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Examining the Possibility of Cognitive Advantages on Measures of Inhibitory Control in Relation to Heightened Levels of Musical Expertise.

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ABSTRACT

Inhibitory control (IC), one of the three major components of executive functions that underlie goal-directed behaviour, appears to be a prime candidate for cognitive improvement as a result of increased musical expertise. Whilst the direct relationship is established, the underlying mechanisms that facilitate this improvement are poorly understood. Impulsivity, a personality trait that can be manifested when inhibitory control is dysfunctional, was hypothesised to potentially be one of the underlying mechanisms that influences improvements in inhibition post-musical learning. To test this hypothesis, ninety-six participants (*M* = 24.9 years, *SD* = 8.5) completed the Barratt Impulsiveness Scale (BIS-11), Dickman Impulsivity Inventory (DII) and the Goldsmith's Musical Sophistication Index (Gold-MSI). A multiple regression analysis was then performed to see whether scores of musical training and musical sophistication could predict lower scores on both measures of impulsivity. No significant relationship could be found, indicating that musical training and sophistication are poor predictors of impulsivity. The present study could not, therefore, elucidate on the foundational mechanisms that facilitate IC improvement following the gain of musical expertise. The implications of these findings are discussed in consideration of the limiting factors that may have contributed to the results.

KEY WORDS:	MUSICAL TRAINING	MUSICAL SOPHISTICATION	EXECUTIVE FUNCTIONS	IMPULSIVITY	INHIBITORY CONTROL

INTRODUCTION

Training programmes purportedly designed to expand the brain's capacity and produce cognitive improvements have been available in various modalities for decades (McDonald et al., 2002). Such programmes exist in many forms and target distinct aspects of cognition, for example training of memory (Owen et al., 2010; Morrison and Chein, 2011; Carlson et al., 2008), processing speed (Dux et al., 2009), attention (Tang and Posner, 2009; Sturm et al., 2010), and more. Via the use of such programmes, it is hypothesised that the brain undergoes structural modifications in the regions where processing takes place that result in cognitive changes (Smith et al., 2009). This is a process known as neuroplasticity, and studies have observed changes in cortical density, increases in synaptic quantities, and dendritic branching as a result of targeted training programmes (Rosenzweig and Bennett, 1995; Chang and Greenough, 1982). Cognitive enhancements arising as a result of training programmes have been seen in certain populations. Elderly participants (Nouchi et al., 2012; Boyke et al., 2010), schoolchildren (Alloway et al., 2013), and patients suffering from localised brain damage, for example Wernicke's aphasia, where the comprehension of spoken words is impaired (Musso et al., 1999; Ellis et al., 1983), are three such examples. Improvements have also been seen after participants had utilised similar principles seen in training programmes but outside of such an environment. Taxi drivers, for example, have been seen to have hippocampal expansions with resulting enhanced navigational skills (Maguire et al., 2000). Nevertheless, whilst there is some congruence as to the beneficial aspects of training programmes, a body of research also exists to contend such a position (Melby-Lervag and Hulme, 2013). Owen et al., (2010) suggest that generalised cognitive improvement may not arise as a result of every type of training intervention.

However, the breadth of research evidence seems to indicate that targeted training programmes can not only induce advantageous effects but carry clinical, developmental and rehabilitative importance, particularly in developing children and those experiencing cognitive decline (Diamond, 2012; Liu-Ambrose et al., 2010).

Research interest has also been focused on whether the cognitive enhancements resulting from task-specific programmes can be transferred to other skills. One such way this is hypothesised to occur is via mediation by executive functions (EFs) (Weinstein et al., 2012), particularly if there is an overlap of brain regions involved (Dahlin et al., 2008: Draganski et al., 2004; Karbach and Verhaeghen, 2014). EFs are defined as the top-down mental processes that are necessary for concentration, goal-directed behaviour, behavioural control, impulse management and many more aspects of cognition (Diamond, 2014). Narrowed down, there is a general agreement that EFs are comprised of three core components: inhibition, working memory and cognitive flexibility (Lehto et al., 2003). Improvements in these components of executive functioning have been widely observed as a result of training programmes; Moreno et al. (2011) report that preschool children, after receiving twenty days of music and visual arts training, performed better on measures of verbal intelligence. Additionally, older adults, after training of EFs including working memory, task-switching and inhibition via a strategy-based videogame, performed stronger on cognitive tests than control subjects (Basak et al., 2008). Brain changes, localised to the prefrontal cortex (PFC), have also been observed post-training (Klingberg, 2010). As the PFC is largely considered to be responsible for executive functioning, it seems reasonable that changes would take place in this region following tasks designed to enhance EFs

