), and specifically on working memory (Chew et al., 2016; Mammarella et al., 2007). With respect to cognitive flexibility and inhibition, while there is a paucity of research examining the effects of short-term music listening/background music, long-term regular music listening had been shown to have no effects on the EF of stroke patients (Särkämö et al., 2008). The current findings suggest that listening to self-selected music does not positively nor negatively affect EF performance. One possible explanation for the inconsistency is the differences in sociocultural background between the current (Asian) and previous (mostly Western) studies that might limit the generalization of the effects of music on cognition. In an attempt to replicate the impact of music on working memory in a Rwandan sample, no positive effects were found (Giroux et al., 2020). The authors suggested that since music cognition is greatly influenced by culture, the effects of music might differ across cultures. There are notable cross-cultural differences in emotional reactions to music, psychological mechanisms (i.e., how music arouses an emotion) and function of music. For instance, in collectivistic cultures music more often has a social function (e.g., to entertain, dance and feel good collectively) than in individualistic cultures (Boer & Fischer, 2012). Emotions aroused by music, such as nostalgia, transcendence and tenderness are reported more frequently in collectivistic cultures than individualistic cultures (Juslin et al., 2016). It should, however, be noted that the collectivism-individualism construct is not dichotomous and heavily critiqued for being overly simplistic in its operationalisation (Fiske, 2002; Oyserman et al., 2002). That said, these findings do highlight potential cultural differences in music cognition. Hence, although the mechanism of music on cognitive performance is not exactly clear yet, it is likely the subtle cultural differences in music cognition influence the impact of music on cognitive performance. Thus, I conjecture this might partly explain my findings in a Malaysian sample, and the current findings corroborate that the effects of music listening on cognitive performance may not be universal.

Ceiling effects might be an alternate explanation for the null effects of listening to preferred music on EF performance given that ceiling effects in EF tasks is commonly observed among university students and in the general population (Chew et al., 2016; Friedman et al., 2016; Patrick et al., 2008). However, the performance in EF tasks did not cluster around the peak performance (see Figure 5.1-5.4), hence ceiling effects is unlikely to account for the current findings. Instead, clustering of performance around the same area (see Figure 5.1-5.4) indicates possible sampling bias, especially for Trail Making Test performance and Go reaction time. This suggests that participants showed similar level of executive functioning and might explain the null findings. Moreover, although I expected elevated autistic traits to be associated with poorer EF performance, no such association was found. The relationship between autistic traits and EF was found in a subthreshold population (higher-than-typical autistic traits; Christ et al., 2010), but not in a general population (Kunihira et al., 2006). A subthreshold population is likely to be more phenotypically similar to the autistic population than a general population sample (Constantino & Todd, 2005). Furthermore, the variance of the AQ scores in the small general population sample was low. This could perhaps also explain why autistic traits are not associated with increased EDA even though previous literature reported that an autistic population displayed elevated EDA in response to preferred music compared to a neurotypical population (Hillier et al., 2016). Therefore, the spread of both AQ scores and EF task performance might have been too low in my study to find a relationship.

Contrary to the findings that EDA are elevated in response to self-selected or preferred music (Rickard, 2004; Salimpoor et al., 2009), EDA did not differ across the three conditions in the current study. However, participants did *rate* their arousal to be significantly higher in the preferred music condition than other conditions. The mismatch in EDA and self-rated arousal also contradicts previous findings suggesting a strong correlation (Gomez & Danuser, 2004; Sato et al., 2020). Differences in the measurement of EDA, such as duration of measurement, recording site and treatment of data, could perhaps explain the inconsistency. However, the decision of recording site and treatment of data (e.g., selecting two minutes of readings) was based on recommendations and previous studies (Rickard, 2004; Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures et al., 2012). Thus, I argue that the impact of procedural differences is likely to be minimal. Instead, it seems more likely that the type of music that participants listen to might explain the discrepant findings. In the current study participants were explicitly asked to select music that they prefer to listen to while working/studying. However, when elevated physiological response was observed, it was always accompanied by emotionally powerful or intensely pleasurable music (Rickard, 2004; Salimpoor et al., 2009). Moreover, there are indications that people play music in the background with the goal to simply avoid silence while carrying out other tasks (Lonsdale & North, 2011). This suggests that people might not choose music that would influence their performance or distract them from the primary task. Hence, the current results imply that the impact of music on EDA is dependent upon their functions (i.e., to use as background vs to experience pleasure), and music to be used as background while working/studying might not lead to observable changes in EDA.

While I hypothesised that elevated self-rated arousal might predict performance on EF tasks, this was not found. Previous findings were mixed, with some demonstrating the mediating role of arousal (Jones et al., 2006), increased arousal without enhanced cognitive performance (Hirokawa, 2004), or enhanced cognitive performance without increased arousal (Smith et al., 2010). Therefore, my findings suggest that self-rated arousal might not be related to behavioural performance. On the other hand, to the best of my knowledge, this is the first study to examine the mediating role of *objective* arousal as indicated by EDA in the relationship between music listening and cognitive performance. In this regard, the current results also contradict the hypothesis; EDA does not predict EF performance across conditions. Although changes in EDA over the full length of experimental conditions did positively predict Go reaction time, which suggests better inhibitory control is associated with elevated EDA, the results should be interpreted carefully. EDA is extremely sensitive to movements and environmental changes, and substantial artefacts might be introduced when EDA is measured over an extended period. The artefacts might also explain the lack of relationship between EF performance and EDA. Moreover, while the EDA reading is standardised by time (i.e., divide by time spent in each session) before converting to changes in EDA, baseline measurement is fixed to two minutes in comparison to experimental sessions that lasted for more than ten minutes. Hence, the results based on full-length EDA might not be reliable and should be further investigated. Overall, my findings combining both subjective and objective arousal do not provide any conclusive evidence to corroborate or reject the role of arousal in mediating music listening and cognitive performance given that there is a lack of relationship between music and EF in the first place, and future studies are warranted.

The dissociation between a direct and indirect effect of music listening on EF is worth mentioning because they would likely rely on a different mechanism. The current findings run counter to the speculated causal mechanism of music listening on EF via physiological arousal. Given the overlap in brain regions regulating physiological arousal and cognitive functions (Mak et al., 2017; Raichle, 2015), stimuli that increase physiological arousal would activate these shared brain regions, and the activation of these shared brain regions would in turn lead to better cognitive functions. However, the current results also do not support a direct effect of music listening on EF. That said, given that the current findings are based on music that people listen to while working/studying, these potential mechanisms are worth exploring with other types of self-selected music (e.g., intensely pleasurable music) in the future.

EDA provides information exclusively about the sympathetic activity that governs the fight-or-flight responses (Braithwaite et al., 2013), whereas other indicators of arousal that reflect both sympathetic and parasympathetic activity (e.g., heart rate) may complement EDA in future investigations. Heart rate generally increases in response to music (Harrer & Harrer, 1977), and is greater when exposed to excitative music than relaxing music (Iwanaga & Moroki, 1999). Furthermore, there is some evidence of reduced parasympathetic activity (as indicated by cardiac function) among ASC, and this reduced parasympathetic activity appears to be related to social symptoms of ASC (Arora et al., 2021). Therefore, multiple indices of arousal should be examined simultaneously in relation to autistic traits and music in future studies to better understand whether arousal is associated with autistic traits and music.

Mixed effects modeling used in the current study took variability within and between participants and conditions simultaneously into account (Brown, 2021). This cannot be achieved through conventional approaches such as ANOVAs and regression which were generally used in the past studies. The conflicting findings on the effects of listening to preferred music on EDA and EF performance, hence, could possibly stem from the difference in statistical approach. Considering the strengths of mixed effects modelling over the conventional approaches, I believe the findings corroborate the existing evidence that demonstrated no effects of music listening on cognition (Giroux et al., 2020; Jäncke & Sandmann, 2010; Steele et al., 1997). Nonetheless, replication of the findings with a larger sample size is warranted. In addition, conditional R-squared (i.e., proportion of variance explained by both fixed and random effects) are higher than marginally R-squared (i.e., proportion of variance explained by the fixed effects) across all models, suggesting individual differences in EF performance and EDA explained most of the variance. This further substantiates the use of mixed effects modeling to account for individual differences in EF performance and EDA to provide a more nuanced view on the effect of listening to music.

The current findings should also be viewed in light of potential limitations. The musical excerpts selected by participants were diverse, and therefore limit my ability to control for the basic music elements such as tempo and mode that have been shown to affect mood and arousal, and subsequently cognitive performance (Husain et al., 2002). However, the benefits of conducting a more ecologically valid experiment likely outweigh the potential confounding effects. Moreover, there are consistent indications that self-selected or preferred music perform similarly in eliciting arousal and enhancing cognitive performance regardless of tempo, genres and the presence or absence of lyrics (Davis & Thaut, 1989; Hirokawa, 2004; Perham & Withey, 2012). Hence, I believe the use of self-selected music was well justified.

In sum, the current study found no effects of listening to preferred music on EF performance and EDA. Both self-rated arousal and EDA were not associated with task performance. Autistic traits did not predict EF performance nor EDA. Therefore, in line with the view that music cognition differs across cultures, future studies should examine the impact of music on cognitive performance from the cultural perspectives to shed light on why music might function differently across cultures.

Chapter 6: Musical Sophistication and its Relationship with Executive Functions, Autistic Traits and Quality of Life

Musical training likely has a positive impact on executive functions (EF) and quality of life. While enhanced musical ability has been observed in the autistic population, research suggests that autistic traits are associated with worse EF and quality of life in both the general and autistic populations. It remains unclear whether autistic traits within the general population are related to better musical abilities, and how that might interact with their EF and quality of life. The current study aimed to examine musical sophistication and its relationship with EF, quality of life and autistic traits. One hundred seventy (129 females; M_{age} = 20.5) university students completed the Goldsmiths Musical Sophistication Index, the Adult Executive Functioning Inventory, the Autism Spectrum Quotient, and the Pediatric Quality of Life Inventory General Core Scales for adults. While no significant association was found between musical sophistication and autistic traits, musical sophistication was associated with fewer EF difficulties. Moreover, participants with more autistic traits and more EF difficulties had a lower quality of life. These effects remained significant after controlling for key demographic variables. EF mediated the effect of musical sophistication on quality of life; greater musical sophistication was related to better EF and, in turn, better quality of life. When looking into the subscales of the Gold-MSI, having fewer EF difficulties was linked to better emotions, musical training, perceptual, and singing abilities. The results offer insights into how musical sophistication is related to EF, autistic traits and quality of life.

Based on:

Chee, Z. J., Leung, Y., de Vries, M. (accepted for publication). Musical Sophistication and its Relationship with Executive Functions, Autistic Traits and Quality of Life. *Psychomusicology: Music, Mind, and Brain*

Musical sophistication reflects the idea that musical abilities are multifaceted. Extensive research had mostly defined musical abilities by the duration/number of years of formal musical training or education, ignoring other traits or activities that do not overtly contribute to musical ability (Levitin, 2012; Ollen, 2006). Although past studies have looked into musical training and its relation to cognitive functions such as executive function (EF) and quality of life (Seinfeld et al., 2013; Shen et al., 2019), very few investigated how general musical sophistication and facets apart from musical training are related to EF and quality of life.

EF and quality of life are also related to autistic traits. More autistic traits are associated with greater difficulties in EF and lower quality of life (Christ et al., 2010; Pisula et al., 2015), but are also linked to better musical abilities (e.g., pitch identification; Dohn et al., 2012). Given the potential relation of autistic traits with musical abilities, EF and quality of life, this study aims to investigate how autistic traits might play a role in the relationship between musical sophistication, EF and quality of life.

Musical sophistication

The concept of musical sophistication is described in Chapter 1. The current chapter used the Gold-MSI to quantify musical sophistication because it encompasses as many dimensions of musical ability as possible. Importantly, the 5+1 factor structure of the Gold-MSI has been replicated (Baker et al., 2020; Lin et al., 2021), supporting its reliability in measuring musical sophistication.

EF and musical sophistication

EF refers to a set of neurocognitive functions that guide our behaviour in an ever-changing environment (Jurado & Rosselli, 2007). There are three core EF domains: inhibition, cognitive flexibility (also known as set-shifting or mental flexibility) and working memory (Diamond, 2013; Miyake et al., 2000). Although there is a lack of high-quality studies (Bowmer et al., 2018; Dumont et al., 2017), musical training has been suggested to have a positive impact on these core domains of EF (Benz et al., 2016; Jaschke et al., 2018; Roden et al., 2014; Shen et al., 2019), However, little is known about whether general musical sophistication, apart from formal musical training, may impose a similar impact. Given that some evidence supports improvements in EF following musical training (Bugos et al., 2007), the musical training subscale of the Gold-MSI is likely to be associated with EF, but the relation of other subscales with EF remains unclear.

There are some indications that the subscales of the Gold-MSI might be associated with EF. A study among university students found that all but one subscale (i.e., singing abilities) of the Gold-MSI were positively associated with working memory, and three of the subscales were positively correlated with inhibition (Okada & Slevc, 2018). Moreover, it was argued that working memory plays a significant role in contributing to musical sophistication beyond musical abilities (Baker et al., 2020). Cognitive flexibility, however, was not related to any of the subscales and general musical sophistication. In contrast, a positive relationship between cognitive flexibility and perceptual abilities was observed among older adults with mild cognitive impairment (Petrovsky et al., 2021). While there was a slight inconsistency across studies, the findings overall suggest a positive relationship between musical sophistication and objective measures (i.e., neuropsychological tasks) of EF. However, it remains unclear whether the self-report musical sophistication would be associated with subjective EF (i.e., self-report). Therefore, the current study aims to examine the relationship between musical sophistication as measured by the Gold-MSI and subjective EF.

EF, quality of life and musical sophistication

EF is suggested to be crucial for one's quality of life (Diamond, 2013). Quality of life is commonly referred to as a multidimensional construct that reflects the subjective perception of one's well-being in social, physical, spiritual, emotional, and cognitive domains (Gill et al., 2013). Young adults with ASC were found to have difficulties in EF, leading to lower quality of life (Dijkhuis et al., 2017). A similar relationship between EF and quality of life is observed in people with other conditions, such as attention-deficit/hyperactivity disorder, epilepsy and schizophrenia (Brown & Landgraf, 2010; Sherman et al., 2006; Tyson et al., 2008). It is possible that musical sophistication, mediated by EF, influences quality of life.

Moreover, musical sophistication may influence quality of life directly. A randomised-controlled study suggested that music listening improves quality of life, and regular musical activities (e.g., singing) have a positive impact on EF in people with dementia (Särkämö et al., 2014). Similarly, music therapy appears to be effective in improving the quality of life of people with severe and enduring mental disorders or terminal cancer (Grocke et al., 2009; Hilliard, 2003). Children and young people also reported benefits of singing on physical, emotional, social, and spiritual domains that are reflected in quality of life (Ashley, 2002; Clift & Hancox, 2001). Recent meta-analytic findings suggest moderate-quality evidence for a positive influence of music interventions on quality of life (McCrary et al., 2022). In comparison to other leisure activities (e.g., books, films, and sports), music was rated as particularly important in the daily life of adolescents and young adults. The importance of music as compared to other leisure activities possibly stems from the versatility of music in serving an individual’s needs such as mood management and social interaction (Lonsdale & North, 2011). Given that people generally enjoy music, certain subscales of the Gold-MSI (e.g., active engagement) might be positively associated with quality of life. However, there is a paucity of research investigating the association between musical sophistication and quality of life explicitly. This study hopes to address the gap in the literature by examining the relationship between musical sophistication and quality of life, and the possible mediating effect of EF.

EF, quality of life, autistic traits and musical sophistication

Musical sophistication is associated with better EF and higher quality of life. However, in autistic individuals, the picture becomes more complicated. Autistic traits are associated with difficulties in EF and lower quality of life (Christ et al., 2010; Pisula et al., 2015), but with enhanced musical abilities (Bonnel et al., 2010; Dohn et al., 2012). A large population-based study reported that children with special abilities, such as music abilities, had more autistic traits than those who without special abilities (Vital et al., 2009). Specifically, autistic traits seem to be positively related to pitch discrimination performance (Dohn et al., 2012; Stewart et al., 2018). Thus, autistic traits may be correlated with the perceptual abilities subscale of the Gold-MSI. While music sophistication, EF and quality of life all seem positively correlated, autistic traits are likely to be positively correlated with perceptual abilities, but negatively correlated with EF and quality of life. Hence, a different pattern of relationship might be observed among musical sophistication, or more specifically, perceptual abilities, EF and quality of life when autistic traits are considered.

Despite some indications of better pitch identification in autism, the exact link between enhanced musical abilities and autistic traits remains unclear, partly because of the heterogeneity within ASC (Ronald et al., 2006). For example, among the autistic individuals investigated, only a few demonstrated better pitch performance compared to age- and IQ-matched controls (Heaton et al., 2008). Although the autistic population might display enhanced musical abilities compared to their typically developing counterparts (Applebaum et al., 1979; Heaton, 2003; Heaton et al., 2001), it is unclear whether the autistic traits within the general population are also related to the broader construct of musical sophistication. General musical sophistication as operationalised by the Gold-MSI includes many items relating to musical training and singing abilities (Müllensiefen et al., 2014), hence autistic traits might not be associated with general musical sophistication. Nevertheless, given that perceptual abilities also contribute to general musical sophistication, the current study aims to examine if autistic traits within the general population are positively related to musical sophistication, and negatively related to EF and quality of life.

The current study

With the current online survey study, I first explored the relation between musical sophistication, subjective EF, autistic traits and quality of life by fitting several statistical models to the data. Given the indications that socioeconomic status is associated with musical sophistication, EF and quality of life (Baker et al., 2020; Last et al., 2018; Ross et al., 2012; Thumboo et al., 2003), I also examined the relationship among musical sophistication, EF and quality of life while controlling for socioeconomic status. I then examined the association of the subscales of the Gold-MSI with EF and autistic traits. I expected that (1) EF would be positively associated with overall quality of life and musical sophistication, and negatively associated with autistic traits, and (2) quality of life would be positively associated with musical sophistication with EF mediating the relationship and negatively associated with autistic traits. (3) Musical training, singing abilities, active engagement and emotions would be positively associated with EF (Okada & Slevc, 2018), and (4) perceptual abilities would be associated with both autistic traits and EF. The direction of the association between perceptual abilities and EF is expected to be positive (Okada & Slevc, 2018; Petrovsky et al., 2021). However, the direction of the association between perceptual abilities and autistic traits is unclear; it could be positive, based on findings that perceptual abilities are positively associated with autistic traits (Dohn et al., 2012), or negative, based on findings that showed a negative association between autistic traits and EF (Christ et al., 2010).

Method

Participants

This study was approved by the Science and Engineering Research Ethics Committee of the University of Nottingham Malaysia (Ethics Identification Number: CZJ060620), and the data were collected between August and November 2020. The participants were recruited through the faculty's study recruitment email and Facebook survey groups in Malaysia. A total of 218 responses were collected, and 170 (129 females, 36 males, and 5 unknown) were complete responses. The participants who completed the questionnaire were aged between 17 and 44 (M = 20.49, SD = 3.16). The participants were primarily university students and the sample consisted of 56.5% Chinese Malaysians, 11.2% Malay, 10.0% Indian Malaysians, and 22.4% others.

Measures

Autistic Traits. The Autism Spectrum Quotient was used to measure autism traits. Refer to Materials and Results section of Chapter 3 for details.

Musical Sophistication. The Goldsmiths Musical Sophistication Index (Gold-MSI; see Appendix IV for the full questionnaire) was used to measure musical sophistication (Müllensiefen et al., 2014). The Gold-MSI consists of 31 items that participants give a rating from 1 (*completely disagree*) to 7 (*completely agree*), and there are 7 items where participants have to indicate the category they belong to (e.g., "I have attended 0 / 1 / 2 / 3 / 4-6 / 7-10 / 11 or more live music events as an audience member in the past twelve months"). Five subscales (i.e., active engagement, perceptual abilities, musical training, singing abilities, emotions) and one general musical sophistication factor were identified in the original paper (Müllensiefen et al., 2014). The validity of the Gold-MSI was supported by its correlations with the tests of musical abilities such as Advanced Measures of Musical Audiation (AMMA) and different listening tests (i.e., melodic memory and beat perception). A higher score denotes that a person is more musically sophisticated. The general musical sophistication consisting of 18 items was found to have good internal reliability, α

= .88, and the internal reliability of the subscales were found to range from acceptable to good, α = .71 - .85.

Executive Function. The Adult Executive Functioning Inventory (ADEXI; see Appendix V for the full questionnaire) was used to measure EF difficulties in two domains: working memory and inhibitory control (Holst & Thorell, 2018). It consists of 14 items in total, and one has to rate from 1 (*definitely not true*) to 5 (*definitely true*). Significant correlations were found between the ADEXI and Barkley's Deficits in Executive Function Scale (89 items) on the subscales that aimed to measure similar constructs, supporting its convergent validity (Holst & Thorell, 2018). A higher score indicates more problems with EF. The test-retest reliability was found to be adequate (r = .68 - .72; Holst & Thorell, 2018) and the internal reliability of the ADEXI was good in the current study, α = .82.

Quality of Life. Quality of life was measured using the Pediatric Quality of Life Inventory™ (PedsQL™; Varni et al., 2001). The self-report version of PedsQL 4.0 Generic Core Scales for adults was used (see Appendix VI for the full questionnaire), which consists of four dimensions: Physical Functioning, Emotional Functioning, Social Functioning and Work/Studies Functioning. There are 23 items in total and the participants are required to rate how much each item (e.g., "Taking a bath or shower by him or herself") was a problem for them in the past month on a scale of 0 (*never*) to 4 (*almost always*). All items are reversely scored and linearly transformed such that a rating of 0,1,2,3 and 4 transforms into 100, 75, 50, 25 and 0 respectively. I used the global score, where a higher score indicates a better overall quality of life. The internal reliability of the PedsQL was found to be good in the current study, α = .89.

Procedure

An online survey was created on Qualtrics. After obtaining consent from participants, participants were asked to fill out the Gold-MSI, AQ-28, ADEXI and PedsQL that were presented in random order. Participants were also asked to provide some basic demographic information. Parents' highest completed education level, estimated total family income, and own highest completed education level were used separately to estimate socioeconomic status considering the findings that show that they should not be combined to represent a latent dimension (Geyer et al., 2006).

Participants could enter a lucky draw for compensation. The survey took approximately 25 minutes to complete.

Results

The data were analysed using SPSS 25.0 and AMOS 25.0. Prior to the path analysis, I conducted a correlation analysis to examine the basic relationship between the variables and check whether there were issues of multicollinearity ($r \geq .85$). The correlation among the variables can be found in Table 6.1. A significant positive correlation was found between musical sophistication and quality of life, $r(168) = .21$, $p = .007$. Negative correlations were found between musical sophistication and EF difficulties, $r(168) = -.23$, $p = .002$, EF difficulties and quality of life, $r(168) = -.48$, $p < .001$, and quality of life and autistic traits, $r(168) = -.30$, $p < .001$. No potential issue of multicollinearity was identified among these variables.