(Miller and Cohen, 2001). However, the ability for task-related cognitive improvements or transfer effects to take place may be restricted up to an indeterminate age (Dahlin et al., 2008). Whilst the efficacy of training programmes themselves has been established across decades of research, McDougall and House (2012) highlight the equal importance of other factors in the production of cognitive improvement, such as perceptions of cognitive change itself. Unfortunately, these factors are sparsely considered in as much necessary detail across research and thus their contribution to cognitive improvement remains unclear. Furthermore, the PFC may only reach full maturation in adulthood, therefore EFs and their ability to be trained may differ from adolescence to adulthood (Sowell et al., 1999). The methodological structure of training programmes and the differences between EFs in regards to how easily they can be trained are also suggested to influence the ability to experience cognitive improvements (Thorell et al., 2008). Therefore, whilst research suggests that brain training – to which it is colloquially referred – is mostly beneficial, there is a degree of contention as to the underlying processes that induce changes.

Particularly, the effects of musical training on executive functioning have been the subject of considerable research interest. Musical practice often involves high levels of control with the need for focused attention and frequent updating and monitoring of tasks. Importantly, these elements overlap with components of executive functioning. It therefore proves plausible that musical training may induce broader changes to these elements of EFs. Bialystok and DePape's (2009) study supports such a contention; participants with musical expertise performed better on an auditory task involving auditory and linguistic conflicts compared to control subjects. Enhanced performance in the areas of verbal fluency, working memory and cognitive flexibility have also been seen in adult musicians compared to non-musically trained controls (Zuk et al., 2014; Moreno et al., 2009). Additionally, Dege et al. (2011) suggest that increases in intelligence seen in young children who had experienced musical training arise as a result of the programme's positive effect on executive control processes. EFs, therefore, are critical in this transference of skills. Furthermore, differences in grey matter volume have also been seen between musicians and non-musicians, particularly in brain regions that are of importance in musical learning, for example the premotor region (Gaser and Schlaug, 2003) and the right auditory cortex (Bermudez and Zatorre, 2006). If musical training engenders processes localised to the PFC, thus expanding cortical volume in that area, it could provide an explanation for changes seen in executive functioning that can be maintained even into old age (Hanna-Pladdy and MacKay, 2011). Based on the abundance of positive research evidence available, it would seem reasonable to suggest that musical training can provide cognitive changes that may even transfer to non-task specific modalities.

Inhibitory control (IC) – one of the three core components of executive functioning – shares many overlapping processes with successful musical practice. IC can be conceptualised as the ability to deter from actions, behaviours and thoughts when necessary (Williams et al., 1999). Typical research techniques to examine IC involve behavioural paradigms that require active inhibition of responses. Such examples include the Stroop test and go/no-go measures, where participants are required to respond to certain stimuli whilst ignoring others (Simmonds et al., 2008). Fluency in musical performances requires similar inhibition of responses to perform successfully. Considerable research, therefore, has been conducted into whether musical training can produce generalised improvements on tasks of inhibition. Moreno and Farzan (2014) report that musical training can lead to long-lasting changes to IC that may not be able to be accomplished by other forms of training. This is perhaps unique to this form of training due to the significant overlap of brain processes involved in both tasks. Furthermore, musical training administered to young children has also led to enhanced performance on measures of IC (Dowsett and Livesey, 2000). These improvements to inhibition also appear to have long-lasting and permanent effects. A recent longitudinal study of 147 primary school children observed significant improvements to IC which, over time, correlated with improved academic performance (Jaschke et al., 2018). Here, the authors suggest that EFs serve to transfer the positive effects of musical training to external skills. However, longitudinal studies are limited in number in this field of research and more are needed to better understand the relationship between musicality and EFs. Additionally, the influence of individual differences is largely left unconsidered and may account for why various studies have found either no positive improvement following musical training, or have been unable to clearly define the relationship (Benz et al., 2016; Slevc et al., 2016). Few studies have made considerations for this problem. Positive effects on long-term improvement, possibly mediated by EFs, have been observed in studies that have attempted to control for individual factors such as socioeconomic status and motivation (dos Santos-Luiz et al., 2015; Schlaug et al., 2005). The effects of parental involvement and support have also been considered as a determinant of successful musical engagement in children (Dai and Schader, 2000). Whilst there has been some contention as to the affected mechanisms that facilitate cognitive change, no studies to date have observed negative effects arising as a result of musical training (Costa-Giomi, 2004). So, whilst the beneficial effects of musical training on IC are not necessarily argued, there is poor clarity as to the underlying mechanisms that are responsible for cognitive improvement.