Table 6.1

Correlation among the variables, N = 170

	Musical Sophistication	EF Difficulties	Quality of Life	Autistic Traits
Musical Sophistication	1.00			
EF Difficulties	-.23**	1.00		
Quality of Life	.21**	-.48**	1.00	
Autistic Traits	-.13	.07	-.30**	1.00

Note. $^{**}p < .01$.

Path analyses

Path analysis was conducted as it could handle multiple dependent variables which, in turn, allows the construction and comparison of more complicated and realistic models (Streiner, 2005). The data met the assumption of univariate normality (skewness < 3 and kurtosis < 10; Weston & Gore, 2006) and multivariate normality (kurtosis < 5; Byrne, 2013). The fit of the models was assessed with χ^2 and its associated *p*-value, and models that were below a significant level would be rejected or deemed not fitting. The Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI) were used in addition to

χ^2 to assess the fit of the model because they are relatively independent of sample size (Schermelleh-Engel et al., 2003). A model is considered a ‘good’ fit by a value of .95 or above for TLI and CFI, and .06 or below for RMSEA (Hu & Bentler, 1999). Akaike Information Criterion (AIC) was also taken into consideration when comparing models where a smaller value indicates a better fit (Schermelleh-Engel et al., 2003). Three models were compared to test my hypotheses. The indirect effects were assessed using a bootstrap sample value of 1000, and 95% bias-corrected confidence intervals (CIs).

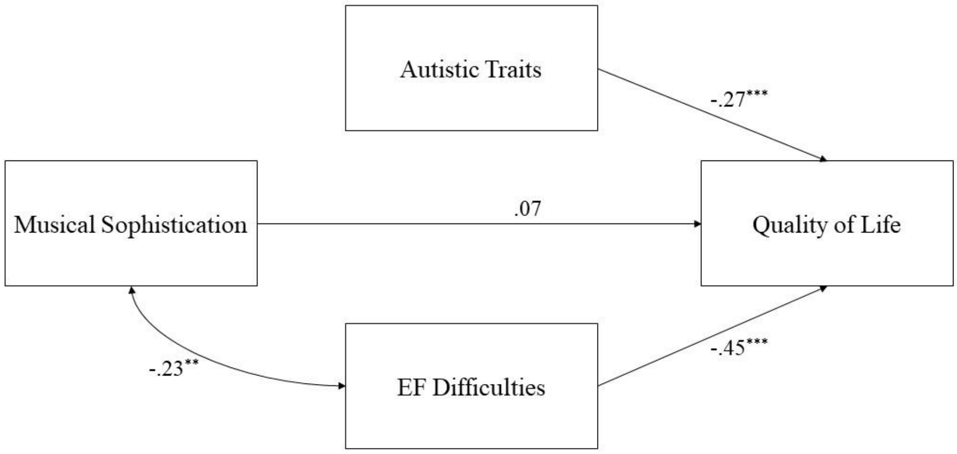
The first “simple” Model (Figure 6.1) tested the effects of musical sophistication, EF difficulties and autistic traits on quality of life. This simple model included the correlation between musical sophistication and EF difficulties because they are significantly correlated. There was a significant direct effect of autistic traits and EF difficulties on quality of life, but musical sophistication had no significant direct effect on quality of life (see Figure 6.1). The model fit the data adequately, χ^2 = 3.01, *df* = 2, *p* = .22, CFI = .985, TLI = .956, RMSEA = .055 (90% confidence interval = .000-.172), AIC = 19.013.

Model 2 builds on model 1 by including mediation paths, based on theoretical constructs. The added paths were from autistic traits to EF difficulties and from musical sophistication to EF difficulties. Model 2 with respective standardised path coefficients can be found in Figure 6.2. In addition to the significant paths found in model 1, a significant direct effect of musical sophistication on EF difficulties was found. The model has a mediocre fit, χ^2 = 2.65, *df* = 1, *p* = .10, CFI = .976, TLI = .856, RMSEA = .099 (90% confidence interval = .000-.252), AIC = 20.652.

Finally, a trimmed model (Model 3) with the non-significant paths of Model 2 (from musical sophistication to quality of life and from autistic traits to EF difficulties) removed was tested. Model 3 with respective standardised path coefficients can be found in Figure 6.3. The model fit the data well, χ^2 = 4.18, *df* = 3, *p* = .24, CFI = .983, TLI = .966, RMSEA = .048 (90% confidence interval = .000-.146), AIC = 18.182.

Figure 6.1

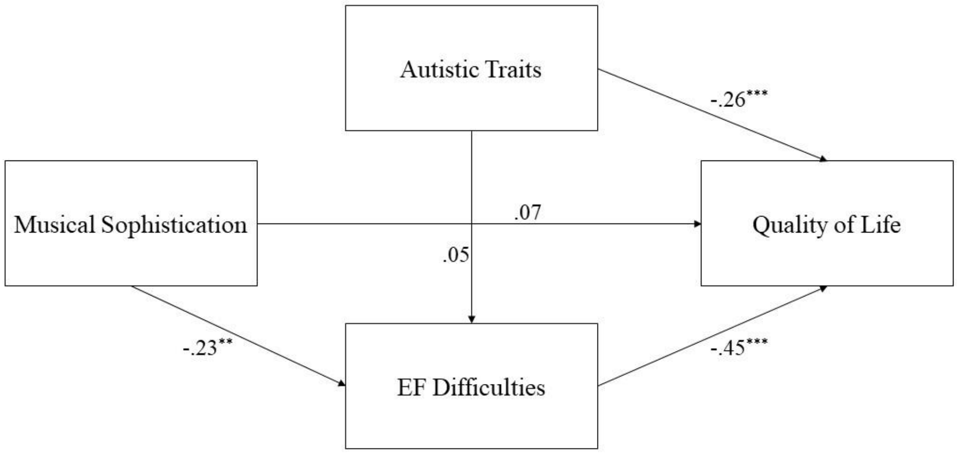
Model 1: The direct effects of musical sophistication, autistic traits and EF difficulties on quality of life, and their respective standardised path coefficients.



Note. $^{**}p < .01$. $^{***}p < .001$

Figure 6.2

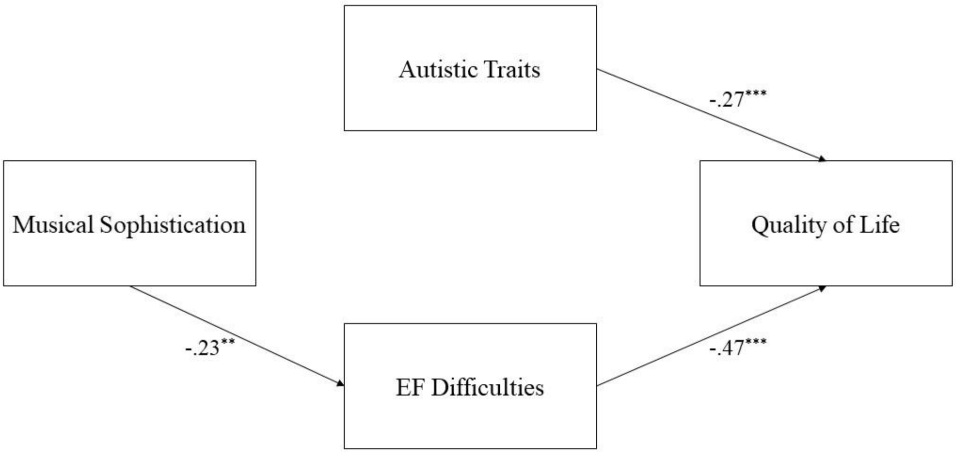
Model 2: The direct and indirect effects of musical sophistication, autistic traits and EF difficulties on quality of life, and their respective standardised path coefficients.



Note. $^{**}p < .01$. $^{***}p < .001$

Figure 6.3

Model 3: The direct effects of musical sophistication on EF difficulties and, autistic traits and EF difficulties on quality of life, and their respective standardised path coefficients.



Note. $^{**}p < .01$. $^{***}p < .001$

The summary of each model's fit indices can be found in Table 6.2. Given that models 1 and 3 are nested models of model 2, chi-square difference tests were conducted. The test indicated that all three models fitted equally well statistically. All models also explained a similar percentage of variance in quality of life (see Table 6.2). Upon inspection of the fit indices, model 3 fitted better than model 1 and model 2. Therefore, model 3 was selected as the final model for interpretation.

Table 6.2

Model comparisons

	Model		
	1	2	3
Model fit measures			
χ^2	3.01	2.65	4.18
df	2	1	3
p	.22	.10	.24
CFI	.985	.976	.983
TLI	.956	.856	.966
RMSEA (90% CI)	.055 (.000-.172)	.099 (.000-.252)	.048 (.000-.146)
AIC	19.013	20.652	18.182
χ^2 difference test			
χ^2 dif Model 1	-	.36	1.17
Model 2			1.53
df dif Model 1	-	1	1
Model 2			2
p Model 1	-	.55	.28
Model 2			.47
Explanatory Power (R^2)			
Quality of Life	.29	.30	.29

The variables that had a significant direct effect on quality of life were autistic traits (β = -.27, p < .001) and EF difficulties (β = -.47, p < .001). There was a significant direct effect of general musical sophistication (β = -.23, p = .002) on EF difficulties. All significant effects remained after controlling for the key demographic variables age, gender, ethnicity and socioeconomic status.

Although there was no significant direct effect of general musical sophistication on quality of life, it was found that there was a significant indirect effect of general musical sophistication on quality of life (β = .11, p = .003). This suggested that EF mediates the relationship between general musical sophistication and quality of life.

Subscales of musical sophistication

I tested possible associations of the Gold-MSI subscales with autistic traits (as indicated by total AQ score) and EF difficulties (as indicated by the total ADEXI score; see Table 6.3) using correlations. Autistic traits were negatively correlated with perceptual abilities, $r(168) = -.20$, $p = .009$, and singing abilities, $r(168) = -.23$, $p = .00$. EF difficulties were significantly correlated with all the Gold-MSI subscales except active engagement. Given that ADEXI comprises two domains of EF (i.e., working memory and inhibition), I additionally tested how they are related to the Gold-MSI subscales. Similar patterns to the total ADEXI were observed on the working memory domain such that it was significantly correlated with all the Gold-MSI subscales except active engagement, whereas inhibition difficulties were negatively correlated with perceptual abilities only (see Table 6.3).

Table 6.3

Correlation among the Gold-MSI subscales, total score on AQ-28 and ADEXI subscales, N = 170

	Autistic Traits	EF Difficulties	Working Memory Difficulties	Inhibition Difficulties
Active Engagement	-.07	.04	.03	.05
Perceptual Abilities	$-.20^{**}$	$-.31^{***}$	$-.32^{***}$	$-.19^{*}$
Musical Training	-.003	$-.27^{***}$	$-.30^{***}$	-.12

Singing Abilities	-.23**	-.20*	-.26**	-.02
Emotions	-.10	-.15*	-.15*	-.10

Note. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Discussion

The current study examined the relationship between musical sophistication, autistic traits, EF and quality of life among a general, mainly student, population. As predicted, more EF difficulties were associated with lower quality of life after controlling for key demographic variables. This is consistent with findings showing that lower quality of life is related to greater EF problems among populations with affective disorders and ASC (Cotrena et al., 2016; de Vries & Geurts, 2015; Dijkhuis et al., 2017; Mackala et al., 2014). Hence, this broadens the findings from clinical samples, where the association between EF and quality of life is rather well-studied, to a mostly university student sample. Although the relationship between EF and quality of life in university students was not studied before, previous studies on university students did show that lower academic performance was associated with more EF difficulties (Ramos-Galarza et al., 2020), and shifting (a domain of EF) had a direct effect on reading comprehension (Georgiou & Das, 2018). Moreover, more EF difficulties were associated with increased anxiety and maladaptive coping strategies (O'Rourke et al., 2020). Given that EFs play a significant role in predicting the academic performance and psychological health of university students, the current findings that showed that more EF difficulties are associated with lower quality of life among the student population align with the literature.

A negative association between autistic traits and quality of life was found, in line with previous findings among university students (Pisula et al., 2015; Reed et al., 2016), and children with ASC (de Vries & Geurts, 2015). However, previous studies among university students also noted that it might not be autistic traits per se that contribute to a lower quality of life (Pisula et al., 2015; Reed et al., 2016). Instead, difficulties commonly *associated* with more autistic traits mediated the relationship between autistic traits and quality of life. For example, depression, loneliness and social anxiety were commonly found to correlate positively with autistic traits (Reed et al., 2016; White et al., 2011), and the latter two were demonstrated to mediate the effect of autistic traits on quality of life (Reed et al., 2016). Additionally, maladaptive coping strategies might be another potential mediator of this relationship (Pisula et al., 2015). The current study showed that self-report EF difficulties did not mediate the relationship (see Figure 6.2). However, I did not measure the previously reported mediators, yet these might have played similar roles in the current data given the similarity in the characteristics of the sample.

There was a negative association between general musical sophistication and EF difficulties as expected, thus supporting studies that demonstrated better EF among musicians in comparison to low-activity musicians and non-musicians (Meyer et al., 2020; Strong & Mast, 2019). Given that musical training is the major subscale contributing to musical sophistication, it corroborates findings demonstrating positive impacts on EF through musical training (Bugos et al., 2007; Degé et al., 2011; Moradzadeh et al., 2015; Shen et al., 2019). That said, while the current findings provide support a positive association between musical training and EF, whether it is causal should be explicitly studied in future research considering the inconclusive evidence (Bowmer et al., 2018; Dumont et al., 2017). Moreover, although general musical sophistication is drawn from all five subscales (Müllensiefen et al., 2014), most of the items still reflect activities that are related to musical performance/training (Baker et al., 2020). This means that the degree of association of other non-performative musical skills with EF cannot be clarified by studying general musical sophistication only. Furthermore, while the factor structure of the Gold-MSI was replicated (Baker et al., 2020; Lin et al., 2021), the distinction between general musical sophistication and its subscales, especially singing abilities and musical training, might not be meaningful given that they are potentially highly correlated (see Supplementary Materials Table 6.1). Hence, the current findings support a positive relationship between musical sophistication and EF, but also suggest that an in-depth investigation of subdomains of musical sophistication using both self-report and objective measures would be more informative in teasing apart how other non-performative musical skills are associated with EF.

The current study found negative correlations between general EF difficulties and all but one subscale of the Gold-MSI. This is largely consistent with the findings among university students and older adults with MCI (Okada & Slevc, 2018; Petrovsky et al., 2021). While active engagement was found to be related to working memory and inhibition (Okada & Slevc, 2018), the current findings found no association with either domain, and general EF. Furthermore, while singing abilities did not correlate with any neuropsychological tests among older adults with MCI (Petrovsky et al., 2021), there was a significant correlation between singing abilities and self-report EF difficulties in the current study. The current findings also highlight that non-performative musical skills, such as perceptual abilities, are associated with EF. However, given the nature of the study design, no causal relationship could be inferred. Hence this should be clarified in future research. That said, the current study extends previous findings by showing that the subdomains of music sophistication are associated with self-report EF difficulties.

My data revealed that working memory was associated with all but one subscale (i.e., active engagement) of the Gold-MSI, which corresponds to past evidence suggesting the involvement of working memory in musical abilities (Dalla Bella et al., 2011; Jerde et al., 2011; Slevc et al., 2016), and musicians are consistently found to outperform non-musicians on working memory tests (D'Souza et al., 2018; Meyer et al., 2020). Therefore, it is not surprising to observe that greater perceptual abilities, singing abilities, musical training and musical emotions are associated with fewer working memory difficulties. Inhibition, in contrast, was only associated with perceptual abilities. While this appears to be in line with the significant correlations found between inhibition and musical perception among children (Janurik et al., 2019), it is inconsistent with findings showing no relationship between inhibition and perceptual abilities among university students (Okada & Slevc, 2018). Furthermore, inhibition appears to be unrelated to musical ability measured by the Musical Ear Test (Slevc et al., 2016), and older musicians performed similarly to matched non-musicians on an inhibition task (Amer et al., 2013). The mixed findings could result from the instruments used to measure inhibition and musical perception, since these constructs can be measured with questionnaires (subjective) or neuropsychological tasks (objective). Self-report EF questionnaires often do not correlate with neuropsychological measures of EF, and both are considered independently clinically useful (Mason et al., 2021; Mohamed et al., 2019). Similarly, the ADEXI, correlates weakly or non-significantly with neuropsychological tests of EF (Holst & Thorell, 2018). The ADEXI is a reliable subjective measure of EF, and indeed replicated the expected relationships with quality of life and musical sophistication, supporting its validity. Similarly, although the perceptual abilities as measured by Gold-MSI were moderately correlated with several listening tests (Müllensiefen et al., 2014), it is unclear if this might be associated with the performance on a Musical Ear Test. Therefore, future studies using objective and subjective measures of EF and musical sophistication might better tease apart the relation. The current findings do suggest that self-estimated musical abilities may be associated with self-report working memory difficulties and to a lesser extent, inhibition.

With the current correlational results, it is not possible to infer causation or rule out the hypothesis that there are pre-existing differences in EF which in turn determine who is more likely to engage in musical activities that lead to higher musical sophistication. However, evidence for a positive effect of musical training and regular engagement in musical activities on EF is accumulating. Several longitudinal studies have shown changes in brain regions underlying EF and improvements in EF performance following years of musical training (Habibi et al., 2018; Hennessy et al., 2019). Contrary to the positive findings, a much shorter musical intervention (i.e., eight weeks) had no effect on EF (Bowmer et al., 2018), highlighting the potential role of intervention duration in the induction of changes in brain and behavioural performance. In terms of engagement in musical activities, the lack of association between active engagement and EF found in the current chapter contradicts the positive impact of regular music listening on EF among patients with dementia in a randomised controlled study (Särkämö et al., 2014). While speculative, the difference in the samples (e.g., non-clinical vs clinical) suggest that regular engagement in musical activities would only benefit individuals with deficits in EF. Overall, the current literature appears to be optimistic for a positive impact of musical training and regular engagement in musical activities on EF. Positive associations between musical sophistication (and its subscales) and EF observed in the current chapter not only corroborate the potential positive impact of musical training/activities, but also shed light on the potential association between receptive musical skills and EF. Future research could possibly examine whether training these receptive skills (e.g., pitch performance) would lead to improvements in EF or whether these receptive skills mediate the potential positive impact of musical training on EF in a longitudinal study.

Consistent with my hypothesis, EF mediates the relationship between musical sophistication and quality of life. While a positive association between musical activities/interventions and quality of life was consistently observed (Clift & Hancox, 2001; McCrary et al., 2022; Särkämö et al., 2014), potential mediators for the effects of musical activities on quality of life were seldom explored previously. Given that musical training might have a positive influence on EF (Benz et al., 2016), and the importance of EF on quality of life (Diamond, 2013), the indirect effect of musical sophistication on quality of life with EF as the mediator seems supported. Importantly, the effects of musical sophistication on EF and EF on quality of life remain after controlling for socioeconomic status, suggesting that musical sophistication and EF explain unique variance in EF and quality of life respectively. Therefore, the current study suggests that engaging in regular musical activities or having greater musical sophistication per se might not have a causal effect on quality of life, but that greater musical sophistication might be associated with better EF which, in turn, is associated with better quality of life. While speculative, it is possible that music therapy or intervention for cognitive rehabilitation such as neurologic music therapy (Thaut et al., 2009) could indirectly influence quality of life through EF. Future research on music therapy or intervention could explore the relationship between EF and quality of life directly.

It is well established that autistic individuals and subthreshold populations show EF difficulties (Christ et al., 2010; Demetriou et al., 2018), but the current study found no association between autistic traits and self-report EF difficulties among the student population. The contradiction could stem from the differences between a subthreshold and a student population. A subthreshold group usually possesses higher-than-typical autistic traits (Christ et al., 2010), whereas the autistic traits of a general student population are likely to distribute across the 'normal' range. The current findings are consistent with findings from a Japanese general population where no association between autistic traits and EF was found (Kunihira et al., 2006). Therefore, it seems that autistic traits among the student population might not be related to EF difficulties.

I postulated that autistic traits might positively correlate with general musical sophistication considering that perceptual abilities contribute to general musical sophistication. However, the lack of such a relationship might not be surprising since general musical sophistication is still mostly defined by performative musical activities (Baker et al., 2020). Moreover, most research focused on lower-level perceptual abilities in music among people with or without ASC (Bonnel et al., 2003; Dohn et al., 2012; Heaton, 2003). This again echoes my view that investigating perceptual abilities in greater detail might be more informative than general musical sophistication.

The negative association between autistic traits and perceptual abilities found in the current study was inconsistent with previous findings (Chamberlain et al., 2013; Dohn et al., 2012; Mottron et al., 2006; Stewart et al., 2018; Vital et al., 2009). This might stem from the used method. The current study used self-report to measure perceptual abilities whereas in previous studies this was measured by tasks. A few items from the Gold-MSI measuring perceptual abilities might involve social aspects (e.g., I am able to judge whether someone is a good singer or not). Given that more autistic traits denote more social difficulties, one might self-report poorer perceptual abilities that involve social aspects. A similar explanation is applicable for the items measuring singing abilities (e.g., I am not able to sing in harmony when somebody is singing a familiar tune). Furthermore, there are mixed findings with respect to the relation between autistic traits and perceptual abilities in the auditory domain (Wenhart & Altenmüller, 2019). This might be the first study to examine the relation of autistic traits with self-report musical abilities instead of perceptual tasks. In light of the inconsistent findings, future studies should consider both self-report and objective measures of musical abilities to better establish their relationship with autistic traits.

There are some limitations to my study. Firstly, the data do not allow inference of causal relationships. For example, it is impossible to conclude if greater musical sophistication leads to better EF or the other way around. Longitudinal studies should be employed in the future to clarify the relationship. Secondly, the relatively small sample size and the sample characteristics (the sample was mainly made up of female university students) may not be representative of the general population (Henrich et al., 2010), hence making it difficult to generalise my findings. Thirdly, general fluid intelligence was not taken into account which has been shown to be associated with musical sophistication (Baker et al., 2020). While the independence of EF and fluid intelligence is debated (Diamond, 2013; Heitz et al., 2006), it might be useful to examine if both uniquely mediate the relation between musical sophistication and quality of life. Fourthly, the current findings should be viewed in light of potential response biases given that the findings are based on self-report questionnaires. For example, Asian participants score higher on the AQ than Western participants (Freeth et al., 2013; see also Chapter 3), suggesting the existence of response bias and one should exercise caution in generalizing findings on autistic traits across cultures. However, compared to the AQ which is constructed based on social norms that are culture dependent, the Gold-MSI, ADEXI and PedsQL are more culturally neutral. Hence, the effect of response bias on these questionnaires is expected to be minimal. Moreover, all data were collected in one country. Lastly, the current results might not be directly comparable to the past findings (Okada & Slevc, 2018; Petrovsky et al., 2021) since I did not include neuropsychological tests. Nonetheless, my findings do add to the current knowledge by specifically looking into self-evaluation of EF, quality of life music and autistic traits.