Whilst research has examined the relationship between musical training and IC, very few studies have examined the underlying constructs of inhibition itself that may be affected by training and thus contribute to broader cognitive change. It has been suggested that dysfunctional inhibitory control can be manifested as heightened impulsivity (Verdejo-Garcia et al., 2007; Logan et al., 1997). Impulsivity refers to the tendency to act quickly without forethought and regard to negative consequences (Moeller et al., 2001). On this basis, it would be reasonable to predict that participants presenting with enhanced IC post-music training would also score lower on measures of impulsivity. Silverman et al. (2003) support such a position, suggesting that music therapy can decrease impulsivity more consistently in comparison to other therapeutic strategies. Similar improvements have also been observed elsewhere in patients with traumatic brain injuries (Thaut et al., 2009), children with hyperactivity disorders (Schachar and Logan, 1990), and those experiencing alcohol dependence issues (Dachinger, 2012). However, it should be noted that, once again, unaccounted-for individual differences may have influenced such results. Additionally, impulsivity itself can be conceptualised as being composed of multiple elements. Dickman (1990) suggests that impulsivity presents in two forms: functional and dysfunctional. The former is seen to be the tendency to act quickly and without forethought when such a style is useful (Colzato et al., 2010). The latter represents the same tendencies with the exception of such a style being used regardless of its situational usefulness. Both constructs can be measured using the Dickman Impulsivity Inventory (DII) (Dickman, 1990). Alternatively, Patton et al. (1995) suggest that impulsivity can be seen as the tendency to act without thinking (motor impulsivity), making spontaneous decisions (cognitive impulsivity) and failing to plan ahead of time (non-planning impulsivity). The Barratt Impulsiveness Scale (BIS-11) attempts to assess these components individually or in conjunction to provide an overall score of impulsivity. Continued research, therefore, has been able to clearly define inhibitory control and impulsivity and establish a relationship between them. However, research has yet to establish whether IC enhancements post-music training may be influenced by modified dysfunctional impulsivity. This study will serve to elucidate on this possible relationship and observe whether heightened musical expertise or levels of training can predict decreased impulsivity.

The present study will aim to address the lack of clarity regarding the mechanisms that contribute to advantageous cognitive change in the executive function of inhibitory control that arises as a result of musical training. Participant populations that could benefit the most from targeted musical training include those suffering from impulsivity disorders (e.g. eating and addiction disorders) (Dawe and Loxton, 2004; Steel and Blaszczynski, 1998), violent offenders (Dolan et al., 2018), patients with mood disorders (e.g. bipolar disorder) (Peluso et al., 2007), children with attention deficit hyperactivity disorder (ADHD) (Nigg, 2001), children in the important developmental period in general (Kochanska et al., 1996), and patients experiencing cognitive decline (Chao and Knight, 1997). The trait of impulsivity will be approached from a broad perspective to determine whether heightened levels of musical training and sophistication will be able to predict decreased impulsivity. Musical sophistication differs from the traditionally held conception of musical ability in that it encompasses other aspects of musicality. This includes, for example, aural skills and intricate knowledge of the components of music (Ollen, 2006). Both constructs can be measured by the Goldsmith's Musical Sophistication Index (Gold-MSI), a 38-item inventory that assesses various components of musicality in those that complete it (Mullensiefen et al., 2014). On the basis of previous research, this study hypothesises that participants who report higher levels of musical training and sophistication on the Gold-MSI will also have lower impulsivity scores on the BIS-11 and DII. These same participants will therefore demonstrate enhanced inhibitory control that this study would posit is the result of their musical expertise.

METHOD

Design

A non-experimental, correlational design was used in the conductance of this research. Self-reported levels of musical sophistication and musical talent were used as the two predictor variables (IVs). Both variables were tested separately against two criterion variables (DVs), which took the form of impulsivity scores on the BIS and DII individually. No control conditions were constructed as part of the experiment.

Participants

The study recruited 96 participants during the course of the research. The majority of participants were female, with 58 identifying as such. 33 were male, with a further 5 respondents indicating that they identified with an alternative gender. The mean age of the overall pool of participants was 24.89 years (SD = 8.48). Participants' ages ranged from 18 to 56. Recruitment was achieved either via random or opportunity sampling methods. Random sampling took the form of an advertisement placed on the Manchester Metropolitan University participation pool to recruit those seeking reimbursement in the form of credits usable on the system itself. Opportunity sampling was also conducted in the form of approaching people outside of the participation pool who were asked whether they would like to take part in the research. Opportunity sampling was used as the primary means of recruitment in order to capture a greater overall quantity of participants and to broaden the age ranges and self-reported levels of musical sophistication and talent. This was important in order to ensure there was little bias towards either side of the musicality spectrum that may have unfairly weighted the results. Furthermore, random sampling methods were necessary in order to capture a specific participant population – university students – that lessened time constraints associated with recruitment whilst also potentially capturing respondents well-versed in the field of music, perhaps current or former students of the subject itself.

Materials

Three self-report inventories were presented to participants and used during this study. The Barratt Impulsiveness Scale (BIS-11) (Patton et al., 1995) was used as one of two inventories measuring the personality trait of impulsivity. The BIS-11 (α = .78) contains 30 items, for example "I say things without thinking" and "I act on the spur of the moment". The Cronbach's alpha level of this inventory indicates that it is an acceptable measurement of impulsivity levels in those who complete it. All items were rated on a Likert scale with values ranging from 1, indicating a response of 'Rarely/Never', to 4, associated with 'Always/Almost always'.

A second self-report inventory measuring impulsivity was also used. The Dickman Impulsivity (DII) (Dickman, 1990) (α = .80) contains 23 items that assess impulsivity in two distinct elements: functional (α = .80) and dysfunctional (α = .79). An example of a question assessing functional impulsivity is "Most of the time I can put my thoughts into words very rapidly". A sample question that loads onto the dysfunctional impulsivity factor is "I frequently buy things without thinking about whether or not I can really afford them". In this study, only the factor of dysfunctional impulsivity was under examination. The Cronbach's alpha level reported for the DII suggests that the inventory is also a strong measure of impulsivity when used with the participants recruited for this study. Finally, responses to all items on the DII take the form of either ‘true’ or ‘false’.

The final inventory used as part of this study was the Goldsmith’s Musical Sophistication Index (Gold-MSI) (Mullensiefen et al., 2014). The Gold-MSI contains both a 38-item self-report inventory (α = .95) and a test battery utilising excerpts of musical performances to test melody and beat perception, amongst other elements. For this study, only the self-report inventory was used. The inventory contains items that pertain to specific components of the broader description of musical sophistication, such as emotions, active engagement, musical training, and so forth. In this study, only the distinct factors of general musical sophistication (α = .94) and musical training (α = .93) were observed. A sample question loading onto the factor of general musical sophistication is “I can sing or play music from memory”. Questions loading onto the factor of musical talent include “I would not consider myself a musician”. Items on the Gold-MSI are scored according to either a 7-point Likert scale, with values ranging from 1 (completely disagree) to 7 (completely agree), or a free-response element where participants are asked about how many years they have been trained in music theory, for example, and respond accordingly. Finally, the Cronbach’s alpha levels for the overall inventory and for the independent subscales are all strong, indicating that the Gold-MSI is an excellent measure of musical sophistication in participants.

Procedure

Prior to data collection, ethical approval for the experimental procedure was granted by the ethics panel at Manchester Metropolitan University. A copy of this application, as well as a requested amendment submitted and granted at a later date, can be found in appendix 5. Subsequent to this, the aforementioned three self-report inventories were collected and presented to participants either via the online survey distribution software known as Qualtrics or as printed hard copies. All of the aforementioned inventories can also be viewed in appendix 5. Additionally, the use of Qualtrics allowed for a link directly to the survey to be shared on the university participation pool. Several printed copies of the survey were also made and distributed to participants by the researcher. All participants who took part in the study were asked beforehand whether they would like to take part. If they agreed to do so, they were provided with an information sheet that outlined the purposes of the experiment and what would be expected of them should they choose to take part. Participants were then guided towards a consent form that required their signature to proceed further. Following that, responses were collected on all three inventories. A debrief sheet was then presented that re-affirmed the purpose of the study. At this stage, the creation of an anonymous code was permitted that served two purposes: to ensure responses were anonymous, and to allow for the removal of specific data from the study at a later stage should any participant wish to no longer have their responses form part of the analysis. Participants who completed the survey via the university-wide participation pool were provided with an appropriate number of system credits for completing the survey. However, participants recruited elsewhere were offered no alternative form of reimbursement for their time. A copy of the information sheet, consent form and debrief, as well as the invitation that participants arriving at the survey from the participation pool were presented with, can be seen in appendix 5 of this report.