The present study found that autistic traits and EF are associated with quality of life and that the relation between musical sophistication and quality of life is mediated by EF. Several subdomains of music sophistication significantly correlated with general EF and specific EF domains. The findings overall suggest that greater musical sophistication is linked to better EF, particularly working memory, which in turn, is associated with better quality of life. Furthermore, specific subscales such as perceptual and singing abilities but not general musical sophistication appear to be related to autistic traits. Therefore, apart from formal musical training, other subdomains of musical sophistication appear positively associated with EF, and better EF seems associated with better quality of life.

Chapter 7: General Discussion

The primary objective of the current thesis was to examine whether and how musical sophistication and its subdimensions are associated with EF and autistic traits. The influence of language on and psychometric properties of the AQ were tested in Chapters 2 and 3. The results from Chapter 2 showed that participants scored significantly higher on the Mandarin than on the English AQ, while no difference was observed between the Bahasa Malaysia and English AQ. The factor structure of the AQ-28 appeared to be relatively stable, and AQ-28 is found to measure autistic traits similarly in Malaysia and the Netherlands as reported in Chapter 3. In Chapter 4, I attempted to confirm the MUSIC preference model in a Malaysian general population sample and examine its associations with Big-Five personality traits and autistic traits. The MUSIC model was partially confirmed with the Intense and Sophisticated factor being virtually identical to the original study conducted with a Western general population. Some of the commonly reported associations between Big-Five personality traits and music preference were observed (e.g., Agreeableness-Unpretentious and Openness-Intense), but the others were not replicated. Lower autistic traits were associated with a greater preference for Contemporary music. Effects of music listening on EF performance and arousal (self-reported and measured by EDA) in relation to autistic traits were examined in Chapter 5. Listening to preferred music did not appear to influence EF and arousal. Moreover, autistic traits were not associated with EF performance nor arousal. In Chapter 6, relationship among musical sophistication, EF, autistic traits and quality of life was explored. Greater musical sophistication was associated with better EF, which in turn, was associated with better quality of life. Higher autistic traits were associated with poorer quality of life, but unrelated to self-report EF.

Autistic traits

Autistic traits are one of the main interests of the current thesis, but the AQ, a widely used instrument to measure autistic traits, has rarely been tested in a non-Western context. There are indications that the AQ may behave differently across cultures; Malaysian students scored significantly higher than British students on the AQ (Freeth et al., 2013). While the authors suggested that cultural differences in expressing and reporting autistic traits might have led to the difference in score, an additional explanation might be a possible contribution of language. That is, the higher scores among Malaysian students could be partially explained by the language they answered in. Malaysian students responded to the AQ in English (Freeth et al., 2013), which is likely not their native/first language. Hence, Chapter 2 attempted to address this gap by Malaysian participants completing both the Mandarin or Bahasa Malaysia AQ and the English AQ. The results showed that participants scored significantly higher on the English AQ than on the Mandarin AQ, but there was no difference in their scores between the Bahasa Malaysia and the English AQ. Language, hence, might partially explain the higher score among Malaysian students than British students (Freeth et al., 2013). It is therefore recommended that AQ should be administered in the native language of the participants, or the non-native language proficiency should be considered when that is not possible.

The factor structure of the AQ might differ across cultures, hence measuring different latent traits (i.e., measurement non-invariance) in different cultures. While the AQ measures autistic traits among British students efficiently, it might be measuring something slightly different when it is completed by Malaysian students. Differences in the AQ score (Freeth et al., 2013) might be a consequence of comparing traits that are incomparable (e.g., comparing an apple to an orange or autistic traits to social traits in general). The original five-factor structure of the AQ (Baron-Cohen et al., 2001) has been debated, and many alternative structures have been proposed (Austin, 2005; Hoekstra et al., 2011; Kloosterman et al., 2011; Russell-Smith et al., 2011). However, evaluation of the AQ factor structure in a non-Western context, especially in Malaysia, is scarce. With that in mind, the factor structure of the AQ-28, a commonly used abridged version of the AQ, was examined in Malaysia and the Netherlands in Chapter 3. Moreover, measurement invariance of the AQ-28 was tested. The hierarchical factor structure of the AQ-28 fitted well in the Netherlands and was acceptable in Malaysia, and the AQ-28 appeared to measure autistic traits similarly in the Netherlands and Malaysia as suggested by measurement invariance analysis. Therefore, the results overall support the use of the AQ-28 in measuring autistic traits among the Malaysian general population.

EF and autistic traits

Neuropsychological measures of EF and self-report EF difficulties are examined in Chapters 5 and 6 respectively. Specifically, working memory was measured by a Corsi Blocks Test, inhibition was measured using a Go-NoGo Task and cognitive flexibility was measured with a Trail Making Test. The ADEXI was used to measure experienced/self-report/subjective EF and contains two subscales measuring working memory and inhibition. Surprisingly, autistic traits were not related to self-report EF, even though autistic traits as measured with the AQ has been reported to correlate to self-report EF measures, e.g., the Barkley Deficits in Executive Functioning Scale (BDEFS; Mason et al., 2021). The ADEXI was found to show acceptable test-retest reliability, high internal consistency and converge strongly with the BDEFS (Holst & Thorell, 2018). Given that the ADEXI and BDEFS measure EF similarly, the discrepancy in the association with the AQ may be due to differences in comprehensiveness. The ADEXI used in Chapter 6 contains only 14 items in total measuring two domains (i.e., working memory and inhibition), but the BDEFS used in Mason et al. (2021) contains 89 items measuring five different domains (i.e., self-organization/problem solving, self-management of time, self-restraint/inhibition, self-regulation of emotions and self-motivation). It is possible that the brief instrument may not be able to assess subtle EF difficulties in comparison to a more comprehensive instrument. Moreover, the ADEXI seems to measure cognitive aspects of EFs exclusively (i.e., cold EFs), whereas the BDEFS reflects EFs underlying the processing of emotional, motivational, and reward-related information (i.e., hot EFs). Although both hot and cold EFs are impaired in ASC (Zimmerman et al., 2016), there is preliminary evidence suggesting that hot EFs might play a more fundamental role in the psychopathology of ASC (Salehinejad et al., 2021). Therefore, autistic traits among the general population might be related to hot EFs only. In contrast, the lack of association between autistic traits and neuropsychological measures of EF is in line with past research (Kunihira et al., 2006; Mason et al., 2021). Neuropsychological measures of EF often do not correlate with self-report EF (Holst & Thorell, 2018; Mason et al., 2021), putting the ecological validity of neuropsychological measures of EF in question. With that in mind, (ab)normal performance on neuropsychological measures of EF may not correspond to subjective EF difficulties in everyday life. Moreover, given that most of the participants were university students, ceiling effects on EF tasks and questionnaires are additionally possible (Friedman et al., 2016; Patrick et al., 2008). Together, the link between self-report EF and autistic traits among general populations remain inconclusive.

The lack of associations between EF (both neuropsychological and self-report) and autistic traits may also be attributed to how autistic traits are conceptualised. While autistic traits reflect the social and repetitive behaviour symptoms of ASC, as evidenced by the original five subscales of the AQ (Baron-Cohen et al., 2001), autistic traits might not necessarily reflect the ASC-specific cognitive patterns. The link between autistic traits among the general population and ASC is not clear (Mottron & Bzdok, 2020), and hence examination of autistic traits among the general population might be relatively less informative for ASC. EF difficulties are prevalent among autistic individuals (Demetriou et al., 2018), but their first-degree unaffected relatives do not seem to display EF difficulties (McLean et al., 2014). Besides, although elevated autistic traits have been found to be associated with EF difficulties among those with subthreshold autistic traits (Christ et al., 2010; Dai et al., 2019; Hyseni et al., 2019), the association disappeared when examining individuals with typical range of or low autistic traits (Dai et al., 2019; Kunihira et al., 2006; Maes et al., 2013). This consistent observation suggests that autistic traits among those with low or typical autistic traits might be qualitatively different from the autistic traits among those with ASC or subthreshold autistic traits. People with low autistic traits may not exhibit the cognitive patterns as seen in ASC. Hence, given that the samples in Chapters 5 and 6 consist mainly of university students with relatively low autistic traits, the lack of an association between EF and autistic traits might not be surprising. The current findings suggest that, in general population samples, EF and autistic traits might be unrelated. Findings from autistic traits in general population samples might not be informative for or generalisable to an ASC population.

Musical sophistication

OMSI was used in Chapters 4 and 5, and the Gold-MSI was used in Chapter 6. Whether the instruments could be used interchangeably to measure musical sophistication is debatable. Pragmatically, though both OMSI and Gold-MSI measure musical sophistication, the differences in how they were developed and range of items included would likely render the latent construct (slightly) different between the two.

However, from a theoretical viewpoint that musical sophistication is multidimensional (Hallam, 2010), the latent construct that OMSI and Gold-MSI measures is likely to overlap. This is supported by the ability of some items from each instrument in predicting the score on the other instrument (Zhang & Schubert, 2019). Therefore, OMSI and Gold-MSI may be used interchangeably in line with this viewpoint, but future research should explicitly test the convergent validity and external correlates of OMSI and Gold-MSI.

Subtle cultural differences in how musical sophistication is conceptualised might also be present. Specifically, the OMSI and Gold-MSI contain an item asking the number of live music events that one attended for the past one year. Attending live music events or concerts is not as common in Malaysia due to limited events and high prices. Conversely, engagement in other musical activities such as karaoke is much more common in Malaysia but is not asked in both instruments. Nonetheless, a CFA confirmed that the factor structure of Gold-MSI fitted well in the Malaysian sample. This suggests that these cultural differences in commonly engaged musical activities are negligible, and there are likely more similarities between cultures in the conceptualisation of musical sophistication. A certain degree of universality can be seen in the emotional reactions to and psychological functions of music (Saarikallio et al., 2021; Schäfer et al., 2012). Moreover, overall musical sophistication as conceptualised by OMSI and Gold-MSI is largely contributed by performative musical skills, and how these skills are defined is similar across cultures (e.g., duration of musical training/education). Therefore, unlike autistic traits which are based on deviation from a culture's social norms, musical sophistication is likely to be a (relatively) universal construct.

In a similar vein, the effects of language on response to OMSI and Gold-MSI are likely to be minimal. This is because established cultural differences are a precondition for language effects, as seen in autistic traits, personality and emotional intelligence (Freeth et al., 2013; Gökçen et al., 2014; Ramírez-Esparza et al., 2006). Problems arise from translation process are also negligible in this thesis since the results of Chapters 4, 5 and 6 was based only on the original English version of OMSI and Gold-MSI. Hence, the evidence thus far suggests that there are more similarities in the conceptualisation of musical sophistication across cultures, it might be safe to assume that the OMSI and Gold-MSI are appropriate measures of the intended latent construct in this thesis.

Musical sophistication and EF

Music listening, a form of active engagement in music, seemed unrelated to working memory, inhibition and cognitive flexibility performance in Chapter 5. This is consistent with the findings from Chapter 6 where all subdomains of musical sophistication were positively associated with general EF and working memory *except* for active engagement. These findings suggest that engagement in music might not be associated with EF. A randomised-controlled study however, reported that regular music listening was beneficial for EF among persons with dementia (Särkämö et al., 2014). It seems that short term engagement in music (i.e., Chapter 5) may not produce observable changes in EF in the general population/students or perhaps the effects of music would be more apparent among individuals with deficits in EF such as dementia. Moreover, the results from Chapter 5 add to the current debate about the effects of listening to music in the background on cognitive performance or EF specifically in relation to arousal. Most studies used self-report arousal when studying the effects of arousal on cognitive performance and the results were mixed; some found positive effects of music on cognitive performance without a change in arousal or mood (Smith et al., 2010), while others reported increased arousal when listening to music but working memory performance did not differ from relaxing and silence conditions (Hirokawa, 2004). Although Chapter 5 attempted to address the gap in the literature by examining whether beneficial effects of music listening on EF would be accompanied by elevated objective arousal (i.e., EDA), the lack of influence of music listening on both EF performance and EDA neither support nor reject the potential role of arousal in mediating the effects of music listening on cognitive performance. Nonetheless, findings from Chapter 5 shed some light on important issues that should be taken into consideration in the future, such as the type of music and measures of objective arousal. Changes in EDA were only observed when listening to pleasurable music (Salimpoor et al., 2009), while Chapter 5 used self-selected music for work/study. Hence, findings from Chapter 5 suggest that self-selected music for work/study might not influence objective arousal, and future studies can examine if this was the case by comparing different types of music. Moreover, while EDA provides exclusive information about the sympathetic activity (Braithwaite et al., 2013), other indicators of arousal that reflect both sympathetic and parasympathetic activity (e.g., heart rate) may complement EDA in future investigations.

Results from Chapter 6 showed that general musical sophistication was associated with better EF, which is in line with findings demonstrating better EF among musicians than non-musicians (Meyer et al., 2020; Strong & Mast, 2019; Suárez et al., 2016). Closer inspection of different subdomains of musical sophistication further suggests that apart from musical training, other subdomains except for active engagement are positively related to EF. While there is some evidence for a positive relation between musical training and EF (Benz et al., 2016; Bowmer et al., 2018; Chen et al., 2021; Shen et al., 2019), the relationship of other musical sophistication subdomains with EF is underexplored. Perceptual abilities were positively associated with cognitive flexibility in both children and adults with mild cognitive impairment (Janurik et al., 2019; Petrovsky et al., 2021), and the results from Chapter 6 extend these findings by showing that working memory and inhibition were also positively associated with perceptual abilities among a general population sample. The vocal sensorimotor loop, a theory on how singing works, implicated the importance of working memory (Berkowska & Dalla Bella, 2009). The vocal sensorimotor loop suggests that perception of a to-be-imitated melody or ongoing vocal production would be fed into working memory and the stored information would subsequently influence or be used to monitor motor planning for vocal production. The positive relation between working memory and singing abilities found in Chapter 6 aligns with this theory.

Patients with Alzheimer or frontotemporal dementia seem to display difficulties in recognising musical emotions, and deficits in EF appear to explain the difficulty to a certain extent (Orjuela-Rojas et al., 2021; Zhou et al., 2019). In Chapter 6, musical emotions were also positively associated with EF, thus supporting the potential role of EF in perceiving musical emotions. Working memory, in particular, has been highlighted to contribute significantly to musical sophistication beyond musical abilities (Baker et al., 2020), and positive associations of working memory with almost all subdomains of musical sophistication shown in Chapter 6 align with this proposition. The importance of working memory in musical sophistication might not be surprising given that musical activities ranging from playing an instrument, reading musical notes, active music listening, humming a melody, perceiving musical emotions, etc clearly taps onto working memory. In contrast with the substantial contribution of working memory to musical sophistication, other domains of EF such as inhibition may only be associated with certain subdomains of musical sophistication, i.e., perceptual abilities (see Chapter 6). Though not investigated in Chapter 6, cognitive flexibility is likely to be associated with musical sophistication. Musical performance tends to require multitasking such as playing an instrument while reading notes or playing different notes with both hands, and these actions essentially demand cognitive flexibility. Together, the findings highlight the potential contribution of general EF and its different domains on musical sophistication.

Musical sophistication and autistic traits

Findings from Chapters 4, 5 and 6 generally suggest that autistic traits among the general population do not display the expected associations with music preference and musical sophistication that are commonly observed in autistic populations. In Chapter 4, autistic traits were expected to be positively associated with preference for Intense or Sophisticated music, but they were found to be negatively associated with a preference for Contemporary music instead. In Chapter 5, autistic traits were expected to be negatively associated with EF performance and music listening might alleviate the EF difficulty associated with elevated autistic traits, but autistic traits were not associated with EF performance. In Chapter 6, autistic traits were expected to be positively associated with perceptual abilities, but a negative association was found instead. The current thesis initially planned to compare neurotypical and autistic adults in Chapters 4, 5 and 6, but the plan was disrupted by the COVID-19 pandemic. Furthermore, the recruitment was challenging, since many autistic adults are not diagnosed or have difficulty accessing support in Malaysia. A survey among Malaysian university students showed that while 2.8% of the students suspected that they had an ASC, only 0.3% of them received a formal diagnosis (Low et al., 2021). The gap likely arises from underdiagnosis by professionals rather than self-overdiagnosis given that knowledge about ASC is generally low in Malaysia compared to other countries like the UK (de Vries et al., 2020). Furthermore, about 81.8% of autism centres in Malaysia set a maximum age of 20 and below for class enrolment (Fikry & Hassan, 2016), suggesting a lack of support for autistic adults. Thus, without an autistic sample, the focus of the current thesis is instead limited to autistic traits among general populations. Poor reliability of the AQ in measuring autistic traits could probably be ruled out as an explanation for the lack of associations given that the psychometric properties of the AQ among the Malaysian general population has been tested and found to be comparable with a Dutch population in Chapter 3. Moreover, even though Chapter 2 highlights the potential influence of language on the response to the AQ, the language in which the AQ and other questionnaires were administered may only have minimal impact since no cross-language or -cultural comparison is involved in Chapters 4, 5 and 6. Therefore, it seems possible that the argument provided under the subheading of “EF and autistic traits” may also explain the discrepant findings when examining autistic traits. That is, people with typical range of or low autistic traits likely do not reflect cognitive patterns of autistic people, and the current findings suggest that autistic traits are negatively associated with singing and perceptual abilities among a general population sample.

Autistic individuals display superior perceptual abilities in the musical domain (Bonnel et al., 2003, 2010; Heaton, 2003; Stanutz et al., 2014), but autistic traits are found to be negatively associated with perceptual abilities in Chapter 6. However, it appears that only a subgroup of the autistic individuals displays such superior perceptual abilities (Heaton et al., 2008), and this subgroup might be genetically distinct from those without superior perceptual abilities (Nurmi et al., 2003). This subgroup among ASC further complicates the already debated link between autistic traits among general and ASC populations (see EF and autistic traits), where in addition to cognitive patterns, such superior abilities may also not be linked to autistic traits among general populations. Therefore, although the current thesis suggests that among general populations, higher autistic traits are associated with reduced preference for Contemporary music and poorer perceptual abilities, future research should specifically investigate these findings among autistic individuals or those with subthreshold autistic traits.

Culture

Across all chapters, cultural differences have been consistently suggested as a plausible explanation for the discrepant findings. In Chapters 2 and 3, social norms associated with different cultures likely explain why Malaysian participants score differently in two languages and score higher than Dutch participants. In the (Western developed) AQ, attention to numbers is considered indicative of autistic traits. However, paying attention to numbers may be considered culturally appropriate or even emphasised in the Chinese culture (Almond et al., 2015; Wong et al., 2019). Thus, these cultural differences likely contribute to the higher scores among Asian participants. In Chapters 4 and 5, it is speculated that cultural differences in music cognition such as perceived emotions of music contribute to the non-success in replicating the MUSIC model and finding a null effect of music listening on EF. Korean, Chinese and Americans perceived mood differently from the same sets of musical excerpts (Lee & Hu, 2014), suggesting that music might function differently across cultures. All these findings emphasise the significance of taking the cultural context into account given that the interpretation, perception, and/or expression of autistic traits and music are highly influenced by culture. Therefore, the current results are in line with other researchers that call for an integration of the cultural framework when examining ASC and music on cognitive performance (de Leeuw et al., 2020; Giroux et al., 2020), and suggest that generalisation of findings from one culture to another should be exercised with caution.

Conclusion

The current thesis demonstrates that greater musical sophistication is associated with better EF, and in turn, better quality of life. Active engagement in the form of music listening, however, does not seem to influence EF. Higher autistic traits are associated with poorer quality of life and a reduced preference for Contemporary music. Arousal seems not elevated in response to self-selected music and not associated with EF and autistic traits. Results concerning psychometric properties of AQ, music preference, personality and music listening on cognitive performance do not fully replicate previous findings from the Western contexts. Future research could integrate the cultural framework when examining autistic traits and music on cognitive performance to elucidate how cultural differences may contribute to the discrepant findings. Nonetheless, some expected relationships, such as the negative associations between autistic traits and quality of life (Reed et al., 2016) and the lack of relationship between neuropsychological measure of EF and autistic traits among general populations (Mason et al., 2021), are also supported by the current results, suggesting that there are also similarities across cultures. In conclusion, while autistic traits are not related to EF and general musical sophistication among general populations, greater musical sophistication is associated with better EF, especially working memory.

The findings of Chapter 2 suggest that in a multilingual country like Malaysia, questionnaires should ideally be administered in one's native language. The AQ-28 can be used in the Malaysian general population and can be compared meaningfully between Malaysia and the Netherlands according to Chapter 3. However, it is yet unclear if this can be generalised to other countries/cultures. More importantly, the validity of the AQ-28 for autistic populations in Malaysia remains unexplored. Cross-cultural validation of the AQ-28 in autistic samples is essential to deriving a Malaysia-specific cut-off. The findings of Chapter 4 suggest that people who have more autistic traits have a lower preference for Contemporary music (e.g., rap and electronica) or music with heavy bass, synthetic or electric sound. This is in line with the prevalence of sensory issues among autistic individuals and the association between autistic traits and sensory abnormalities (Iarocci & McDonald, 2006; Jussila et al., 2020). That said, future research should directly examine the music preferences of autistic individuals. Results of Chapter 5 suggest that preferred music does not elevate physiological arousal and improve cognitive performance. Importantly, cognitive performance was not disrupted by music listening, suggesting that listening to preferred music while working/studying does not have a detrimental effect. Therefore, contrary to some of the common beliefs that music is disruptive, listening to music that we like does not affect our task performance, while it might even make some tasks more enjoyable. Lastly, the findings of Chapter 6 suggest that activities that promote musical sophistication are positively associated with EF, which in turn, promote quality of life. Hence, while speculative, music therapy (e.g., neurologic music therapy; Thaut, 2010) that targets EF directly might be beneficial for clinical populations with EF difficulties, and in turn, improve their quality of life.

References

Agelink van Rentergem, J. A., Lever, A. G., & Geurts, H. M. (2019). Negatively phrased items of the Autism Spectrum Quotient function differently for groups with and without autism. *Autism*, *23*(7), 1752–1764. https://doi.org/10.1177/1362361319828361

Albury, N. J. (2017). Mother tongues and languaging in Malaysia: Critical linguistics under critical examination. *Language in Society*, *46*(4), 567–589. https://doi.org/10.1017/S0047404517000239

Almond, D., Chee, C. P., Sviatschi, M. M., & Zhong, N. (2015). Auspicious birth dates among Chinese in California. *Economics and Human Biology*, *18*, 153–159. https://doi.org/10.1016/j.ehb.2015.05.005

Amer, T., Kalender, B., Hasher, L., Trehub, S. E., & Wong, Y. (2013). Do Older Professional Musicians Have Cognitive Advantages? *PLoS ONE*, *8*(8), 1–8. https://doi.org/10.1371/journal.pone.0071630

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders*. American Psychiatric Association. https://doi.org/10.1176/APPI.BOOKS.9780890425596

Angel, L. A., Polzella, D. J., & Elvers, G. C. (2010). Background music and cognitive performance. *Perceptual and Motor Skills*, *110*(3 C), 1059–1064. https://doi.org/10.2466/pms.110.3c.1059-1064

Applebaum, E., Egel, A. L., Koegel, R. L., & Imhoff, B. (1979). Measuring musical abilities of autistic children. *Journal of Autism and Developmental Disorders*, *9*(3), 279–285. https://doi.org/10.1007/BF01531742

Arora, I., Bellato, A., Ropar, D., Hollis, C., & Groom, M. J. (2021). Is autonomic function during resting-state atypical in Autism: A systematic review of evidence. *Neuroscience and Biobehavioral Reviews*, *125*(May 2020), 417–441. https://doi.org/10.1016/j.neubiorev.2021.02.041

Ashley, M. (2002). Singing, gender and health: Perspectives from boys singing in a church choir. *Health Education*, *102*(4), 180–187. https://doi.org/10.1108/09654280210434255

Austin, E. J. (2005). Personality correlates of the broader autism phenotype as assessed by the Autism Spectrum Quotient (AQ). *Personality and Individual Differences, 38*(2), 451–460. https://doi.org/10.1016/j.paid.2004.04.022

Autism Research Centre. (n.d.). *Tests Archive - Autism Research Centre*. Retrieved January 10, 2021, from https://www.autismresearchcentre.com/tests/

Auyeung, B., Baron-Cohen, S., Wheelwright, S., & Allison, C. (2008). The autism spectrum quotient: Children's version (AQ-Child). *Journal of Autism and Developmental Disorders*, *38*(7), 1230–1240. https://doi.org/10.1007/s10803-007-0504-z

Bachman, J. G., & O' Malley, P. M. (1984). Yea-Saying, Nay-Saying, and Going to Extremes: Black-White Differences in Response Styles. *The Public Opinion Quarterly*, *48*(2), 491–509.

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences*, *1118*, 122–141. https://doi.org/10.1196/annals.1412.011

Baker, D. J., Ventura, J., Calamia, M., Shanahan, D., & Elliott, E. M. (2020). Examining musical sophistication: A replication and theoretical commentary on the Goldsmiths Musical Sophistication Index. *Musicae Scientiae*, *24*(4), 411–429. https://doi.org/10.1177/1029864918811879

Barger, B., Nabi, R., & Hong, L. Y. (2010). Standard Back-Translation Procedures May Not Capture Proper Emotion Concepts: A Case Study of Chinese Disgust Terms. *Emotion*, *10*(5), 703–711. https://doi.org/10.1037/a0021453

Baron-Cohen, S. (2009). Autism: The empathizing-systemizing (E-S) theory. *Annals of the New York Academy of Sciences*, *1156*, 68–80. https://doi.org/10.1111/j.1749-6632.2009.04467.x

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The systemizing quotient: an investigation of adults with Asperger syndrome or high−functioning autism, and normal sex differences. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *358*(1430), 361–374.

https://doi.org/10.1098/rstb.2002.1206

Baron-Cohen, S., & Wheelwright, S. (2004). The Empathy Quotient: An Investigation of Adults with Asperger Syndrome or High Functioning Autism, and Normal Sex Differences. *Journal of Autism and Developmental Disorders*, *34*(2), 163–175. https://doi.org/https://doi.org/10.1023/B:JADD.0000022607.19833.00

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Males and Females, Scientists and Mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17. https://doi.org/10.1023/A:1005653411471

Baron-Epel, O., Kaplan, G., Weinstein, R., & Green, M. S. (2010). Extreme and acquiescence bias in a bi-ethnic population. *European Journal of Public Health*, *20*(5), 543–548. https://doi.org/10.1093/eurpub/ckq052

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Baumgartner, H., & Steenkamp, J. B. E. M. (2001). Response styles in marketing research: A cross-national investigation. *Journal of Marketing Research*, *38*(2), 143–156. https://doi.org/10.1509/jmkr.38.2.143.18840

Benz, S., Sellaro, R., Hommel, B., & Colzato, L. S. (2016). Music makes the world go round: The impact of musical training on non-musical cognitive functions-a review. *Frontiers in Psychology*, *6*(JAN), 1–5. https://doi.org/10.3389/fpsyg.2015.02023

Berkowska, M., & Dalla Bella, S. (2009). Acquired and congenital disorders of sung performance: A review. *Advances in Cognitive Psychology*, *5*(1), 69–83. https://doi.org/10.2478/v10053-008-0068-2

Bezdjian, S., Baker, L. A., Lozano, D. I., & Raine, A. (2009). Assessing inattention and impulsivity in children during the Go/NoGo task. *British Journal of Developmental Psychology*, *27*(2), 365–383. https://doi.org/10.1348/026151008X314919

Bishop, D. V. M., Maybery, M., Wong, D., Maley, A., & Hallmayer, J. (2006). Characteristics of the broader phenotype in autism: A study of siblings using the children's communication checklist-2. *American Journal of Medical Genetics - Neuropsychiatric Genetics*, *141 B*(2), 117–122. https://doi.org/10.1002/ajmg.b.30267

Boer, D., & Fischer, R. (2012). Towards a holistic model of functions of music listening across cultures: A culturally decentred qualitative approach. *Psychology of Music*, *40*(2), 179–200. https://doi.org/10.1177/0305735610381885

Boer, D., Hanke, K., & He, J. (2018). On Detecting Systematic Measurement Error in Cross-Cultural Research: A Review and Critical Reflection on Equivalence and Invariance Tests. *Journal of Cross-Cultural Psychology*, *49*(5), 713–734. https://doi.org/10.1177/0022022117749042

Bolt, D. M., & Johnson, T. R. (2009). Addressing Score Bias and Differential Item Functioning Due to Individual Differences in Response Style. *Applied Psychological Measurement*, *33*(5), 335–352.

Bond, M. H., & Yang, K. S. (1982). Ethnic affirmation versus cross-cultural accommodation: The Variable Impact of Questionnaire Language on Chinese Bilinguals from Hong Kong. *Journal of Cross-Cultural Psychology*, *13*(2), 169–185. https://doi.org/10.1177/0022002182013002003

Bonnel, A., McAdams, S., Smith, B., Berthiaume, C., Bertone, A., Ciocca, V., Burack, J. A., & Mottron, L. (2010). Enhanced pure-tone pitch discrimination among persons with autism but not Asperger syndrome. *Neuropsychologia*, *48*(9), 2465–2475. https://doi.org/10.1016/j.neuropsychologia.2010.04.020

Bonnel, A., Mottron, L., Peretz, I., Trudel, M., Gallun, E., & Bonnel, A. M. (2003). Enhanced pitch sensitivity in individuals with autism: A signal detection analysis. *Journal of Cognitive Neuroscience*, *15*(2), 226–235. https://doi.org/10.1162/089892903321208169

Bonneville-Roussy, A., Rentfrow, P. J., Xu, M. K., & Potter, J. (2013). Music through the ages: Trends in musical engagement and preferences from adolescence through middle adulthood. *Journal of Personality and Social Psychology*, *105*(4), 703–717. https://doi.org/10.1037/a0033770

Borella, E., Carretti, B., & Pelegrina, S. (2010). The Specific Role of Inhibition in Reading Comprehension in Good and Poor Comprehenders. *Journal of Learning Disabilities*, *43*(6), 541–552. https://doi.org/10.1177/0022219410371676

Boucher, H. C., & O'Dowd, M. C. (2011). Language and the Bicultural Dialectical Self. *Cultural Diversity and Ethnic Minority Psychology*, *17*(2), 211–216. https://doi.org/10.1037/a0023686

Bowie, C. R., & Harvey, P. D. (2006). Administration and interpretation of the Trail Making Test. *Nature Protocols*, *1*(5), 2277–2281. https://doi.org/10.1038/nprot.2006.390

Bowmer, A., Mason, K., Knight, J., & Welch, G. (2018). Investigating the impact of a musical intervention on preschool children's executive function. *Frontiers in Psychology*, *9*(DEC), 1–16. https://doi.org/10.3389/fpsyg.2018.02389

Braithwaite, J., Watson, D., Jones, R., & Rowe, M. (2013). A Guide for Analysing Electrodermal Activity (EDA) & Skin Conductance Responses (SCRs) for Psychological Experiments. …, 1–42. https://doi.org/10.1017.S0142716405050034

Bringman, H., Giesecke, K., Thörne, A., & Bringman, S. (2009). Relaxing music as pre-medication before surgery: A randomised controlled trial. *Acta Anaesthesiologica Scandinavica*, *53*(6), 759–764. https://doi.org/10.1111/j.1399-6576.2009.01969.x

Brown, T. E., & Landgraf, J. M. (2010). Improvements in Executive Function Correlate with Enhanced Performance and Functioning and Health-Related Quality of Life: Evidence From 2 Large, Double-Blind, Randomized, Placebo-Controlled Trials in ADHD. *Postgraduate Medicine*, *122*(5), 42–51. https://doi.org/10.3810/pgm.2010.09.2200

Brown, V. A. (2021). An Introduction to Linear Mixed-Effects Modeling in R.

Advances in Methods and Practices in Psychological Science, *4*(1). https://doi.org/10.1177/2515245920960351

Buck, K. K., Atkinson, T. M., & Ryan, J. P. (2008). Evidence of practice effects in variants of the Trail Making Test during serial assessment. *Journal of Clinical and Experimental Neuropsychology*, *30*(3), 312–318. https://doi.org/10.1080/13803390701390483

Bugos, J. A., Perlstein, W. M., McCrae, C. S., Brophy, T. S., & Bedenbaugh, P. H. (2007). Individualized Piano Instruction enhances executive functioning and working memory in older adults. *Aging and Mental Health*, *11*(4), 464–471. https://doi.org/10.1080/13607860601086504

Byrne, B. M. (2013). Structural Equation Modeling With AMOS. In *Structural Equation Modeling With AMOS*. https://doi.org/10.4324/9781410600219

Carruthers, S., Kinnaird, E., Rudra, A., Smith, P., Allison, C., Auyeung, B., Chakrabarti, B., Wakabayashi, A., Baron-Cohen, S., Bakolis, I., & Hoekstra, R. A. (2018). A cross-cultural study of autistic traits across India, Japan and the UK. *Molecular Autism*, *9*(1), 1–10. https://doi.org/10.1186/s13229-018-0235-3

Cassidy, G., & MacDonald, R. A. R. (2007). The effect of background music and background noise on the task performance of introverts and extraverts. *Psychology of Music*, *35*(3), 517–517–537. http://eds.a.ebscohost.com/eds/pdfviewer/pdfviewer?vid=1&sid=6140e492-99e4-4c1e-9a84-87606a95ab36%40sdc-v-sessmgr06%0Ahttp://search.ebscohost.com/login.aspx?direct=true&db=rih&AN=2007-02699&site=ehost-live

Chamberlain, R., McManus, I. C., Riley, H., Rankin, Q., & Brunswick, N. (2013). Local processing enhancements associated with superior observational drawing are due to enhanced perceptual functioning, not weak central coherence. *Quarterly Journal of Experimental Psychology*, *66*(7), 1448–1466. https://doi.org/10.1080/17470218.2012.750678

Chen, C., Lee, S. Y., & Stevenson, H. W. (1995). Response style and cross-cultural comparisons of rating scales among east asian and north american students. *Psychological Science*, *6*(3), 170–175. https://doi.org/10.1111/j.1467-

9280.1995.tb00327.x

Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Chen, J., Scheller, M., Wu, C., Hu, B., Peng, R., Liu, C., Liu, S., Zhu, L., & Chen, J. (2021). The relationship between early musical training and executive functions: Validation of effects of the sensitive period. *Psychology of Music*. https://doi.org/10.1177/0305735620978690

Chen, S. X., Benet-Martínez, V., & Ng, J. C. K. (2014). Does Language Affect Personality Perception? A Functional Approach to Testing the Whorfian Hypothesis. *Journal of Personality*, *82*(2), 130–143. https://doi.org/10.1111/jopy.12040

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling*, *9*(2), 233–255. https://doi.org/10.1207/S15328007SEM0902_5

Chew, A. S. Q., Yu, Y. T., Chua, S. W., & Gan, S. K. E. (2016). The effects of familiarity and language of background music on working memory and language tasks in Singapore. *Psychology of Music*, *44*(6), 1431–1438. https://doi.org/10.1177/0305735616636209

Chraif, M., Mitrofan, L., Golu, F., & Gâtej, E. (2014). The Influence of Relaxation Music on Abstract Visual Short Term Memory Retrieval Task at Young Students at Psychology. *Procedia - Social and Behavioral Sciences*, *127*(2007), 852–857. https://doi.org/10.1016/j.sbspro.2014.03.367

Christ, S. E., Kanne, S. M., & Reiersen, A. M. (2010). Executive Function in Individuals With Subthreshold Autism Traits. *Neuropsychology*, *24*(5), 590–598. https://doi.org/10.1037/a0019176

Clift, S. M., & Hancox, G. (2001). The perceived benefits of singing: Findings from preliminary surveys of a university college choral society. *Journal of The Royal Society for the Promotion of Health*, *121*(4), 248–256. https://doi.org/10.1177/146642400112100409

Cohen, R. A. (2011). *Yerkes–Dodson Law*. https://doi.org/10.1007/978-0-387-79948-3

Colley, A. (2008). Young people's musical taste: Relationship with gender and gender-related traits. *Journal of Applied Social Psychology*, *38*(8), 2039–2055. https://doi.org/10.1111/j.1559-1816.2008.00379.x

Colvert, E., Tick, B., Mcewen, F., Stewart, C., Curran, S. R., Woodhouse, E., Gillan, N., Hallett, V., Lietz, S., Garnett, T., Ronald, A., Plomin, R., Rijsdijk, F., Happé, F., & Bolton, P. (2015). Heritability of Autism Spectrum Disorder in a UK Population-Based Twin Sample. We performed joint continuous-ordinal liability Europe PMC Funders Group. *JAMA Psychiatry*, *72*(5), 415–423. https://doi.org/10.1001/jamapsychiatry.2014.3028.Heritability

Constantino, J. N., & Todd, R. D. (2005). Intergenerational transmission of subthreshold autistic traits in the general population. *Biological Psychiatry*, *57*(6), 655–660. https://doi.org/10.1016/j.biopsych.2004.12.014

Corbett, B. A., Constantine, L. J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatry Res.*, *166*(2–3), 210–222. https://doi.org/10.1016/j.psychres.2008.02.005.Examining

Cotrena, C., Branco, L. D., Shansis, F. M., & Fonseca, R. P. (2016). Executive function impairments in depression and bipolar disorder: Association with functional impairment and quality of life. *Journal of Affective Disorders*, *190*, 744–753. https://doi.org/10.1016/j.jad.2015.11.007

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in Brain Research*, *169*, 323–338. https://doi.org/10.1016/S0079-6123(07)00020-9.What

Crescioni, A. W., Ehrlinger, J., Alquist, J. L., Conlon, K. E., Baumeister, R. F., Schatschneider, C., & Dutton, G. R. (2011). High trait self-control predicts positive health behaviors and success in weight loss. *Journal of Health Psychology*, *16*(5), 750–759. https://doi.org/10.1177/1359105310390247

Culpepper, R., & Zimmerman, R. (2006). Culture-Based Extreme Response Bias in

Surveys Employing Variable Response Items: An Investigation of Response Tendency among Hispanic-Americans. *Journal of International Business Research*, *5*(2), 75.

D'Souza, A. A., Moradzadeh, L., & Wiseheart, M. (2018). Musical training, bilingualism, and executive function: working memory and inhibitory control. *Cognitive Research: Principles and Implications*, *3*(1). https://doi.org/10.1186/s41235-018-0095-6

Dai, M., Lin, L., Liang, J., Wang, Z., & Jing, J. (2019). Gender Difference in the Association Between Executive Function and Autistic Traits in Typically Developing Children. *Journal of Autism and Developmental Disorders*, *49*(3), 1182–1192. https://doi.org/10.1007/s10803-018-3813-5

Dalla Bella, S., Berkowska, M., & Sowiński, J. (2011). Disorders of pitch production in tone deafness. *Frontiers in Psychology*, *2*(JUL), 1–11. https://doi.org/10.3389/fpsyg.2011.00164

Davis, W. B., & Thaut, M. H. (1989). The Influence of Preferred Relaxing Music on Measures of State Anxiety , Relaxation , and Physiological Responses. *Journal of Music Therapy*, *26*(4), 168–187.

de Leeuw, A., Happé, F., & Hoekstra, R. A. (2020). A Conceptual Framework for Understanding the Cultural and Contextual Factors on Autism Across the Globe. *Autism Research*, *13*(7), 1029–1050. https://doi.org/10.1002/aur.2276

de Vries, M., Cader, S., Colleer, L., Batteux, E., Yasdiman, M. B., Tan, Y. J., & Sheppard, E. (2020). University Students' Notion of Autism Spectrum Conditions: A Cross-Cultural Study. *Journal of Autism and Developmental Disorders*, *50*(4), 1281–1294. https://doi.org/10.1007/s10803-019-04343-z

de Vries, M., & Geurts, H. (2015). Influence of Autism Traits and Executive Functioning on Quality of Life in Children with an Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *45*(9), 2734–2743. https://doi.org/10.1007/s10803-015-2438-1

Degé, F., Kubicek, C., & Schwarzer, G. (2011). Music lessons and intelligence: A relation mediated by executive functions. *Music Perception*, *29*(2), 195–201.

https://doi.org/10.1525/mp.2011.29.2.195

Delsing, M. J. M. H., Bogt, T. F. M. Ter, Engels, R. C. M. E., & Meeus, W. H. J. (2008). Adolescents' Music Preferences and Personality Characteristics. *European Journal of Personality*, *22*, 109–130. https://doi.org/10.1002/per.665

Demetriou, E. A., Lampit, A., Quintana, D. S., Naismith, S. L., Song, Y. J. C., Pye, J. E., Hickie, I., & Guastella, A. J. (2018). Autism spectrum disorders: A meta-analysis of executive function. *Molecular Psychiatry*, *23*(5), 1198–1204. https://doi.org/10.1038/mp.2017.75

Dewinter, J., De Graaf, H., & Begeer, S. (2017). Sexual Orientation, Gender Identity, and Romantic Relationships in Adolescents and Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *47*(9), 2927–2934. https://doi.org/10.1007/s10803-017-3199-9

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dijkhuis, R. R., Ziermans, T. B., Van Rijn, S., Staal, W. G., & Swaab, H. (2017). Self-regulation and quality of life in high-functioning young adults with autism. *Autism*, *21*(7), 896–906. https://doi.org/10.1177/1362361316655525

Dohn, A., Garza-Villarreal, E. A., Heaton, P., & Vuust, P. (2012). Do musicians with perfect pitch have more autism traits than musicians without perfect pitch? an empirical study. *PLoS ONE*, *7*(5), 1–8. https://doi.org/10.1371/journal.pone.0037961

Dumont, E., Syurina, E. V., Feron, F. J. M., & van Hooren, S. (2017). Music interventions and child development: A critical review and further directions. *Frontiers in Psychology*, *8*(SEP). https://doi.org/10.3389/fpsyg.2017.01694

Dunn, P. G., De Ruyter, B., & Bouwhuis, D. G. (2012). Toward a better understanding of the relation between music preference, listening behavior, and personality. *Psychology of Music*, *40*(4), 411–428. https://doi.org/10.1177/0305735610388897

Education First. (2019). *EF English Proficiency Index A Ranking of 100 Countries and Regions by English Skills*. www.ef.com/epi

English, M. C. W., Gignac, G. E., Visser, T. A. W., Whitehouse, A. J. O., & Maybery, M. T. (2020). A comprehensive psychometric analysis of autism-spectrum quotient factor models using two large samples: Model recommendations and the influence of divergent traits on total-scale scores. *Autism Research*, *13*(1), 45–60. https://doi.org/10.1002/aur.2198

Etaugh, C., & Michals, D. (1975). Effects on Reading Comprehension of Preferred Music and Frequency of Studying to Music. *Perceptual and Motor Skills*, *41*, 553–554.

Ferreri, L., Bigand, E., Perrey, S., Muthalib, M., Bard, P., & Bugaiska, A. (2014). Less effort, better results: How does music act on prefrontal cortex in older adults during verbal encoding? an fNIRS study. *Frontiers in Human Neuroscience*, *8*(MAY), 1–11. https://doi.org/10.3389/fnhum.2014.00301

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics (5th Edition)*. SAGE Publications.

Figner, B., & Murphy, R. O. (2011). Using skin conductance in judgment and decision making research. *... Tracing Methods for Decision Research*, *JANUARY*, 1–33. http://books.google.com/books?hl=en&lr=&id=DBx5AgAAQBAJ&oi=fnd&pg=PA163&dq=Using+skin+conductance+in+judgment+and+decision+making+research&ots=0untpIlmBa&sig=RhcZ68GTW8oalyarjYV5WAN6TUw%0Ahttps://mail.google.com/mail/u/0/%0Apap

Fikry, A., & Hassan, H. (2016). Characteristics of Autism Center in Malaysia. *Environment-Behaviour Proceedings Journal*, *1*(4), 75. https://doi.org/10.21834/e-bpj.v1i4.173

Fischer, R., & Karl, J. A. (2019). A primer to (cross-cultural) multi-group invariance testing possibilities in R. *Frontiers in Psychology*, *10*(JULY), 1–18. https://doi.org/10.3389/fpsyg.2019.01507

Fiske, A. P. (2002). Using individualism and collectivism to compare cultures - A critique of the validity and measurement of the constructs: Comment on Oyserman et al. (2002). *Psychological Bulletin*, *128*(1), 78–88. https://doi.org/10.1037/0033-2909.128.1.78

Freeth, M., Sheppard, E., Ramachandran, R., & Milne, E. (2013). A cross-cultural comparison of autistic traits in the UK, India and Malaysia. *Journal of Autism and Developmental Disorders*, *43*(11), 2569–2583. https://doi.org/10.1007/s10803-013-1808-9

Friedman, M. (1937). The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. *Journal of the American Statistical Association*, *32*(200), 675–701.

Friedman, N. P., Miyake, A., Altamirano, L. J., Corley, R. P., Young, S. E., Rhea, S. A., & Hewitt, J. K. (2016). Stability and Change in Executive Function Abilities From Late Adolescence to Early Adulthood: A Longitudinal Twin Study. *Developmental Psychology*, *52*(2), 326–340. https://doi.org/10.1037/dev0000075.Stability

Fung, C. V. (1996). Musicians' and nonmusicians' preferences for world musics: Relation to musical characteristics and familiarity. *Journal of Research in Music Education*, *44*(1), 60–83. https://doi.org/10.2307/3345414

Furnham, A., & Strbac, L. (2002). Music is as distracting as noise: The differential distraction of background music and noise on the cognitive test performance of introverts and extraverts. *Ergonomics*, *45*(3), 203–217. https://doi.org/10.1080/00140130210121932

Gadermann, A. M., Guhn, M., & Zumbo, B. D. (2012). Estimating ordinal reliability for likert-type and ordinal item response data: A conceptual, empirical, and practical guide. *Practical Assessment, Research and Evaluation*, *17*(3), 1–13.