RESULTS

All of the responses that were provided on the BIS-11, DII and Gold-MSI were collected via Qualtrics and then exported into SPSS v.24.0. for subsequent analysis.

Preparation of data

The data was pre-screened prior to analysis and no outlying scores were detected that may have influenced the analysis. Additionally, items 1, 7, 8, 9, 10, 12, 13, 15, 20, 29 and 30 on the BIS-11 were reverse-scored as per the author's instructions. Similarly, items 9, 11, 13, 14, 17, 21, 23, 25 and 27 on the Gold-MSI were also reverse-scored, following guidelines established by the authors. On the DII, items 1, 4, 6, 9, 11, 13, 20, 21 and 22 were reverse-scored to follow the original procedure. Following this, SPSS was used to compute the total scores on the BIS-11, the dysfunctional impulsivity scale of the DII, and the musical sophistication and training factors of the Gold-MSI. These were then used as the basis for analysis.

Reliability Analysis

All of the self-report inventories were subjected to an internal consistency analysis to determine their efficacy at measuring their respective constructs. This was achieved via the production of Cronbach's alpha levels. The BIS-11 (α = .78) was determined to be an acceptable measurement of human impulsivity and appropriate for use with the population recruited for this study. The second measure of impulsivity used in the study, namely the DII, also reached a strong level of internal consistency (α = .80), as did the dysfunctional impulsivity subscale used within (α = .79). The scale was considered to be appropriate for use within this sample. Moreover, the Gold-MSI (α = .95) was observed to have a particularly high consistency level that suggests the inventory is a strong and accurate measure of musical sophistication. Similarly, strong levels were observed for the general musical sophistication (α = .94) and musical training (α = .93) subscales within the overall inventory. Thus, these are also considered good measurements of their respective constructs for use within this population. Finally, all relevant SPSS output tables for the aforementioned Cronbach's alpha levels can be seen in appendix 1.

Descriptive statistics

Descriptive statistics for the scores on the BIS-11, dysfunctional impulsivity scale of the DII, and the musical sophistication and musical talent factors of the Gold-MSI were compiled and can be seen in Table 1.

Table 1. Mean (SD) for participant scores on the BIS-11, DII (dysfunctional impulsivity) and Gold-MSI (musical sophistication and musical training).

Inventory	**Scores**	**95% CI**	
	M (SD)	*LL*	*UL*
BIS-11	64.16 (9.97)	62.14	66.18
Dysfunctional Impulsivity	21.70 (2.77)	20.71	21.83
Musical Sophistication	80.48 (23.32)	75.72	85.17
Musical Training	27.39 (12.57)	24.85	29.94

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

Pearson's correlations were also conducted for each variable (see Table 2). As is evident, only the two measures of impulsivity – the BIS-11 and DII – significantly correlated with each other, $r(95) = -.75$, $p < .001$. The relevant output tables produced by SPSS can be seen in appendix 2.

Table 2. Correlations between all variables used in the study.

Variable	Impulsivity (BIS-11)	Dysfunctional Impulsivity (DII)	Musical Sophistication	Musical Training
Impulsivity (BIS-11)		-.75*	-.11	-.13
Dysfunctional Impulsivity (DII)			.11	.11
Musical Sophistication				.88
Musical Training				

Note. * indicates *p* <.001.

Regression Analysis

Prior to analysis, it was important to ensure that the data met the assumptions necessary for a multiple regression analysis to be performed between the two predictor variables and the BIS-11 as the criterion variable. Any violation of the underlying assumptions would indicate that an analysis of this type would be an inappropriate statistical test to conduct on the data collected. Specifically, the absence of outliers, independent errors, multicollinearity, homoscedasticity and the linearity of data were all examined. An analysis of standard residuals indicated that no outliers were present within the data (Std. Residual Min. = -2.29, Std. Residual Max. = 2.32). Following this, tests of collinearity were performed, the results of which indicate that no multicollinearity was detected between the predictor variables (musical sophistication: tolerance = .22, VIF = 4.53; musical training: tolerance = .22, VIF = 4.53). Furthermore, the data was examined for independent errors and was considered to have met this underlying assumption necessary for a multiple regression analysis to be performed (Durbin-Watson = 1.94). Finally, a scatterplot was produced to determine whether the data confirmed the assumptions of data linearity and homoscedasticity (see Figure 1). Upon examination, the data was considered to have met both of these assumptions. All relevant SPSS output tables produced in the examination of these assumptions can be viewed in appendix 3 of this report. In summary, the data was deemed to have confirmed the criteria necessary for a multiple regression analysis to be performed.

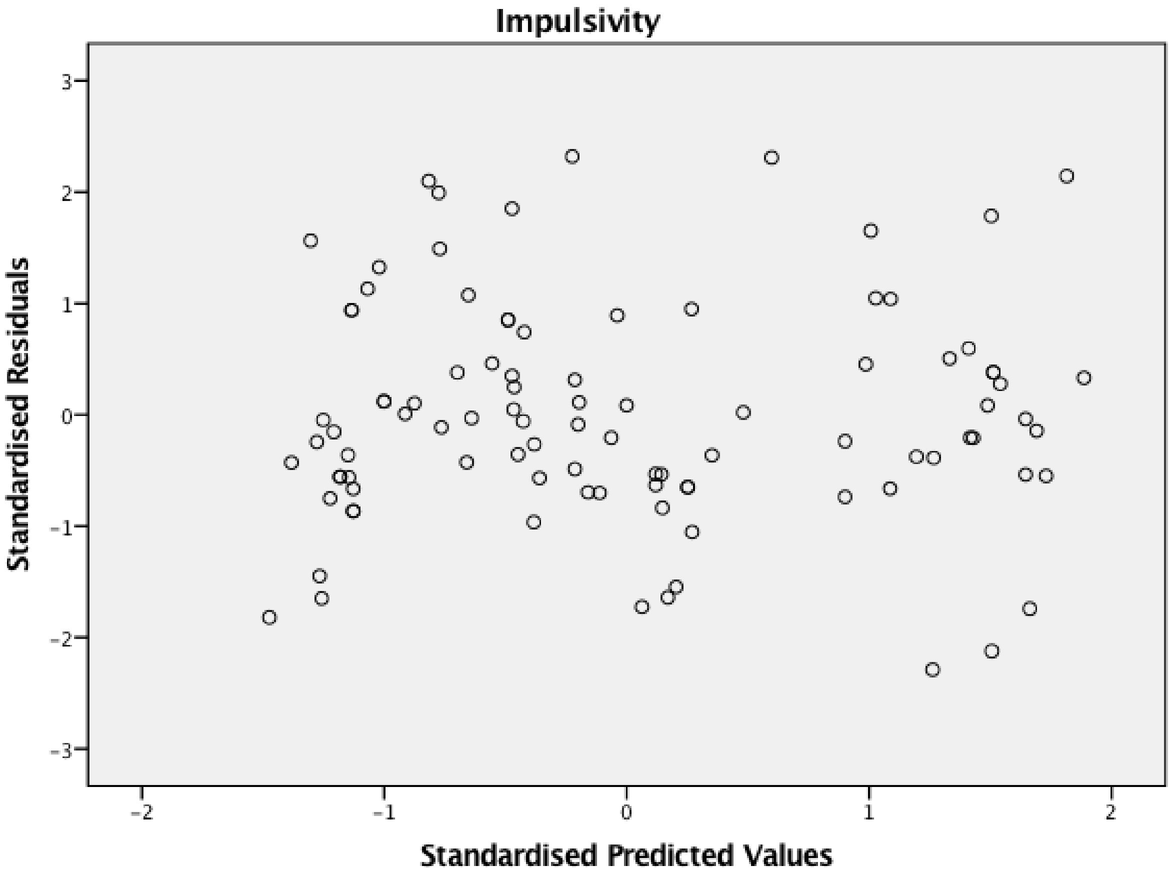

Figure 1: Scatterplot indicating data linearity and homoscedasticity between the two predictor variables and the BIS-11.