George, D., Stickle, K., Rachid, F., & Wopnford, A. (2007). The association between types of music enjoyed and cognitive, behavioral, and personality factors of those who listen. *Psychomusicology: A Journal of Research in Music Cognition*, *19*(2), 32–56. https://doi.org/10.1037/h0094035

George, E. M., & Coch, D. (2011). Music training and working memory: An ERP study. *Neuropsychologia*, *49*(5), 1083–1094. https://doi.org/10.1016/j.neuropsychologia.2011.02.001

Georgiou, G. K., & Das, J. P. (2018). Direct and indirect effects of executive function on reading comprehension in young adults. *Journal of Research in Reading*, *41*(2), 243–258. https://doi.org/10.1111/1467-9817.12091

Getz, L. M., Marks, S., & Roy, M. (2014). The influence of stress, optimism, and music training on music uses and preferences. *Psychology of Music*, *42*(1), 71–85. https://doi.org/10.1177/0305735612456727

Geurts, H. M., Stek, M., & Comijs, H. (2016). Autism characteristics in older adults with depressive disorders. *American Journal of Geriatric Psychiatry*, *24*(2), 161–169. https://doi.org/10.1016/j.jagp.2015.08.003

Geyer, S., Hemström, Ö., Peter, R., & Vågerö, D. (2006). Education, income, and occupational class cannot be used interchangeably in social epidemiology. Empirical evidence against a common practice. *Journal of Epidemiology and Community Health*, *60*(9), 804–810. https://doi.org/10.1136/jech.2005.041319

Giannouli, V., Kolev, V., & Yordanova, J. (2019). Is there a specific Vivaldi effect on verbal memory functions? Evidence from listening to music in younger and older adults. *Psychology of Music*, *47*(3), 325–341. https://doi.org/10.1177/0305735618757901

Gilbert, S. J., & Burgess, P. W. (2008). Executive function. *Current Biology*, *18*(3), R110–R114. https://doi.org/10.1016/B978-0-12-809324-5.06001-6

Gill, D. L., Hammond, C. C., Reifsteck, E. J., Jehu, C. M., Williams, R. A., Adams, M. M., Lange, E. H., Becofsky, K., Rodriguez, E., & Shang, Y.-T. (2013). Physical Activity and Quality of Life. *Journal of Preventive Medicine and Public Health*, *46*, S28–S34.

Ginocchio, J. (2009). The effects of different amounts and types of music training on music style preference. *Bulletin of the Council for Research in Music Education*, *182*(182), 7–17. https://doi.org/10.2307/27861458

Giroux, S. V., Caparos, S., Gosselin, N., Rutembesa, E., & Blanchette, I. (2020). Impact of Music on Working Memory in Rwanda. *Frontiers in Psychology*, *11*(April), 1–10. https://doi.org/10.3389/fpsyg.2020.00774

Gökçen, E., Frederickson, N., & Petrides, K. V. (2016). Theory of Mind and Executive Control Deficits in Typically Developing Adults and Adolescents with

High Levels of Autism Traits. *Journal of Autism and Developmental Disorders*, *46*(6), 2072–2087. https://doi.org/10.1007/s10803-016-2735-3

Gökçen, E., Furnham, A., Mavroveli, S., & Petrides, K. V. (2014). A cross-cultural investigation of trait emotional intelligence in Hong Kong and the UK. *Personality and Individual Differences*, *65*, 30–35. https://doi.org/10.1016/j.paid.2014.01.053

Gomez, P., & Danuser, B. (2004). Affective and physiological responses to environmental noises and music. *International Journal of Psychophysiology*, *53*(2), 91–103. https://doi.org/10.1016/j.ijpsycho.2004.02.002

Gosling, S. D., Rentfrow, P. J., & Swann, W. B. (2003). A very brief measure of the Big-Five personality domains. *Journal of Research in Personality*, *37*(6), 504–528. https://doi.org/10.1016/S0092-6566(03)00046-1

Greenberg, D. M., Baron-Cohen, S., Stillwell, D. J., Kosinski, M., & Rentfrow, P. J. (2015). Musical preferences are linked to cognitive styles. *PLoS ONE*, *10*(7), 1–22. https://doi.org/10.1371/journal.pone.0131151

Greenberg, D. M., Kosinski, M., Stillwell, D. J., Monteiro, B. L., Levitin, D. J., & Rentfrow, P. J. (2016). The Song Is You: Preferences for Musical Attribute Dimensions Reflect Personality. *Social Psychological and Personality Science*, *7*(6), 597–605. https://doi.org/10.1177/1948550616641473

Greenberg, D. M., Wride, S. J., Snowden, D. A., Spathis, D., Potter, J., & Rentfrow, P. J. (2022). Universals and Variations in Musical Preferences : A Study of Preferential Reactions to Western Music in 53 Countries. *Journal of Personality and Social Psychology*, *122*(2), 286–309.

Greenleaf, E. A. (1992). Measuring extreme response style. *Public Opinion Quarterly*, *56*(3), 328–351. https://doi.org/10.1086/269326

Grocke, D., Bloch, S., & Castle, D. (2009). The effect of group music therapy on quality of life for participants living with a severe and enduring mental illness. *Journal of Music Therapy*, *46*(2), 90–104. https://doi.org/10.1093/jmt/46.2.90

Grove, R., Begeer, S., Scheeren, A. M., Weiland, R. F., & Hoekstra, R. A. (2021). Evaluating the latent structure of the non-social domain of autism in autistic adults. *Molecular Autism*, *12*(1), 1–13. https://doi.org/10.1186/s13229-020-00401-x

Grove, R., Hoekstra, R. A., Wierda, M., & Begeer, S. (2017). Exploring sex differences in autistic traits: A factor analytic study of adults with autism. *Autism*, *21*(6), 760–768. https://doi.org/10.1177/1362361316667283

Gürgen, E. T. (2016). Musical preference and music education: Musical preferences of Turkish university students and their levels in genre identification. *International Journal of Music Education*, *34*(4), 459–471. https://doi.org/10.1177/0255761415619390

Habibi, A., Damasio, A., Ilari, B., Sachs, M. E., & Damasio, H. (2018). Music training and child development: A review of recent findings from a longitudinal study. *Annals of the New York Academy of Sciences*, *1423*(1), 73–81. https://doi.org/10.1111/nyas.13606

Halekoh, U., & Højsgaard, S. (2014). A kenward-Roger approximation and parametric bootstrap methods for tests in linear mixed models-the R package pbkrtest. *Journal of Statistical Software*, *59*(9), 1–32. https://doi.org/10.18637/jss.v059.i09

Hallam, S. (2010). 21st Century Conceptions of Musical Ability. *Psychology of Music*, *38*(3), 308–330. https://doi.org/10.1177/0305735609351922

Hallam, S., Price, J., & Katsarou, G. (2002). The effects of background music on primary school pupils' task performance. *Educational Studies*, *28*(2), 111–122. https://doi.org/10.1080/03055690220124551

Harkness, J., Pennell, B.-E., & Schoua-Glusberg, A. (2004). Survey Questionnaire Translation and Assessment. *Methods for Testing and Evaluating Survey Questionnaires*, 453–473. https://doi.org/10.1002/0471654728.ch22

Harrer, G., & Harrer, H. (1977). Music, Emotion and Autonomic Function. In *Music and the Brain*. Butterworth-Heinemann. https://doi.org/10.1016/b978-0-433-06703-0.50019-x

Harzing, A. W. (2005). Does the use of English-language questionnaires in cross-national research obscure national differences? *International Journal of Cross*

Cultural Management, *5*(2), 213–224. https://doi.org/10.1177/1470595805054494

Harzing, A. W. (2006). Response styles in cross-national survey research: A 26-country study. *International Journal of Cross Cultural Management*, *6*(2), 243–266. https://doi.org/10.1177/1470595806066332

Harzing, A. W., Baldueza, J., Barner-Rasmussen, W., Barzantny, C., Canabal, A., Davila, A., Espejo, A., Ferreira, R., Giroud, A., Koester, K., Liang, Y. K., Mockaitis, A., Morley, M. J., Myloni, B., Odusanya, J. O. T., O'Sullivan, S. L., Palaniappan, A. K., Prochno, P., Choudhury, S. R., … Zander, L. (2009). Rating versus ranking: What is the best way to reduce response and language bias in cross-national research? *International Business Review*, *18*(4), 417–432. https://doi.org/10.1016/j.ibusrev.2009.03.001

Harzing, A. W., Brown, M., Köster, K., & Zhao, S. (2012). Response Style Differences in Cross-National Research: Dispositional and Situational Determinants. *Management International Review*, *52*(3), 341–363. https://doi.org/10.1007/s11575-011-0111-2

Harzing, A. W., Maznevski, M., Fischlmayr, I., Yaconi, L. L., Wittenberg, K., Myloni, B., Kong Low, J. C., Castro, F. B., Zander, L., Karlsson, C., Romani, L., & Feely, A. (2002). The interaction between language and culture: A test of the cultural accommodation hypothesis in seven count ries. *Language and Intercultural Communication*, *2*(2), 120–139. https://doi.org/10.1080/14708470208668081

Heaton, P. (2003). Pitch memory, labelling and disembedding in autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *44*(4), 543–551. https://doi.org/10.1111/1469-7610.00143

Heaton, P., Hermelin, B., & Pring, L. (1998). Autism and Pitch Processing: A Precursor for Savant Musical Ability? *Music Perception: An Interdisciplinary Journal*, *15*(3), 291–305.

Heaton, P., Pring, L., & Hermelin, B. (2001). Musical processing in high functioning children with autism. *Annals of the New York Academy of Sciences*, *930*, 443–444. https://doi.org/10.1111/j.1749-6632.2001.tb05765.x

Heaton, P., Williams, K., Cummins, O., & Happé, F. (2008). Autism and pitch processing splinter skills: A group and subgroup analysis. *Autism*, *12*(2), 203–219. https://doi.org/10.1177/1362361307085270

Hee, O. C. (2014). Validity and Reliability of the Big Five Personality Traits Scale in Malaysia. *International Journal of Innovation and Applied Studies*, *5*(4), 309–315. http://www.ijias.issr-journals.org/

Heitz, R. P., Redick, T. S., Hambrick, D. Z., Kane, M. J., Conway, A. R. A., & Engle, R. W. (2006). Working memory, executive function, and general fluid intelligence are not the same. *Behavioral and Brain Sciences*, *29*(2), 135–136. https://doi.org/10.1017/S0140525X06279032

Heng, G. J., Leong, L. A., Lim, J. X., Ho, M. R., & Chen, S.-H. A. (2018). Music preferences in an Asian culture : An examination of the MUSIC model in a Singaporean context. *Proceedings of ICMPC15/ESCOM10*.

Hennessy, S. L., Sachs, M. E., Ilari, B., & Habibi, A. (2019). Effects of Music Training on Inhibitory Control and Associated Neural Networks in School-Aged Children: A Longitudinal Study. *Frontiers in Neuroscience*, *13*(October), 1–16. https://doi.org/10.3389/fnins.2019.01080

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences*, *33*(2–3), 61–135. https://doi.org/10.1017/S0140525X0999152X

Hill, E. L. (2004). Evaluating the theory of executive dysfunction in autism. Developmental Review. *Developmental Review*, *24*, 189–233. www.elsevier.com/locate/dr

Hilliard, R. E. (2003). The Effects of Music Therapy on the Quality and Length of Life of People Diagnosed with Terminal Cancer. *Journal of Music Therapy*, *40*(2), 113–137. https://doi.org/10.1093/jmt/40.2.113

Hillier, A., Kopec, J., Poto, N., Tivarus, M., & Beversdorf, D. Q. (2016). Increased physiological responsiveness to preferred music among young adults with autism spectrum disorders. *Psychology of Music*, *44*(3), 481–492. https://doi.org/10.1177/0305735615576264

Hirokawa, E. (2004). Effects of music listening and relaxation instructions on arousal changes and the working memory task in older adults. *Journal of Music Therapy*, *41*(2), 107–127. https://doi.org/10.1093/jmt/41.2.107

Hladká, A., & Martinková, P. (2020). difNLR: Generalized Logistic Regression Models for DIF and DDF Detection. *R Journal*, *12*(1), 300–323. https://doi.org/10.32614/rj-2020-014

Hoekstra, R. A., Bartels, M., Cath, D. C., & Boomsma, D. I. (2008). Factor structure, reliability and criterion validity of the autism-spectrum quotient (AQ): A study in Dutch population and patient groups. *Journal of Autism and Developmental Disorders*, *38*(8), 1555–1566. https://doi.org/10.1007/s10803-008-0538-x

Hoekstra, R. A., Vinkhuyzen, A. A. E., Wheelwright, S., Bartels, M., Boomsma, D. I., Baron-Cohen, S., Posthuma, D., & Van Der Sluis, S. (2011). The construction and validation of an abridged version of the autism-spectrum quotient (AQ-short). *Journal of Autism and Developmental Disorders*, *41*(5), 589–596. https://doi.org/10.1007/s10803-010-1073-0

Hofstede Insights. (n.d.). *Compare countries - Hofstede Insights*. Retrieved June 14, 2021, from https://www.hofstede-insights.com/product/compare-countries/

Holst, Y., & Thorell, L. B. (2018). Adult executive functioning inventory (ADEXI): Validity, reliability, and relations to ADHD. *International Journal of Methods in Psychiatric Research*, *27*(1). https://doi.org/10.1002/mpr.1567

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Huang, Y., Arnold, S. R. C., Foley, K. R., Lawson, L. P., Richdale, A. L., & Trollor, J. N. (2021). Factors associated with age at autism diagnosis in a community sample of Australian adults. *Autism Research*, *14*(12), 2677–2687. https://doi.org/10.1002/aur.2610

Hui, C. H., & Triandis, H. C. (1989). Effects of culture and response format on extreme response style. *Journal of Cross-Cultural Psychology*, *20*(3), 296–309. https://doi.org/10.1177/0022022189203004

Hurst, R. M., Mitchell, J. T., Kimbrel, N. A., Kwapil, T. K., & Nelson-Gray, R. O. (2007). Examination of the reliability and factor structure of the Autism Spectrum Quotient (AQ) in a non-clinical sample. *Personality and Individual Differences*, *43*(7), 1938–1949. https://doi.org/10.1016/j.paid.2007.06.012

Husain, G., Thompson, W. F., & Schellenberg, E. G. (2002). Effects of Musical Tempo and Mode on Arousal, Mood, and Spatial Abilities. *Music Perception*, *20*(2), 151–171.

Hyde, K. L., Lerch, J., Norton, A., Forgeard, M., Winner, E., Evans, A. C., & Schlaug, G. (2009). The effects of musical training on structural brain development: A longitudinal study. *Annals of the New York Academy of Sciences*, *1169*, 182–186. https://doi.org/10.1111/j.1749-6632.2009.04852.x

Hyseni, F., Blanken, L. M. E., Muetzel, R., Verhulst, F. C., Tiemeier, H., & White, T. (2019). Autistic traits and neuropsychological performance in 6- to-10-year-old children: a population-based study. *Child Neuropsychology*, *25*(3), 352–369. https://doi.org/10.1080/09297049.2018.1465543

Iarocci, G., & McDonald, J. (2006). Sensory integration and the perceptual experience of persons with autism. *Journal of Autism and Developmental Disorders*, *36*(1), 77–90. https://doi.org/10.1007/s10803-005-0044-3

IBM Corp. (2017). *IBM SPSS Statistics for Windows* (25.0). IBM Corp.

Israel, S., Lerer, E., Shalev, I., Uzefovsky, F., Reibold, M., Bachner-Melman, R., Granot, R., Bornstein, G., Knafo, A., Yirmiya, N., & Ebstein, R. P. (2008). Molecular genetic studies of the arginine vasopressin 1a receptor (AVPR1a) and the oxytocin receptor (OXTR) in human behaviour: from autism to altruism with some notes in between. *Progress in Brain Research*, *170*(08), 435–449. https://doi.org/10.1016/S0079-6123(08)00434-2

Iwanaga, M., & Moroki, Y. (1999). Subjective and physiological responses to music stimuli controlled over activity and preference. *Journal of Music Therapy*, *36*(1), 26–38. https://doi.org/10.1093/jmt/36.1.26

Jäncke, L., & Sandmann, P. (2010). Music listening while you learn: No influence of background music on verbal learning. *Behavioral and Brain Functions*, *6*, 1–14.

https://doi.org/10.1186/1744-9081-6-3

Janurik, M., Szabó, N., & Józsa, K. (2019). The Relationship of Musical Perception and the Executive Function Among 7-Year-Old Children. *EDULEARN19 Proceedings*, *1*(November), 4818–4826. https://doi.org/10.21125/edulearn.2019.1199

Jaschke, A. C., Honing, H., & Scherder, E. J. A. (2018). Longitudinal Analysis of Music Education on Executive Functions in Primary School Children. *Frontiers in Neuroscience*, *12*(February). https://doi.org/10.3389/fnins.2018.00103

Jaušovec, N., Jaušovec, K., & Gerlič, I. (2006). The influence of Mozart's music on brain activity in the process of learning. *Clinical Neurophysiology*, *117*(12), 2703–2714. https://doi.org/10.1016/j.clinph.2006.08.010

Jerde, T. A., Childs, S. K., Handy, S. T., Nagode, J. C., & Pardo, J. V. (2011). Dissociable systems of working memory for rhythm and melody. *NeuroImage*, *57*(4), 1572–1579. https://doi.org/10.1016/j.neuroimage.2011.05.061

Ji, L., Zhang, Z., & Nisbett, R. E. (2004). Is It Culture or Is It Language ? Examination of Language Effects in Cross-Cultural Research on Categorization. *Journal of Personality and Social Psychology*, *87*(1), 57–65. https://doi.org/10.1037/0022-3514.87.1.57

John, O. P., & Srivastava, S. (1999). The Big Five trait taxonomy: History, Measurement, and Theoretical Perspectives. In *Handbook of personality: Theory and Research* (Vol. 2, pp. 102–138).

Johnson, T., Kulesa, P., Cho, Y. I., & Shavitt, S. (2005). The relation between culture and response styles: Evidence from 19 countries. *Journal of Cross-Cultural Psychology*, *36*(2), 264–277. https://doi.org/10.1177/0022022104272905

Jones, M. H., West, S. D., & Estell, D. B. (2006). The Mozart effect: Arousal, preference, and spatial performance. *Psychology of Aesthetics, Creativity, and the Arts*, *S*(1), 26–32. https://doi.org/10.1037/1931-3896.s.1.26

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review*, *17*(3), 213–233. https://doi.org/10.1007/s11065-007-9040-z

Juslin, P. N., Barradas, G. T., Ovsiannikow, M., Limmo, J., & Thompson, W. F. (2016). Prevalence of emotions, mechanisms, and motives in music listening: A comparison of individualist and collectivist cultures. *Psychomusicology: Music, Mind, and Brain*, *26*(4), 293–326. https://doi.org/10.1037/pmu0000161

Jussila, K., Junttila, M., Kielinen, M., Ebeling, H., Joskitt, L., Moilanen, I., & Mattila, M. L. (2020). Sensory Abnormality and Quantitative Autism Traits in Children With and Without Autism Spectrum Disorder in an Epidemiological Population. *Journal of Autism and Developmental Disorders*, *50*(1), 180–188. https://doi.org/10.1007/s10803-019-04237-0

Kanner, L. (1943). Autistic Disturbances of Affective Contact. *Nervous Child*, *2*(3), 217–250. https://doi.org/10.3998/mpub.9365350

Karl, J. (2021). *ccpsyc: Package for Cross-Cultural Analyses version 0.2.4*. https://rdrr.io/github/Jo-Karl/ccpsyc/

Kessels, R. P. C., Zandvoort, M. J. E. Van, Postma, A., Kappelle, L. J., & de Haan, E. H. F. (2000). The Corsi Block-Tapping Task : Standardization and Normative Data The Corsi Block-Tapping Task : Standardization and Normative Data. *Applied Neuropsychology*, *7*(4), 252–258. https://doi.org/10.1207/S15324826AN0704

Kloosterman, P. H., Keefer, K. V., Kelley, E. A., Summerfeldt, L. J., & Parker, J. D. A. (2011). Evaluation of the factor structure of the Autism-Spectrum Quotient. *Personality and Individual Differences*, *50*(2), 310–314. https://doi.org/10.1016/j.paid.2010.10.015

Knight, W. E. J., & Rickard, N. S. (2001). Relaxing Music Prevents Stress-Induced Increases in Subjective Anxiety, Systolic Blood Pressure, and Heart Rate in Healthy Males and Females. *Journal of Music Therapy*, *38*(4), 254–272. https://doi.org/10.1093/jmt/38.4.254

Ko, H. Y., Lee, W. H., Won, E. K., Ban, J. J., Jung, D. E., & Kim, Y. (2018). The reliability and validity of the Korean version of the autism-spectrum quotient. *Psychiatry Investigation*, *15*(8), 783–789. https://doi.org/10.30773/pi.2018.02.18.1

Koh, H. C., & Milne, E. (2012). Evidence for a cultural influence on field-independence in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *42*(2), 181–190. https://doi.org/10.1007/s10803-011-1232-y

Kristen, S., & Shevy, M. (2013). A comparison of German and American listeners' extra musical associations with popular music genres. *Psychology of Music*, *41*(6), 764–778. https://doi.org/10.1177/0305735612451785

Kuenssberg, R., Murray, A. L., Booth, T., & McKenzie, K. (2014). Structural validation of the abridged Autism Spectrum Quotient-Short Form in a clinical sample of people with autism spectrum disorders. *Autism*, *18*(2), 69–75. https://doi.org/10.1177/1362361312467708

Kunihira, Y., Senju, A., Dairoku, H., Wakabayashi, A., & Hasegawa, T. (2006). "Autistic" traits in non-autistic Japanese populations: Relationships with personality traits and cognitive ability. *Journal of Autism and Developmental Disorders*, *36*(4), 553–566. https://doi.org/10.1007/s10803-006-0094-1

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models . *Journal of Statistical Software*, *82*(13). https://doi.org/10.18637/jss.v082.i13

Laajaj, R., Macours, K., Hernandez, D. A. P., Arias, O., Gosling, S. D., Potter, J., Rubio-Codina, M., & Vakis, R. (2019). Challenges to capture the big five personality traits in non-WEIRD populations. *Science Advances*, *5*(7). https://doi.org/10.1126/sciadv.aaw5226

Last, B. S., Lawson, G. M., Breiner, K., Steinberg, L., & Farah, M. J. (2018). Childhood socioeconomic status and executive function in childhood and beyond. *PLoS ONE*, *13*(8), 1–12. https://doi.org/10.1371/journal.pone.0202964

Lau, W. Y. P., Gau, S. S. F., Chiu, Y. N., Wu, Y. Y., Chou, W. J., Liu, S. K., & Chou, M. C. (2013). Psychometric properties of the Chinese version of the Autism Spectrum Quotient (AQ). *Research in Developmental Disabilities*, *34*(1), 294–305. https://doi.org/10.1016/j.ridd.2012.08.005

LeBlanc, A., Jin, Y. C., Stamou, L., & McCrary, J. (1999). Effect of Age , Country , and Gender on Music Listening Preferences. *Bulletin of the Council for Research* *in Music Education*, *Summar*(141), 72–76.