Similarly, it was necessary to test the underlying assumptions of a multiple regression analysis between the predictor variables and the dysfunctional impulsivity scale of the DII as the criterion variable. An examination of standard residuals suggested that no outliers were present (Std. Residual Min. = -2.70, Std. Residual Max. = 1.20). Tests of collinearity also indicated that no multicollinearity was found between the predictor variables (musical sophistication: tolerance = .22, VIF = 4.53; musical training: tolerance = .22, VIF = 4.53). The data also met the assumption of independent errors (Durbin-Watson = 1.96). A scatterplot was subsequently created that confirmed that the data conformed to assumptions of linearity and homoscedasticity (see Figure 2). Therefore, the data was considered to have met the conditions necessary for a multiple regression analysis between these variables to proceed. All relevant SPSS output tables can be viewed in appendix 4 of this report.

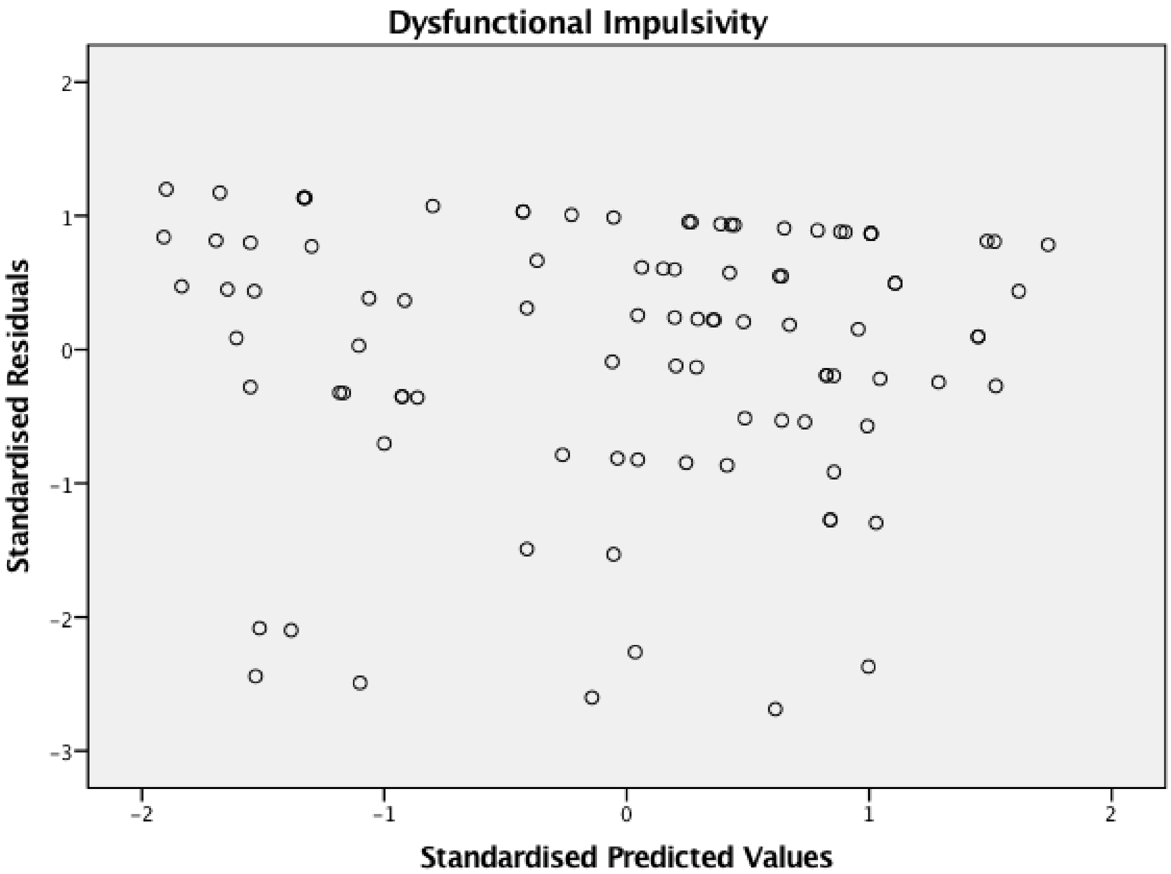

Figure 2: Scatterplot indicating data linearity and homoscedasticity between the two predictor variables and the dysfunctional impulsivity sub-scale of the DII.