Lee, J. H., & Hu, X. (2014). Cross-cultural Similarities and Differences in Music Mood Perception. *IConference 2014 Proceedings*. https://doi.org/10.9776/14081

Levitin, D. J. (2012). What Does It Mean to Be Musical? *Neuron*, *73*(4), 633–637. https://doi.org/10.1016/j.neuron.2012.01.017

Lin, H. R., Kopiez, R., Müllensiefen, D., & Wolf, A. (2021). The Chinese version of the Gold-MSI: Adaptation and validation of an inventory for the measurement of musical sophistication in a Taiwanese sample. *Musicae Scientiae, 25*(2), 226–251. https://doi.org/10.1177/1029864919871987

Liu, F., Scheeren, A. M., Grove, R., Hoekstra, R. A., Wang, K., Guo, D., Wang, C., & Begeer, S. (2021). Exploring Cultural Differences in Autistic Traits: A Factor Analytic Study of Children with Autism in China and the Netherlands. *Journal of Autism and Developmental Disorders*, *0123456789*. https://doi.org/10.1007/s10803-021-05342-9

Lodi-Smith, J., Rodgers, J. D., Luna, V. M., Khan, S., Long, C. J., Kozlowski, K. F., Donnelly, J. P., Lopata, C., & Thomeer, M. L. (2021). The Relationship of Age with the Autism-Spectrum Quotient Scale in a Large Sample of Adults. *Autism in Adulthood*, *3*(2), 147–156. https://doi.org/10.1089/AUT.2020.0010

Lonsdale, A. J., & North, A. C. (2011). Why do we listen to music? A uses and gratifications analysis. *British Journal of Psychology*, *102*(1), 108–134. https://doi.org/10.1348/000712610X506831

Lorenzo-Seva, U., & ten Berge, J. M. F. (2006). Tucker's congruence coefficient as a meaningful index of factor similarity. *Methodology*, *2*(2), 57–64. https://doi.org/10.1027/1614-2241.2.2.57

Low, H. M., Zainal, M. S., Pang, J. C., de Vries, M., & Ang, Y. (2021). Identification, accessibility, and support for university students with an autism spectrum disorder (ASD) in Malaysia. *International Special Education Ecosystem Exhibition and Conference (ISEE 2021)*.

Lucy, J. A. (2015). Sapir-Whorf Hypothesis. In *International Encyclopedia of Social & Behavioral Sciences* (Second Edi, Vol. 20, pp. 903–906). Elsevier.

https://doi.org/10.1016/B978-0-08-097086-8.52017-0

Lui, P. P., Samuel, D. B., Rollock, D., Leong, F. T. L., & Chang, E. C. (2020). Measurement Invariance of the Five Factor Model of Personality: Facet-Level Analyses Among Euro and Asian Americans. *Assessment*, *27*(5), 887–902. https://doi.org/10.1177/1073191119873978

Mackala, S., Ahn, S., Hıdıroğlu, C., Michalak, E., Yatham, L., & Ivan, T. (2014). C-17 * the association between subjective cognitive functioning and quality of life in bipolar disorder. *Archives of Clinical Neuropsychology*, *29*(6), 578–579. https://doi.org/10.1177/026988118800200315

Maes, J. H. R., Vissers, C. T., Egger, J. I. M., & Eling, P. A. T. M. (2013). On the relationship between autistic traits and executive functioning in a non-clinical Dutch student population. *Autism*, *17*(4), 379–389. https://doi.org/10.1177/1362361312442009

Mak, L. E., Minuzzi, L., MacQueen, G., Hall, G., Kennedy, S. H., & Milev, R. (2017). The Default Mode Network in Healthy Individuals: A Systematic Review and Meta-Analysis. *Brain Connectivity*, *7*(1), 25–33. https://doi.org/10.1089/brain.2016.0438

Mammarella, N., Fairfield, B., & Cornoldi, C. (2007). Does music enhance cognitive performance in healthy older adults? The Vivaldi effect. *Aging Clinical and Experimental Research*, *19*(5), 394–399. https://doi.org/10.1007/BF03324720

Mansouri, F. A., Acevedo, N., Illipparampil, R., Fehring, D. J., Fitzgerald, P. B., & Jaberzadeh, S. (2017). Interactive effects of music and prefrontal cortex stimulation in modulating response inhibition. *Scientific Reports*, *7*(1), 1–13. https://doi.org/10.1038/s41598-017-18119-x

Mariath, L. M., da Silva, A. M., Kowalski, T. W., Gattino, G. S., De Araujo, G. A., Figueiredo, F. G., Tagliani-Ribeiro, A., Roman, T., Vianna, F. S. L., Schuler-Faccini, L., & Schuch, J. B. (2017). Music genetics research: Association with musicality of a polymorphism in the AVPR1A gene. *Genetics and Molecular Biology*, *40*(2), 421–429. https://doi.org/10.1590/1678-4685-GMB-2016-0021

Marshall, R., & Lee, C. (1998). *A Cross-Cultural, Between-Gender Study of Extreme*

Response Style. ACR European Advances. https://www.acrwebsite.org/volumes/11158/volumes/e03/E-03/full

Masataka, N. (2017). Neurodiversity, giftedness, and aesthetic perceptual judgment of music in children with autism. *Frontiers in Psychology*, *8*(SEP), 1–7. https://doi.org/10.3389/fpsyg.2017.01595

Mason, L. A., Zimiga, B. M., Anders-Jefferson, R., & Paap, K. R. (2021). Autism Traits Predict Self-reported Executive Functioning Deficits in Everyday Life and an Aversion to Exercise. *Journal of Autism and Developmental Disorders*, *51*(8), 2725–2750. https://doi.org/10.1007/s10803-020-04741-8

Masuda, T., Ellsworth, P. C., Mesquita, B., Leu, J., Tanida, S., & Van de Veerdonk, E. (2008). Placing the Face in Context: Cultural Differences in the Perception of Facial Emotion. *Journal of Personality and Social Psychology*, *94*(3), 365–381. https://doi.org/10.1037/0022-3514.94.3.365

McCrary, J. M., Altenmüller, E., Kretschmer, C., & Scholz, D. S. (2022). Association of Music Interventions With Health-Related Quality of Life. *JAMA Network Open*, *5*(3), e223236. https://doi.org/10.1001/jamanetworkopen.2022.3236

McLean, R. L., Johnson Harrison, A., Zimak, E., Joseph, R. M., & Morrow, E. M. (2014). Executive function in probands with autism with average IQ and their unaffected first-degree relatives. *Journal of the American Academy of Child and Adolescent Psychiatry*, *53*(9), 1001–1009. https://doi.org/10.1016/j.jaac.2014.05.019

McNamara, L., & Ballad, M. E. (1999). Resting Arousal, Sensation Seeking, and Music Preference. *Genetic, Social, and General Psychology Monographs*, *125*(3), 229–250. http://dx.doi.org/10.1016/j.jaci.2012.05.050

Meilleur, A. A. S., Jelenic, P., & Mottron, L. (2015). Prevalence of Clinically and Empirically Defined Talents and Strengths in Autism. *Journal of Autism and Developmental Disorders*, *45*(5), 1354–1367. https://doi.org/10.1007/s10803-014-2296-2

Messner, W. (2017). Market research in India: does the choice of language cause questionnaire contamination? *Journal of Indian Business Research*, *9*(2), 149–

168. https://doi.org/10.1108/JIBR-09-2016-0100

Meyer, J., Oguz, P. G., & Moore, K. S. (2020). Superior fluid cognition in trained musicians. *Psychology of Music*, *48*(3), 434–447. https://doi.org/10.1177/0305735618808089

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mohamed, Z., Carlisle, A. C. S., Livesey, A. C., & Mukherjee, R. A. S. (2019). Comparisons of the BRIEF parental report and neuropsychological clinical tests of executive function in Fetal Alcohol Spectrum Disorders: data from the UK national specialist clinic. *Child Neuropsychology*, *25*(5), 648–663. https://doi.org/10.1080/09297049.2018.1516202

Mone, I. S., Benga, O., & Opre, A. (2016). Cross-cultural differences in socialization goals as a function of power distance, individualism-collectivism and education. *Romanian Journal of Experimental Applied Psychology*, *7*(1). https://doi.org/10.15303/rjeap.2016.si1.a71

Moore, S. (2018). *Examining the Possibility of Cognitive Advantages on Measures of Inhibitory Control in Relation to Heightened Levels of Musical Expertise* [Manchester Metropolitan University]. http://ieeeauthorcenter.ieee.org/wp-content/uploads/IEEE-Reference-Guide.pdf%0Ahttp://wwwlib.murdoch.edu.au/find/citation/ieee.html%0Ahttps://doi.org/10.1016/j.cie.2019.07.022%0Ahttps://github.com/ethereum/wiki/wiki/White-Paper%0Ahttps://tore.tuhh.de/hand

Moradzadeh, L., Blumenthal, G., & Wiseheart, M. (2015). Musical Training, Bilingualism, and Executive Function: A Closer Look at Task Switching and Dual-Task Performance. *Cognitive Science*, *39*(5), 992–1020. https://doi.org/10.1111/cogs.12183

Mottron, L., & Bzdok, D. (2020). Autism spectrum heterogeneity: fact or artifact? *Molecular Psychiatry*, *25*(12), 3178–3185. https://doi.org/10.1038/s41380-020-0748-y

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*(1), 27–43. https://doi.org/10.1007/s10803-005-0040-7

Mueller, S. T., & Piper, B. J. (2014). The Psychology Experiment Building Language (PEBL) and PEBL Test Battery. *Journal of Neuroscience Methods*, *222*, 250–259. https://doi.org/10.1016/j.jneumeth.2013.10.024.The

Müllensiefen, D., Gingras, B., Musil, J., & Stewart, L. (2014). The musicality of non-musicians: An index for assessing musical sophistication in the general population. *PLoS ONE*, *9*(2). https://doi.org/10.1371/journal.pone.0089642

Murray, A. L., Booth, T., McKenzie, K., & Kuenssberg, R. (2016). What range of trait levels can the Autism-Spectrum Quotient (AQ) measure reliably? An item response theory analysis. *Psychological Assessment*, *28*(6), 673–683. https://doi.org/10.1037/pas0000215

Murray, A. L., Booth, T., McKenzie, K., Kuenssberg, R., & O'Donnell, M. (2014). Are autistic traits measured equivalently in individuals with and without an autism spectrum disorder? an invariance analysis of the autism spectrum quotient short form. *Journal of Autism and Developmental Disorders*, *44*(1), 55–64. https://doi.org/10.1007/s10803-013-1851-6

Murray, A. L., McKenzie, K., Kuenssberg, R., & Booth, T. (2017). Do the Autism Spectrum Quotient (AQ) and Autism Spectrum Quotient Short Form (AQ-S) Primarily Reflect General ASD Traits or Specific ASD Traits? A Bi-Factor Analysis. *Assessment*, *24*(4), 444–457. https://doi.org/10.1177/1073191115611230

Muth, C., Bales, K. L., Hinde, K., Maninger, N., Mendoza, S. P., & Ferrer, E. (2016). Alternative Models for Small Samples in Psychological Research: Applying Linear Mixed Effects Models and Generalized Estimating Equations to Repeated Measures Data. *Educational and Psychological Measurement*, *76*(1), 64–87. https://doi.org/10.1177/0013164415580432

Nantais, K. M., & Schellenberg, E. G. (1999). The mozart effect: An Artifact of Preference. *Psychological Science*, *10*(4), 370–373.

https://doi.org/10.1111/1467-9280.00170

Nave, G., Minxha, J., Greenberg, D. M., Kosinski, M., Stillwell, D., & Rentfrow, J. (2018). Musical Preferences Predict Personality: Evidence From Active Listening and Facebook Likes. *Psychological Science*, *29*(7), 1145–1158. https://doi.org/10.1177/0956797618761659

Nisbett, R. E., & Miyamoto, Y. (2005). The influence of culture: Holistic versus analytic perception. *Trends in Cognitive Sciences*, *9*(10), 467–473. https://doi.org/10.1016/j.tics.2005.08.004

Norman, G. (2010). Likert scales, levels of measurement and the “laws” of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y

North, A. C., & Davidson, J. W. (2013). Musical taste, employment, education, and global region. *Scandinavian Journal of Psychology*, *54*(5), 432–441. https://doi.org/10.1111/sjop.12065

North, A. C., Hargreaves, D. J., & O’Neill, S. A. (2000). The importance of music to adolescents. *British Journal of Educational Psychology*, *70*(2), 255–272. https://doi.org/10.1348/000709900158083

Nurmi, E. L., Dowd, M., Tadevosyan-Leyfer, O., Haines, J. L., Folstein, S. E., & Sutcliffe, J. S. (2003). Exploratory subsetting of autism families based on savant skills improves evidence of genetic linkage to 15q11-q13. *Journal of the American Academy of Child and Adolescent Psychiatry*, *42*(7), 856–863. https://doi.org/10.1097/01.CHI.0000046868.56865.0F

O’Rourke, E. J., Halpern, L. F., & Vaysman, R. (2020). Examining the Relations Among Emerging Adult Coping, Executive Function, and Anxiety. *Emerging Adulthood*, *8*(3), 209–225. https://doi.org/10.1177/2167696818797531

Okada, B. M., & Slevc, L. R. (2018). Individual differences in musical training and executive functions : A latent variable approach. *Memory & Cognition*, *46*(7), 1076–1092.

Ollen, J. E. (2006). *A criterion-related validity test of selected indicators of musical sophistication using expert ratings* [Doctoral dissertation, The Ohio State

University]. https://doi.org/10.19744/j.cnki.11-1235/f.2006.09.027

Orjuela-Rojas, J. M., Montañés, P., Rodríguez, I. L. L., & González-Marín, N. R. (2021). Recognition of musical emotions in the behavioral variant of frontotemporal dementia. *Revista Colombiana de Psiquiatria*, *50*(2), 74–81. https://doi.org/10.1016/j.rcp.2020.01.002

Oyserman, D., Coon, H. M., & Kemmelmeier, M. (2002). Rethinking individualism and collectivism: Evaluation of theoretical assumptions and meta-analyses. *Psychological Bulletin*, *128*(1), 3–72. https://doi.org/10.1037/0033-2909.128.1.3

Patrão, A. (2018). Linguistic relativism in the age of global lingua franca: Reconciling cultural and linguistic diversity with globalization. *Lingua*, *210–211*, 30–41. https://doi.org/10.1016/j.lingua.2018.04.006

Patrick, M. E., Blair, C., & Maggs, J. L. (2008). Executive function, approach sensitivity, and emotional decision making as influences on risk behaviors in young adults. *Journal of Clinical and Experimental Neuropsychology*, *30*(4), 449–462. https://doi.org/10.1080/13803390701523109

Pereira, C. S., Teixeira, J., Figueiredo, P., Xavier, J., Castro, S. L., & Brattico, E. (2011). Music and Emotions in the Brain: Familiarity Matters. *PLoS ONE*, *6*(11). https://doi.org/10.1371/journal.pone.0027241

Perham, N., & Withey, T. (2012). Liked Music Increases Spatial Rotation Performance Regardless of Tempo. *Current Psychology*, *31*(2), 168–181. https://doi.org/10.1007/s12144-012-9141-6

Petrovsky, D. V., Johnson, J. K., Tkacs, N., Mechanic-Hamilton, D., Hamilton, R. H., & Cacchione, P. Z. (2021). Musical and cognitive abilities in older adults with mild cognitive impairment. *Psychology of Music*, *49*(1), 124–137. https://doi.org/10.1177/0305735619843993

Pietschnig, J., Voracek, M., & Formann, A. K. (2010). Mozart effect-Shmozart effect: A meta-analysis. *Intelligence*, *38*(3), 314–323. https://doi.org/10.1016/j.intell.2010.03.001

Pisula, E., Danielewicz, D., Kawa, R., & Pisula, W. (2015). Autism spectrum quotient, coping with stress and quality of life in a non-clinical sample - an exploratory report. *Health and Quality of Life Outcomes*, *13*(1), 1–9. https://doi.org/10.1186/s12955-015-0370-x

Pisula, E., Kawa, R., Szostakiewicz, Ł., Łucka, I., Kawa, M., & Rynkiewicz, A. (2013). Autistic Traits in Male and Female Students and Individuals with High Functioning Autism Spectrum Disorders Measured by the Polish Version of the Autism-Spectrum Quotient. *PLoS ONE*, *8*(9), 1–12. https://doi.org/10.1371/journal.pone.0075236

R Core Team. (2021). *R: A Language and Environment for Statistical Computing* (4.1.1). R Foundation for Statistical Computing. https://www.r-project.org

Raichle, M. E. (2015). The Brain's Default Mode Network. *Annual Review of Neuroscience, 38*, 433–447. https://doi.org/10.1146/annurev-neuro-071013-014030

Ralston, D. A., Cunniff, M. K., & Gustafon, D. J. (1995). Cultural Accommodation: The Effect of Language on the Responses of Bilingual Hong Kong Chinese Managers. *Journal of Cross-Cultural Psychology*, *26*(6), 714–727. https://doi.org/10.1017/CBO9781107415324.004

Ramírez-Esparza, N., Gosling, S. D., Benet-Martínez, V., Potter, J. P., & Pennebaker, J. W. (2006). Do bilinguals have two personalities? A special case of cultural frame switching. *Journal of Research in Personality*, *40*(2), 99–120. https://doi.org/10.1016/j.jrp.2004.09.001

Ramos-Galarza, C., Acosta-Rodas, P., Bolaños-Pasquel, M., & Lepe-Martínez, N. (2020). The role of executive functions in academic performance and behaviour of university students. *Journal of Applied Research in Higher Education*, *12*(3), 444–455. https://doi.org/10.1108/JARHE-10-2018-0221

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature, 365*(6447), 611–611.

Reed, P., Giles, A., Gavin, M., Carter, N., & Osborne, L. A. (2016). Loneliness and Social Anxiety Mediate the Relationship between Autism Quotient and Quality of Life in University Students. *Journal of Developmental and Physical Disabilities*, *28*(5), 723–733. https://doi.org/10.1007/s10882-016-9504-2

Rentfrow, P. J., Goldberg, L. R., & Levitin, D. J. (2011). The Structure of Musical Preferences: A Five-Factor Model. *Journal of Personality and Social Psychology, 100*(6), 1139–1157. https://doi.org/10.1037/a0022406.The

Rentfrow, P. J., Goldberg, L. R., Stillwell, D. J., Kosinski, M., Gosling, S. D., & Levitin, D. J. (2012). The Song Remains the Same: A Replication and Extension of the MUSIC Model. *Music Perception*, *30*(2), 161–185. https://doi.org/10.1038/jid.2014.371

Rentfrow, P. J., & Gosling, S. D. (2003). The Do Re Mi's of Everyday Life: The Structure and Personality Correlates of Music Preferences. *Journal of Personality and Social Psychology*, *84*(6), 1236–1256. https://doi.org/10.1037/0022-3514.84.6.1236

Rentfrow, P. J., & Gosling, S. D. (2007). The content and validity of music-genre stereotypes among college students. *Psychology of Music*, *35*(2), 306–326. https://doi.org/10.1177/0305735607070382

Rentfrow, P. J., McDonald, J. A., & Oldmeadow, J. A. (2009). You are what you listen to: Young people's stereotypes about music fans. *Group Processes and Intergroup Relations*, *12*(3), 329–344. https://doi.org/10.1177/1368430209102845

Revelle, W. (2021). *psych: Procedures for Psychological, Psychometric, and Personality Research* (R package version 2.1.9). Northwestern University. https://cran.r-project.org/web/packages/psych/psych.pdf

Richard, M. O., & Toffoli, R. (2009). Language influence in responses to questionnaires by bilingual respondents: A test of the Whorfian hypothesis. *Journal of Business Research*, *62*(10), 987–994. https://doi.org/10.1016/j.jbusres.2008.10.016

Rickard, N. S. (2004). Intense emotional responses to music: a test of the physiological arousal hypothesis. *Psychology of Music*, *32*(4), 371–388.

Rickard, N. S., Wong, W. W., & Velik, L. (2012). Relaxing music counters heightened consolidation of emotional memory. *Neurobiology of Learning and Memory*, *97*(2), 220–228. https://doi.org/10.1016/j.nlm.2011.12.005

Roden, I., Grube, D., Bongard, S., & Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. *Psychology of Music*, *42*(2), 284–298. https://doi.org/10.1177/0305735612471239

Ronald, A., Happé, F., Bolton, P., Butcher, L. M., Price, T. S., Wheelwright, S., Baron-Cohen, S., & Plomin, R. (2006). Genetic heterogeneity between the three components of the autism spectrum: A twin study. *Journal of the American Academy of Child and Adolescent Psychiatry*, *45*(6), 691–699. https://doi.org/10.1097/01.chi.0000215325.13058.9d

Ross, N. A., Garner, R., Bernier, J., Feeny, D. H., Kaplan, M. S., Mcfarland, B., Orpana, H. M., & Oderkirk, J. (2012). Trajectories of health-related quality of life by socio-economic status in a nationally representative Canadian cohort. *J Epidemiol Community Health*, *66*(7), 593–598. https://doi.org/10.1136/jech.2010.115378.Trajectories

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(2). https://doi.org/10.18637/jss.v048.i02

Russell-Smith, S. N., Maybery, M. T., & Bayliss, D. M. (2011). Relationships between autistic-like and schizotypy traits: An analysis using the Autism Spectrum Quotient and Oxford-Liverpool Inventory of Feelings and Experiences. *Personality and Individual Differences*, *51*(2), 128–132. https://doi.org/10.1016/j.paid.2011.03.027

Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., & Baron-Cohen, S. (2015). Measuring autistic traits in the general population: a systematic review of the Autism-Spectrum Quotient (AQ) in a nonclinical population sample of 6,900 typical adult males and females. *Molecular Autism*, *6*(1), 1–12. https://doi.org/10.1186/2040-2392-6-2

Saarikallio, S., Alluri, V., Maksimainen, J., & Toiviainen, P. (2021). Emotions of music listening in Finland and in India: Comparison of an individualistic and a collectivistic culture. *Psychology of Music*, *49*(4), 989–1005. https://doi.org/10.1177/0305735620917730

Salehinejad, M. A., Ghanavati, E., Rashid, M. H. A., & Nitsche, M. A. (2021). Hot and cold executive functions in the brain: A prefrontal-cingular network. *Brain and Neuroscience Advances*, *5*, 239821282110077. https://doi.org/10.1177/23982128211007769

Salimpoor, V. N., Benovoy, M., Longo, G., Cooperstock, J. R., & Zatorre, R. J. (2009). The rewarding aspects of music listening are related to degree of emotional arousal. *PLoS ONE*, *4*(10). https://doi.org/10.1371/journal.pone.0007487

Särkämö, T., Tervaniemi, M., Laitinen, S., Forsblom, A., Soinila, S., Mikkonen, M., Autti, T., Silvennoinen, H. M., Erkkilä, J., Laine, M., Peretz, I., & Hietanen, M. (2008). Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. *Brain*, *131*(3), 866–876. https://doi.org/10.1093/brain/awn013

Särkämö, T., Tervaniemi, M., Laitinen, S., Numminen, A., Kurki, M., Johnson, J. K., & Rantanen, P. (2014). Cognitive, emotional, and social benefits of regular musical activities in early dementia: Randomized controlled study. *Gerontologist*, *54*(4), 634–650. https://doi.org/10.1093/geront/gnt100

Sato, W., Kochiyama, T., & Yoshikawa, S. (2020). Physiological correlates of subjective emotional valence and arousal dynamics while viewing films. *Biological Psychology*, *157*(October), 107974. https://doi.org/10.1016/j.biopsycho.2020.107974

Schaefer, J., Giangrande, E., Weinberger, D. R., & Dickinson, D. (2013). The global cognitive impairment in schizophrenia: Consistent over decades and around the world. *Schizophrenia Research*, *150*(1), 42–50. https://doi.org/10.1016/j.schres.2013.07.009

Schäfer, T., & Sedlmeier, P. (2009). From the functions of music to music preference. *Psychology of Music*, *37*(3), 279–300. https://doi.org/10.1177/0305735608097247

Schäfer, T., & Sedlmeier, P. (2011). Does the Body Move the Soul? The Impact of Arousal on Music Preference. *Music Perception: An Interdisciplinary Journal*, *29*(1), 37–50. https://doi.org/10.1017/CBO9781107415324.004

Schäfer, T., Tipandjan, A., & Sedlmeier, P. (2012). The functions of music and their relationship to music preference in India and Germany. *International Journal of Psychology*, *47*(5), 370–380. https://doi.org/10.1080/00207594.2012.688133

Schedl, M. (2017). Investigating country-specific music preferences and music recommendation algorithms with the LFM-1b dataset. *International Journal of Multimedia Information Retrieval*, *6*(1), 71–84. https://doi.org/10.1007/s13735-017-0118-y

Schellenberg, E. G., Nakata, T., Hunter, P. G., & Tamoto, S. (2007). Exposure to music and cognitive performance: Tests of children and adults. *Psychology of Music*, *35*(1), 5–19. http://search.ebscohost.com/login.aspx?direct=true&db=rih&AN=2007-00089&site=ehost-live

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online*, *8*(2), 23–74.

Schmitt, D. P., Allik, J., McCrae, R. R., Benet-Martínez, V., Alcalay, L., Ault, L., Austers, I., Bennett, K. L., Bianchi, G., Boholst, F., Borg Cunen, M. A., Braeckman, J., Brainerd, E. G., Caral, L. G. A., Caron, G., Martina Casullo, M., Cunningham, M., Daibo, I., De Backer, C., … Sharan, M. B. (2007). The geographic distribution of Big Five personality traits: Patterns and profiles of human self-description across 56 nations. *Journal of Cross-Cultural Psychology*, *38*(2), 173–212. https://doi.org/10.1177/0022022106297299

Seinfeld, S., Figueroa, H., Ortiz-Gil, J., & Sanchez-Vives, M. V. (2013). Effects of music learning and piano practice on cognitive function, mood and quality of life in older adults. *Frontiers in Psychology*, *4*(NOV), 1–13. https://doi.org/10.3389/fpsyg.2013.00810

Shen, Y., Lin, Y., Liu, S., Fang, L., & Liu, G. (2019). Sustained effect of music training on the enhancement of executive function in preschool children. *Frontiers in Psychology*, *10*(AUG), 1–14. https://doi.org/10.3389/fpsyg.2019.01910

Sherman, E. M. S., Slick, D. J., & Eyrl, K. L. (2006). Executive dysfunction is a significant predictor of poor quality of life in children with epilepsy. *Epilepsia*, *47*(11), 1936–1942. https://doi.org/10.1111/j.1528-1167.2006.00816.x

Sievers, B., Polansky, L., Casey, M., & Wheatley, T. (2013). Music and movement share a dynamic structure that supports universal expressions of emotion. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(1), 70–75. https://doi.org/10.1073/pnas.1209023110

Silvestrini, N., & Gendolla, G. H. E. (2007). Mood effects on autonomic activity in mood regulation. *Psychophysiology*, *44*(4), 650–659. https://doi.org/10.1111/j.1469-8986.2007.00532.x

Simmons, L. C., & Schindler, R. M. (2003). Cultural Superstitions and the Price Endings Used in Chinese Advertising. *Journal of International Marketing*, *11*(2), 101–111.

Singmann, H., Bolker, B., Westfall, J., Aust, F., Ben-Shachar, M. S., Højsgaard, S., Fox, J., Lawrence, M. A., Mertens, U., Love, J., Lenth, R., & Christensen, R. H. B. (2021). *Package ‘ afex ’* (1.0-1). https://github.com/singmann/afex

Slevc, L. R., Davey, N. S., Buschkuehl, M., & Jaeggi, S. M. (2016). Tuning the mind: Exploring the connections between musical ability and executive functions. *Cognition*, *152*, 199–211. https://doi.org/10.1016/j.cognition.2016.03.017

Smith, A., Waters, B., & Jones, H. (2010). Effects of prior exposure to office noise and music on aspects of working memory. *Noise and Health*, *12*(49), 235–243. https://doi.org/10.4103/1463-1741.70502

Soares-Quadros Júnior, J. F., Lorenzo, O., Herrera, L., & Araújo Santos, N. S. (2019). Gender and religion as factors of individual differences in musical preference. *Musicae Scientiae*, *23*(4), 525–539. https://doi.org/10.1177/1029864918774834

Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, Boucsein, W., Fowles, D. C., Grimnes, S., Ben-Shakhar, G., Roth, W. T., Dawson, M. E., & Filion, D. L. (2012). Publication recommendations for electrodermal measurements. *Psychophysiology*, *49*(8), 1017–1034. https://doi.org/10.1111/j.1469-8986.2012.01384.x

Stanutz, S., Wapnick, J., & Burack, J. A. (2014). Pitch discrimination and melodic memory in children with autism spectrum disorders. *Autism*, *18*(2), 137–147. https://doi.org/10.1177/1362361312462905

Steele, K. M., Ball, T. N., & Runk, R. (1997). Listening to Mozart Does Not Enhance Backwards Digit Span Performance. *Perceptual and Motor Skills*, *84*, 1179–1184.

Steele, K. M., Bass, K. E., & Crook, M. D. (1999). The mystery of the mozart effect: Failure to Replicate. *Psychological Science*, *10*(4), 366–369. https://doi.org/10.1111/1467-9280.00169

Steinmetz, H. (2013). Analyzing observed composite differences across groups: Is partial measurement invariance enough? *Methodology*, *9*(1), 1–12. https://doi.org/10.1027/1614-2241/a000049

Stevenson, J. L., & Hart, K. R. (2017). Psychometric properties of the autism-spectrum quotient for assessing low and high levels of autistic traits in college students. *Journal of Autism and Developmental Disorders*, *47*(6), 1838–1853. https://doi.org/10.1007/s10803-017-3109-1

Stewart, M. E., Griffiths, T. D., & Grube, M. (2018). Autistic Traits and Enhanced Perceptual Representation of Pitch and Time. *Journal of Autism and Developmental Disorders*, *48*(4), 1350–1358. https://doi.org/10.1007/s10803-015-2517-3

Streiner, D. L. (2005). Finding our way: An introduction to path analysis. *Canadian Journal of Psychiatry*, *50*(2), 115–122. https://doi.org/10.1177/070674370505000207

Strong, J. V., & Mast, B. T. (2019). The cognitive functioning of older adult instrumental musicians and non-musicians. *Aging, Neuropsychology, and Cognition*, *26*(3), 367–386. https://doi.org/10.1080/13825585.2018.1448356

Suárez, L., Elangovan, S., & Au, A. (2016). Cross-sectional study on the relationship between music training and working memory in adults. *Australian Journal of Psychology*, *68*(1), 38–46. https://doi.org/10.1111/ajpy.12087

Swaminathan, S., Schellenberg, E. G., & Khalil, S. (2017). Revisiting the association between music lessons and intelligence: Training effects or music aptitude?

Intelligence, *62*, 119–124. https://doi.org/10.1016/j.intell.2017.03.005

Talamini, F., Altoè, G., Carretti, B., & Grassi, M. (2017). Musicians have better memory than nonmusicians: A meta-analysis. *PLoS ONE*, *12*(10), 1–21. https://doi.org/10.1371/journal.pone.0186773

Tavassoli, T., Hoekstra, R. A., & Baron-Cohen, S. (2014). The Sensory Perception Quotient (SPQ): Development and validation of a new sensory questionnaire for adults with and without autism. *Molecular Autism*, *5*(1), 1–10. https://doi.org/10.1186/2040-2392-5-29

Teo, T., Hargreaves, D. J., & Lee, J. (2008). Musical preference, identification, and familiarity: A multicultural comparison of secondary students from Singapore and the United Kingdom. *Journal of Research in Music Education*, *56*(1), 18–32. https://doi.org/10.1177/0022429408322953

Thaut, M. H. (2010). Neurologic Music Therapy in Cognitive Rehabilitation. *Music Perception: An Interdisciplinary Journal*, *27*(4), 281–285. https://doi.org/10.1017/CBO9781107415324.004

Thaut, M. H., Gardiner, J. C., Holmberg, D., Horwitz, J., Kent, L., Andrews, G., Donelan, B., & McIntosh, G. R. (2009). Neurologic music therapy improves executive function and emotional adjustment in traumatic brain injury rehabilitation. *Annals of the New York Academy of Sciences*, *1169*(2), 406–416. https://doi.org/10.1111/j.1749-6632.2009.04585.x

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, mood, and the Mozart effect. *Psychological Science*, *12*(3), 248–251. https://doi.org/10.1111/1467-9280.00345

Thompson, W. F., Schellenberg, E. G., & Letnic, A. K. (2012). Fast and loud background music disrupts reading comprehension. *Psychology of Music*, *40*(6), 700–708. https://doi.org/10.1177/0305735611400173

Thumboo, J., Fong, K. Y., Machin, D., Chan, S. P., Soh, C. H., Leong, K. H., Feng, P. H., Thio, S. T., & Boey, M. L. (2003). Quality of life in an urban Asian population: The impact of ethnicity and socio-economic status. *Social Science and Medicine*, *56*(8), 1761–1772. https://doi.org/10.1016/S0277-9536(02)00171-

5

Triandis, H. C. (1993). Collectivism and Individualism as Cultural Syndromes. *Cross-Cultural Research*, *27*(3–4), 155–180. https://doi.org/10.1177/106939719302700301

Triandis, H. C. (2015). Collectivism and Individualism: Cultural and Psychological Concerns. In *International Encyclopedia of the Social & Behavioral Sciences: Second Edition* (Second Edi, Vol. 4, Issue 1762). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.24008-7

Tsang, S., Royse, C. F., & Terkawi, A. S. (2017). Guidelines for developing, translating, and validating a questionnaire in perioperative and pain medicine. *Saudi Journal of Anesthesia*, *11*(Suppl 1), S80. https://doi.org/10.4103/sja.SJA

Tyson, P. J., Laws, K. R., Flowers, K. A., Mortimer, A. M., & Schulz, J. (2008). Attention and executive function in people with schizophrenia: Relationship with social skills and quality of life. *International Journal of Psychiatry in Clinical Practice*, *12*(2), 112–119. https://doi.org/10.1080/13651500701687133

Ukkola-Vuoti, L., Kanduri, C., Oikkonen, J., Buck, G., Blancher, C., Raijas, P., Karma, K., Lähdesmäki, H., & Järvelä, I. (2013). Genome-Wide Copy Number Variation Analysis in Extended Families and Unrelated Individuals Characterized for Musical Aptitude and Creativity in Music. *PLoS ONE*, *8*(2). https://doi.org/10.1371/journal.pone.0056356

Van Herk, H., Poortinga, Y. H., & Verhallen, T. M. M. (2004). Response styles in rating scales: Evidence of method bias in data from six EU countries. *Journal of Cross-Cultural Psychology*, *35*(3), 346–360. https://doi.org/10.1177/0022022104264126

Van Vaerenbergh, Y., & Thomas, T. D. (2013). Response styles in survey research: A literature review of antecedents, consequences, and remedies. *International Journal of Public Opinion Research*, *25*(2), 195–217. https://doi.org/10.1093/ijpor/eds021

Varni, J. W., Seid, M., & Kurtin, P. S. (2001). PedsQL™ 4.0: Reliability and Validity of the Pediatric Quality of Life Inventory™ Version 4.0 Generic Core Scales in

Healthy and Patient Populations. *Medical Care*, *39*(8), 800–812. https://doi.org/10.1097/00005650-200108000-00006

Vella, E. J., & Mills, G. (2017). Personality, uses of music, and music preference: The influence of openness to experience and extraversion. *Psychology of Music*, *45*(3), 338–354. https://doi.org/10.1177/0305735616658957

Verrusio, W., Ettorre, E., Vicenzini, E., Vanacore, N., Cacciafesta, M., & Mecarelli, O. (2015). The Mozart Effect: A quantitative EEG study. *Consciousness and Cognition*, *35*, 150–155. https://doi.org/10.1016/j.concog.2015.05.005

Vetrayan, J., Mohamed Nazir, S. U. H., & Victor Paulraj, S. J. P. (2016). Play Preference and Pretend Play Skills between Typically Developed Children and Autism. *Environment-Behaviour Proceedings Journal*, *1*(3), 23. https://doi.org/10.21834/e-bpj.v1i3.345

Vital, P. M., Ronald, A., Wallace, G. L., & Happé, F. (2009). Relationship between special abilities and autistic-like traits in a large population-based sample of 8-year-olds. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *50*(9), 1093–1101. https://doi.org/10.1111/j.1469-7610.2009.02076.x

Wakabayashi, A., Baron-Cohen, S., Wheelwright, S., & Tojo, Y. (2006). The Autism-Spectrum Quotient (AQ) in Japan: A cross-cultural comparison. *J Autism Dev Disord*, *36*(2), 263–270. https://doi.org/10.1007/s10803-005-0061-2

Ward, J., Ren, Z., & Qiu, J. (2021). Autistic Traits in the Neurotypical Chinese Population: A Chinese Version of Glasgow Sensory Questionnaire and a Cross-Cultural Difference in Attention-to-Detail. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-020-04829-1

Wenhart, T., & Altenmüller, E. (2019). A tendency towards details? Inconsistent results on auditory and visual local-to-global processing in absolute pitch musicians. *Frontiers in Psychology*, *10*(JAN), 1–14. https://doi.org/10.3389/fpsyg.2019.00031

Weston, R., & Gore, P. A. (2006). A Brief Guide to Structural Equation Modeling. *The Counseling Psychologist*, *34*(5), 719–751. https://doi.org/10.1177/0011000006286345

Wheelwright, S., Baron-Cohen, S., Goldenfeld, N., Delaney, J., Fine, D., Smith, R., Weil, L., & Wakabayashi, A. (2006). Predicting Autism Spectrum Quotient (AQ) from the Systemizing Quotient-Revised (SQ-R) and Empathy Quotient (EQ). *Brain Research, 1079*(1), 47–56. https://doi.org/10.1016/j.brainres.2006.01.012

White, S. W., Ollendick, T. H., & Bray, B. C. (2011). College students on the autism spectrum: Prevalence and associated problems. *Autism*, *15*(6), 683–701. https://doi.org/10.1177/1362361310393363

Whitehouse, A. J. O., Hickey, M., & Ronald, A. (2011). Are Autistic traits in the general population stable across development? *PLoS ONE*, *6*(8), 2–9. https://doi.org/10.1371/journal.pone.0023029

Wilkins, R. W., Hodges, D. A., Laurienti, P. J., Steen, M., & Burdette, J. H. (2014). Network science and the effects of music preference on functional Brain connectivity: From Beethoven to Eminem. *Scientific Reports*, *4*, 1–8. https://doi.org/10.1038/srep06130

Wong, W. C., Abdullah, N. A. H., & Lim, H. E. (2019). The Value of Chinese Superstitions in Malaysia: Evidence from Car Plate Auctioning. *Singapore Economic Review*, *64*(1), 115–137. https://doi.org/10.1142/S0217590817430081

Yang, K. S., & Bond, M. H. (1980). Ethnic Affirmation By Chinese Bilinguals. *Journal of Cross-Cultural Psychology*, *11*(4), 411–425. http://hjb.sagepub.com.proxy.lib.umich.edu/content/9/2/183.full.pdf+html

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459–482. https://doi.org/10.1037/h0073415

Yoo, H., Kang, S., & Fung, V. (2018). Personality and world music preference of undergraduate non-music majors in South Korea and the United States. *Psychology of Music*, *46*(5), 611–625. https://doi.org/10.1177/0305735617716757

Zavala-Rojas, D. (2018). Exploring Language Effects in Crosscultural Survey Research: Does the Language of Administration Affect Answers About Politics? *Methods, Data, Analyses: A Journal for Quantitative Methods and Survey*

Methodology (Mda), *12*(1), 127–150. https://doi.org/10.12758/mda.2017.16

Zhang, J. D., & Schubert, E. (2019). A Single Item Measure for Identifying Musician and Nonmusician Categories Based on Measures of Musical Sophistication. *Music Perception: An Interdisciplinary Journal*, *36*(5), 457–467. https://doi.org/https://doi.org/10.1525/mp.2019.36.5.457

Zhang, L., Sun, Y., Chen, F., Wu, D., Tang, J., Han, X., Ye, J., & Wang, K. (2016). Psychometric properties of the Autism-Spectrum Quotient in both clinical and non-clinical samples: Chinese version for mainland China. *BMC Psychiatry*, *16*(1), 1–10. https://doi.org/10.1186/s12888-016-0915-5

Zhang, S., Hu, S., Chao, H. H., Ide, J. S., Luo, X., Farr, O. M., & Li, C. S. R. (2014). Ventromedial prefrontal cortex and the regulation of physiological arousal. *Social Cognitive and Affective Neuroscience*, *9*(7), 900–908. https://doi.org/10.1093/scan/nst064

Zhou, S. S., Gao, X., Hu, Y. J., Zhu, Y. M., Tian, Y. H., & Wang, K. (2019). Selective impairment of musical emotion recognition in patients with amnesic mild cognitive impairment and mild to moderate Alzheimer disease. *Chinese Medical Journal*, *132*(19), 2308–2314. https://doi.org/10.1097/CM9.0000000000000460

Zimmerman, D. L., Ownsworth, T., O'donovan, A., Roberts, J., & Gullo, M. J. (2016). Independence of hot and cold executive function deficits in high-functioning adults with autism spectrum disorder. *Frontiers in Human Neuroscience*, *10*(FEB2016), 1–14. https://doi.org/10.3389/fnhum.2016.00024

Zuk, J., Benjamin, C., Kenyon, A., & Gaab, N. (2014). Behavioral and neural correlates of executive functioning in musicians and non-musicians. *PLoS ONE*, *9*(6). https://doi.org/10.1371/journal.pone.0099868

Zumbo, B. D., Gadermann, A. M., & Zeisser, C. (2007). Ordinal Versions of Coefficients Alpha and Theta for Likert Rating Scales. *Journal of Modern Applied Statistical Methods*, *6*(1), 21–29.

Zweigenhaft, R. L. (2008). A Do Re Mi Encore: A Closer Look at the Personality Correlates of Music Preferences. *Journal of Individual Differences*, *29*(1), 45–

55. https://doi.org/10.1027/1614-0001.29.1.45

Supplementary Material

Supplementary Table 3.1

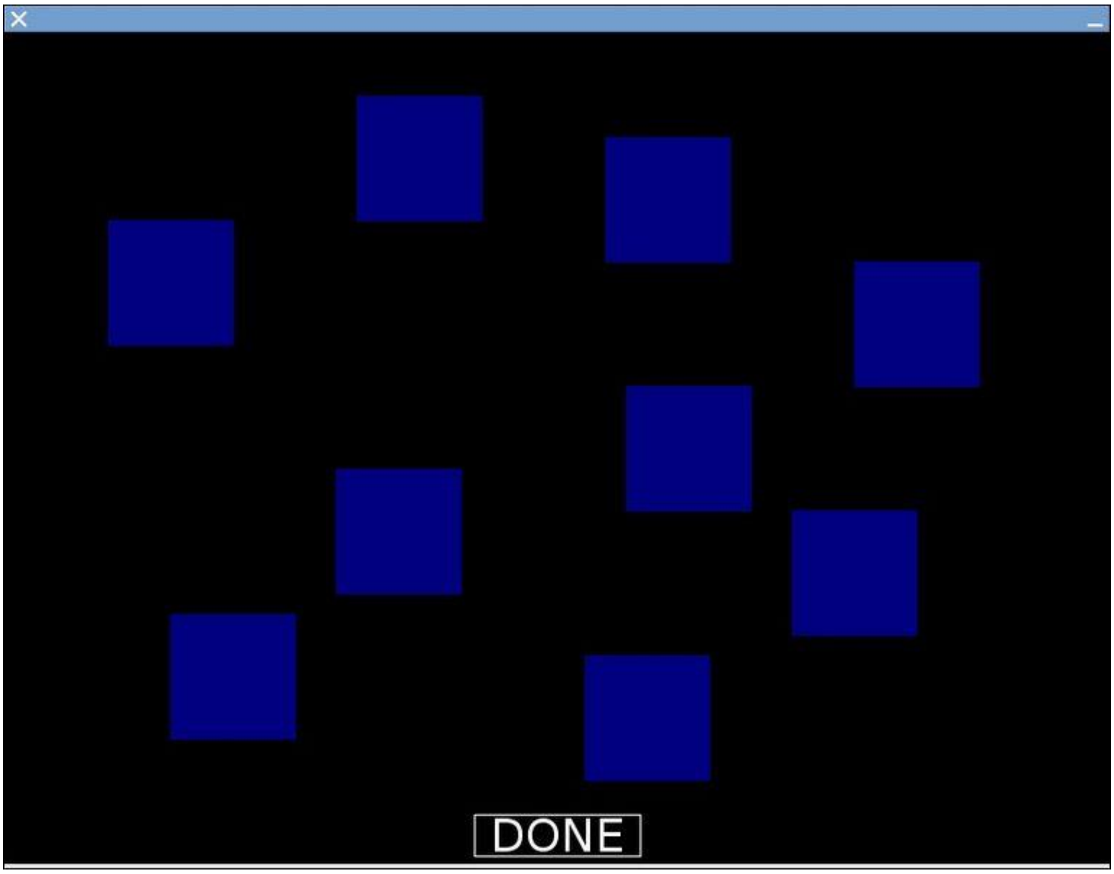
The items of AQ-28

Social Behaviour	Numbers/Patterns
Social Skills	
1. I prefer to do things with others rather than on my own	5. I usually notice car number plates or similar strings of information
9. I find social situations easy	7. I am fascinated by dates
10. I would rather go to a library than a party	13. I am fascinated by numbers
12. I find myself drawn more strongly to people than to things	16. I notice patterns in things all the time
15. I find it hard to make new friends	22. I like to collect information about categories of things (e.g., types of car, types of bird, types of train, types of plant, etc.)
24. I enjoy social occasions	
27. I enjoy meeting new people	
Routine	
2. I prefer to do things the same way over and over again	
17. It does not upset me if my daily routine is disturbed	
19. I enjoy doing things spontaneously	
26. New situations make me anxious	
Switching	
4. I frequently get so strongly absorbed in one thing that I lose sight of other things	

8. In a social group, I can easily keep track of several different people's conversations
18. I find it easy to do more than one thing at once
21. If there is an interruption, I can switch back to what I was doing very quickly
Imagination
3. If I try to imagine something, I find it very easy to create a picture in my mind
6. When I'm reading a story, I can easily imagine what the characters might look like
11. I find making up stories easy
14. When I'm reading a story, I find it difficult to work out the characters' intentions
20. I find it easy to work out what someone is thinking or feeling just by looking at their face
23. I find it difficult to imagine what it would be like to be someone else
25. I find it difficult to work out people's intentions
28. I find it very easy to play games with children that involve pretending

Supplementary Figure 5.1

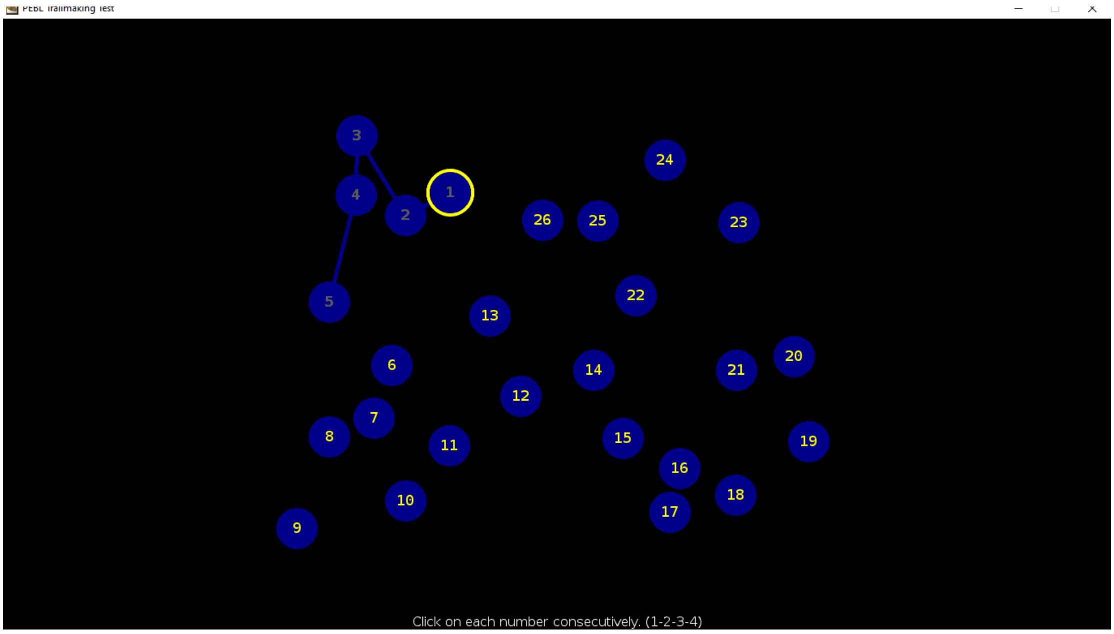
Visual Representation of the Corsi Blocks Test



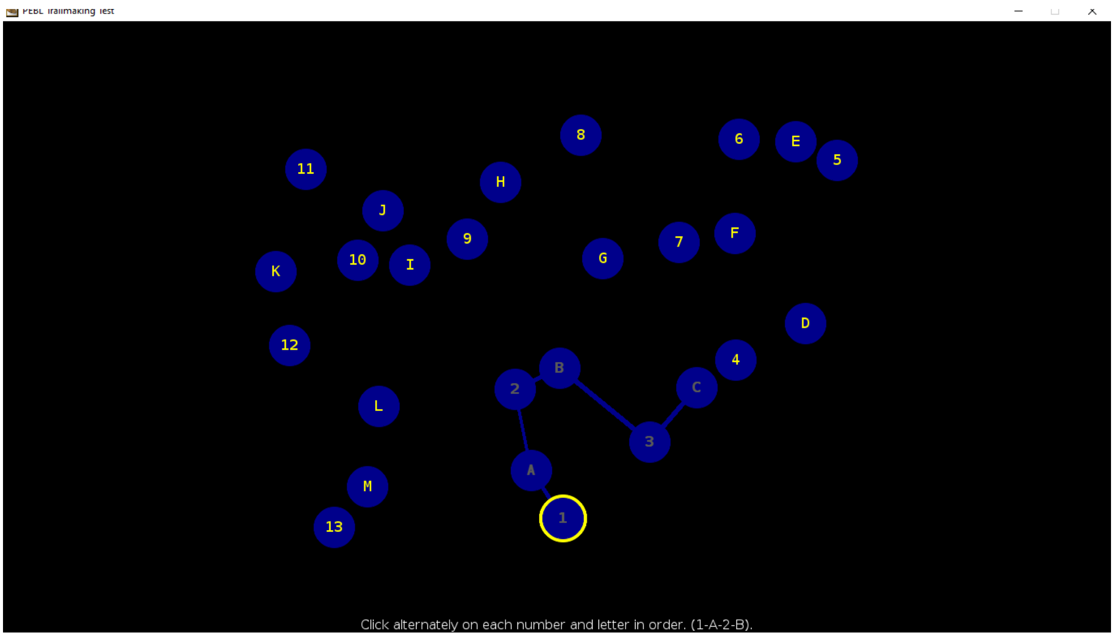
Supplementary Figure 5.2

Visual representation of Trail Making Test Part A and B

(a)

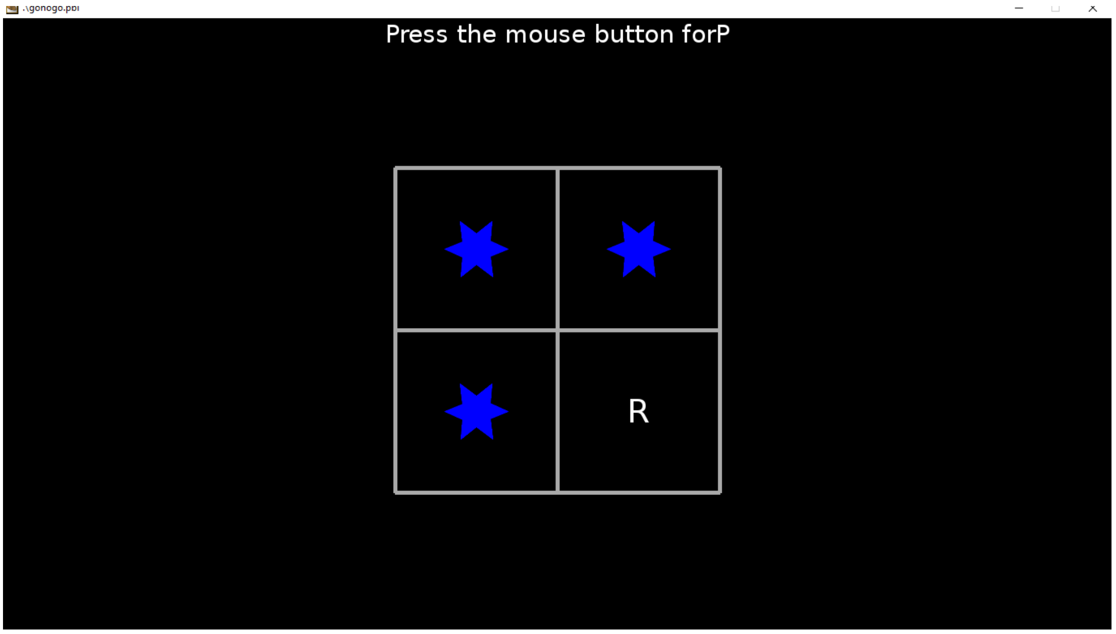


(b)



Supplementary Figure 5.3

Visual representation of Go-NoGo Task



Supplementary Table 6.1

Correlations among general musical sophistication and its subscales.

	General Musical Sophistication	Active Engagement	Perceptual Abilities	Musical Training	Singing Abilities
Active Engagement	.65***				
Perceptual Abilities	.78***	.45***			
Musical Training	.78***	.39***	.54***		
Singing Abilities	.82***	.43***	.66***	.48***	
Emotions	.55***	.65***	.54***	.28***	.35***

Note. ***$p < .001$

Appendices

Appendix I: Autism Spectrum Quotient-50 (AQ-50) in English

1.	I prefer to do things with others rather than on my own.	definitely agree	slightly agree	slightly disagree	definitely disagree
2.	I prefer to do things the same way over and over again.	definitely agree	slightly agree	slightly disagree	definitely disagree
3.	If I try to imagine something, I find it very easy to create a picture in my mind.	definitely agree	slightly agree	slightly disagree	definitely disagree
4.	I frequently get so strongly absorbed in one thing that I lose sight of other things.	definitely agree	slightly agree	slightly disagree	definitely disagree
5.	I often notice small sounds when others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
6.	I usually notice car number plates or similar strings of information.	definitely agree	slightly agree	slightly disagree	definitely disagree
7.	Other people frequently tell me that what I've said is impolite, even though I think it is polite.	definitely agree	slightly agree	slightly disagree	definitely disagree
8.	When I'm reading a story, I can easily imagine what the characters might look like.	definitely agree	slightly agree	slightly disagree	definitely disagree
9.	I am fascinated by dates.	definitely agree	slightly agree	slightly disagree	definitely disagree
10.	In a social group, I can easily keep track of several different people's conversations.	definitely agree	slightly agree	slightly disagree	definitely disagree
11.	I find social situations easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
12.	I tend to notice details that others do not.	definitely	slightly	slightly	definitely

	agree	agree	disagree	disagree
13. I would rather go to a library than a party.	definitely agree	slightly agree	slightly disagree	definitely disagree
14. I find making up stories easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
15. I find myself drawn more strongly to people than to things.	definitely agree	slightly agree	slightly disagree	definitely disagree
16. I tend to have very strong interests which I get upset about if I can't pursue.	definitely agree	slightly agree	slightly disagree	definitely disagree
17. I enjoy social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
18. When I talk, it isn't always easy for others to get a word in edgeways.	definitely agree	slightly agree	slightly disagree	definitely disagree
19. I am fascinated by numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
20. When I'm reading a story, I find it difficult to work out the characters' intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
21. I don't particularly enjoy reading fiction.	definitely agree	slightly agree	slightly disagree	definitely disagree
22. I find it hard to make new friends.	definitely agree	slightly agree	slightly disagree	definitely disagree
23. I notice patterns in things all the time.	definitely agree	slightly agree	slightly disagree	definitely disagree

24. I would rather go to the theatre than a museum.	definitely agree / slightly agree / slightly disagree / definitely disagree
25. It does not upset me if my daily routine is disturbed.	definitely agree / slightly agree / slightly disagree / definitely disagree
26. I frequently find that I don't know how to keep a conversation going.	definitely agree / slightly agree / slightly disagree / definitely disagree
27. I find it easy to "read between the lines" when someone is talking to me.	definitely agree / slightly agree / slightly disagree / definitely disagree
28. I usually concentrate more on the whole picture, rather than the small details.	definitely agree / slightly agree / slightly disagree / definitely disagree
29. I am not very good at remembering phone numbers.	definitely agree / slightly agree / slightly disagree / definitely disagree
30. I don't usually notice small changes in a situation, or a person's appearance.	definitely agree / slightly agree / slightly disagree / definitely disagree
31. I know how to tell if someone listening to me is getting bored.	definitely agree / slightly agree / slightly disagree / definitely disagree
32. I find it easy to do more than one thing at once.	definitely agree / slightly agree / slightly disagree / definitely disagree
33. When I talk on the phone, I'm not sure when it's my turn to speak.	definitely agree / slightly agree / slightly disagree / definitely disagree
34. I enjoy doing things spontaneously.	definitely agree / slightly agree / slightly disagree / definitely disagree
35. I am often the last to understand the point of a joke.	definitely agree / slightly agree / slightly disagree / definitely disagree

36.	I find it easy to work out what someone is thinking or feeling just by looking at their face.	definitely agree	slightly agree	slightly disagree	definitely disagree
37.	If there is an interruption, I can switch back to what I was doing very quickly.	definitely agree	slightly agree	slightly disagree	definitely disagree
38.	I am good at social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
39.	People often tell me that I keep going on and on about the same thing.	definitely agree	slightly agree	slightly disagree	definitely disagree
40.	When I was young, I used to enjoy playing games involving pretending with other children.	definitely agree	slightly agree	slightly disagree	definitely disagree
41.	I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).	definitely agree	slightly agree	slightly disagree	definitely disagree
42.	I find it difficult to imagine what it would be like to be someone else.	definitely agree	slightly agree	slightly disagree	definitely disagree
43.	I like to plan any activities I participate in carefully.	definitely agree	slightly agree	slightly disagree	definitely disagree
44.	I enjoy social occasions.	definitely agree	slightly agree	slightly disagree	definitely disagree
45.	I find it difficult to work out people's intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
46.	New situations make me anxious.	definitely agree	slightly agree	slightly disagree	definitely disagree
47.	I enjoy meeting new people.	definitely agree	slightly agree	slightly disagree	definitely disagree

48.	I am a good diplomat.	definitely agree	slightly agree	slightly disagree	definitely disagree
49.	I am not very good at remembering people's date of birth.	definitely agree	slightly agree	slightly disagree	definitely disagree
50.	I find it very easy to play games with children that involve pretending.	definitely agree	slightly agree	slightly disagree	definitely disagree

Appendix II: Ollen Musical Sophistication Index (OMSI)

1. How old are you today?
_____ age in years !

2. At what age did you begin sustained musical activity? “Sustained musical activity” might include regular music lessons or daily musical practice that lasted for at least three consecutive years. If you have never been musically active for a sustained time period, answer with zero.
_____ age at start of sustained musical activity

3. How many years of private music lessons have you received? !
If you have received lessons on more than one instrument, including voice, give the number of years for the one instrument/voice you've studied longest.
If you have never received private lessons, answer with zero.
_____ years of private lessons

4. For how many years have you engaged in regular, daily practice of a musical instrument or singing? “Daily” can be defined as 5 to 7 days per week. A “year” can be defined as 10 to 12 months. If you have never practiced regularly, or have practiced regularly for fewer than 10 months, answer with zero.
_____ years of regular practice

5. Which category comes nearest to the amount of time you currently spend practicing an instrument (or voice)? Count individual practice time only; not group rehearsals.
● I rarely or never practice singing or playing an instrument
● About 1 hour per month
● About 1 hour per week
● About 15 minutes per day
● About 1 hour per day
● More than 2 hours per day

6. Have you ever enrolled in any music courses offered at college (or university)?
● No ˙ (Skip to #8)
● Yes

7. (If Yes) How much college-level coursework in music have you completed? If more than one category applies, select your most recently completed level.
● None
● 1 or 2 NON-major courses (e.g., music appreciation, playing or singing in an ensemble)
● 3 or more courses for NON-majors
● An introductory or preparatory music program for Bachelor’s level work

● 1 year of full-time coursework in a Bachelor of Music degree program (or equivalent)
● 2 years of full-time coursework in a Bachelor of Music degree program (or equivalent)
● 3 or more years of full-time coursework in a Bachelor of Music degree program (or equivalent)
● Completion of a Bachelor of Music degree program (or equivalent)
● One or more graduate-level music courses or degrees

8. Which option best describes your experience at composing music?
● Have never composed any music
● Have composed bits and pieces, but have never completed a piece of music
● Have composed one or more complete pieces, but none have been performed
● Have composed pieces as assignments or projects for one or more music classes; one or more of my pieces have been performed and/or recorded within the context of my educational environment
● Have composed pieces that have been performed for a local audience
● Have composed pieces that have been performed for a regional or national audience (e.g., nationally known performer or ensemble, major concert venue, broadly distributed recording)

9. To the best of your memory, how many live concerts (of any style, with free or paid admission) have you attended as an audience member in the past 12 months? Please do not include regular religious services in your count, but you may include special musical productions or events.
● None
● '1-4
● '5-8
● '9-12
● 13 or more

10. Which title best describes you?
● Nonmusician
● Music-loving nonmusician
● Amateur musician
● Serious amateur musician
● Semiprofessional musician
● Professional musician

Appendix III: Ten Item Personality Inventory (TIPI)

Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
1	2	3	4	5	6	7

I see myself as:
1. _____ Extraverted, enthusiastic.
2. _____ Critical, quarrelsome.
3. _____ Dependable, self-disciplined.
4. _____ Anxious, easily upset.
5. _____ Open to new experiences, complex.
6. _____ Reserved, quiet.
7. _____ Sympathetic, warm.
8. _____ Disorganized, careless.
9. _____ Calm, emotionally stable.
10. _____ Conventional, uncreative.

Appendix IV: Goldsmiths Musical Sophistication Index (Gold-MSI)

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 doingmusic-related activities.	1	2	3	4	5	6	7
2. I sometimes choose music that can trigger shivers down my spine.	1	2	3	4	5	6	7
3. I enjoy writing about music, for example on blogs and forums.	1	2	3	4	5	6	7
4. If somebody starts singing a song I don't know, I can usually join in.	1	2	3	4	5	6	7
5. I am able to judge whether someone isa good singer or not.	1	2	3	4	5	6	7
6. I usually know when I'm hearing a song for the first time.	1	2	3	4	5	6	7
7. I can sing or play music from memory.	1	2	3	4	5	6	7
8. I'm intrigued by musical styles I'm not familiar with and want to find out more.	1	2	3	4	5	6	7
9. Pieces of music rarely evoke emotions for me.	1	2	3	4	5	6	7

10. I am able to hit the right notes whenI sing along with a recording.	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 in a performance of a song even if I know the tune.	1	2	3	4	5	6	7
12. I can compare and discuss differences between two performances or versions of the same piece of music.	1	2	3	4	5	6	7
13. I have trouble recognizing a familiar song when played in a different way or by a different performer.	1	2	3	4	5	6	7
14. I have never been complimented for my talents as a musical performer.	1	2	3	4	5	6	7
15. I often read or search the internet for things related to music.	1	2	3	4	5	6	7
16. I often pick certain music to motivate or excite me.	1	2	3	4	5	6	7
17. I am not able to sing in harmony when somebody is singing a familiar tune.	1	2	3	4	5	6	7

18. I can tell when people sing or play out of time with the beat.	1	2	3	4	5	6	7
19. I am able to identify what is special about a given musical piece.	1	2	3	4	5	6	7
20. I am able to talk about the emotions that a piece of music 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 music.	1	2	3	4	5	6	7
22. I can tell when people sing or play out of tune.	1	2	3	4	5	6	7
23. When I sing, I have no idea whether I'm in tune or not.	1	2	3	4	5	6	7
24. Music 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 singing in public because I'm afraid that I would sing wrong notes.	1	2	3	4	5	6	7
26. When I hear a piece of music I can usually identify its genre.	1	2	3	4	5	6	7

27. I would not consider myself a musician.	1	2	3	4	5	6	7
28. I keep track of new music that I come across (e.g. new artists or recordings).	1	2	3	4	5	6	7
29. After hearing a new song two or three times, I can usually sing it by myself.	1	2	3	4	5	6	7
30. I only need to hear a new tune once and I can sing it back hours later.	1	2	3	4	5	6	7
31. Music 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 musical instrument (including voice) 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 instrument.

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

35. I have had formal training in music theory for **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 on a musical instrument (including voice) during my lifetime.

37. I can play **0 / 1 / 2 / 3 / 4 / 5 / 6 or more** musical instruments.

38. I listen attentively to music 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 instrument I play best (including voice) is ______

Appendix V: Adult Executive Functioning Inventory (ADEXI)

Definitely not true	**Not true**	**Partially true**	**True**	**Definitely true**
1	**2**	**3**	**4**	**5**

1. I have difficulty remembering lengthy instructions	1	2	3	4	5
2. I sometimes have difficulty remembering what I am doing in the middle of an activity	1	2	3	4	5
3. I have a tendency to do things without first thinking about what could happen	1	2	3	4	5
4. I sometimes have difficulty stopping myself from doing something that Ilike even though someone tells me that it is not allowed.	1	2	3	4	5
5. When someone asks me to do several things, I sometimes remember onlythe first or last	1	2	3	4	5
6. I sometimes have difficulty refraining from smiling or laughing in situationswhere it is inappropriate	1	2	3	4	5
7. I have difficulty coming up with a different way of solving a problem whenI get stuck	1	2	3	4	5
8. When someone asks me to fetch something, I sometimes forget what I am supposed to fetch	1	2	3	4	5
9. I have difficulty planning for an activity (e.g., remembering to bring everything necessary when going on a trip/to work/to school)	1	2	3	4	5
10. I sometimes have difficulty stopping an activity that I like (e.g., I watch TVor sit in front of the computer in the evening even though it is time to go to bed)	1	2	3	4	5

11.	I sometimes have difficulty understanding verbal instructions unless I amalso shown how to do something	1	2	3	4	5
12.	I have difficulties with tasks or activities that involve several steps	1	2	3	4	5
13.	I have difficulty thinking ahead or learning from experience	1	2	3	4	5
14.	People that I meet sometimes seem to think that I am more lively/wilder compared to other people my age	1	2	3	4	5

Appendix VI: Pediatric Quality of Life Inventory (PedsQL)

In the past ***ONE month****, how much of a* ***problem*** *has this been for you …*

ABOUT MY HEALTH AND ACTIVITIES *(problems with…)*	**Never**	**Almost Never**	**Some-times**	**Often**	**Almost Always**
1. It is hard for me to walk more than a couple of streets (about 100 metres)	0	1	2	3	4
2. It is hard for me to run	0	1	2	3	4
3. It is hard for me to do sports activities or exercise	0	1	2	3	4
4. It is hard for me to lift heavy things	0	1	2	3	4
5. It is hard for me to have a bath or shower by myself	0	1	2	3	4
6. It is hard for me to do chores around the house	0	1	2	3	4
7. I have aches or pains	0	1	2	3	4
8. I feel tired	0	1	2	3	4

ABOUT MY FEELINGS *(problems with…)*	**Never**	**Almost Never**	**Some-times**	**Often**	**Almost Always**
1. I feel afraid or scared	0	1	2	3	4
2. I feel sad	0	1	2	3	4
3. I feel angry	0	1	2	3	4
4. I have trouble sleeping	0	1	2	3	4
5. I worry about what will happen to me	0	1	2	3	4

HOW I GET ALONG WITH OTHERS *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. I have trouble getting along with other adults	0	1	2	3	4
2. Other adults do not want to be friends with me	0	1	2	3	4
3. Other adults tease me	0	1	2	3	4
4. I cannot do things that others my age can do	0	1	2	3	4
5. It is hard to keep up with other people my age	0	1	2	3	4

ABOUT MY WORK/STUDIES *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. It is hard to pay attention at work or college/university	0	1	2	3	4
2. I forget things	0	1	2	3	4
3. I have trouble keeping up with my work or studies	0	1	2	3	4
4. I miss work or college/university because of not feeling well	0	1	2	3	4
5. I miss work or college/university to go to the doctor or hospital	0	1	2	3	4

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