Following the examination of the underlying assumptions, a multiple regression analysis was performed on the data to investigate the extent to which musical sophistication and training can predict changes in self-reported levels of impulsivity on the BIS-11. The regression was tested using the ‘enter’ method. Upon examining the results of the analysis, a non-significant model was observed, $F(2, 93) = .86$, $p = .42$. A very weak relationship between the variables was noted ($R = .14$). Using the predictor model, only an estimated 1.8% ($R^2_{adj} = -0.3\%$) of variance in impulsivity scores on the BIS-11 could be explained by musical sophistication and musical training scores. Of the variables used, musical training was stronger than musical sophistication at predicting impulsivity scores, $\beta = -.18$, $t(94) = -.82$, $p = .41$. Musical sophistication, in comparison, was even weaker at predicting scores on the impulsivity scale, $\beta = .06$, $t(94) = .25$, $p = .80$. Each predictor variable and its respective contribution to variances in impulsivity scores can be seen in Table 3.

Table 3. Summary of the multiple regression analysis in predicting impulsivity scores on the BIS-11.

Variable	*B*	***SE B*** **(Std. Error)**	***β*** **(Beta Score)**
Constant	66.20	4.13	
Sophistication	.02	.09	.06
Musical Training	-.14	.17	-.18
Note: $R^2 = .02$			

Note. $p > .05$ on all variables used.

A multiple regression analysis was also performed on the data to examine whether musical sophistication and training can predict self-reported scores of dysfunctional impulsivity as measured by the DII. This regression was tested using the ‘enter’ method. Overall, a non-significant model was found, $F(2, 93) = .22$, $p = .54$. A weak relationship between the variables was also observed ($R = .12$). Using the model to predict impulsivity scores on the DII, only an estimated 1.3% (R^2_{adj} = -0.8%) of variance in dysfunctional impulsivity scores could be explained by the predictor model. Of the two predictor variables used, musical training was only marginally stronger than musical training at predicting impulsivity scores, β = .07, $t(94)$ = .35, p = .73. Comparatively, musical sophistication was weaker at predicting dysfunction impulsivity scores, β = .04, $t(94)$ = .19, p = .85. Therefore, as was the case in the previous regression analysis performed, the predictor variables could not significantly predict scores on the dysfunctional impulsivity scale of the DII. A Table summarising each predictor variable and its contribution to variances in scores can be seen in Table 4.

Table 4. Summary of the multiple regression analysis in predicting dysfunctional impulsivity scores.

Variable	***B***	***SE B* (Std. Error)**	***B* (Beta Score)**
Constant	20.41	1.15	
Sophistication	.05	.03	.04
Musical Training	.18	.05	.08
Note: R^2 = .01			

Note. p > .05 on all variables used.

As is made clear from the results of the regression analyses performed on the data, both musical sophistication and musical training were very weak and non-significant predictors of impulsivity scores on both the BIS-11 and the DII. Musical training was stronger than musical sophistication according to both analyses, however this does not deter from the fact that both are notably poor and cannot be considered accurate predictors of impulsivity in participants.

DISCUSSION

The positive relationship between musicality and enhanced inhibitory control is a well-established one within the field of psychological research. Many studies have found improved IC post-training in a variety of different populations (Moreno and Farzan, 2014; Dowsett and Livesey, 2000), with transfer to non-task specific skills that are not intrinsic to music practice possible under presupposed conditions (Jaschke et al., 2018). The nature of this relationship has been less clear in some research (Benz et al., 2016), however there is a general congruence in opinion that musicality, amongst other forms of training, is cognitively advantageous. Inhibition, as one of the three core executive functions that govern human goal-directed behaviour, is considered to be constructed of multiple processes (Bari and Robbins, 2013). Impulsivity, a condition in which behaviour is produced without prior thought, is thought to be a core behaviour in which disinhibition is manifested (Logan et al., 1997). The goal of the present study, therefore, was to investigate whether impulsivity is modified by musical training and sophistication and, in turn, produces broader improvements to inhibitory control. Based on previous research that suggests impulsivity is intrinsically linked to inhibition, it was hypothesised that impulsivity may be one of the underlying mechanisms that is responsible for improved IC. The results of the present study were not able to confirm this hypothesis, and the affected mechanisms underlying this relationship remain unclear.

Impulsivity, as conceptualised by Dickman (1990), is not a unidimensional construct. Functional impulsivity, relating to the rapidity of thoughts and behaviours when necessary, and dysfunctional impulsivity, where such actions are cumbersome to typical functioning, are wholly different constructs with distinct implications. A participant who has had musical training or is musically sophisticated who presents with improved IC would, therefore, be theorised as having lower dysfunctional impulsive tendencies according to the DII. This was not a result that this study was able to observe. However, a question remains as to the possible beneficial effects of functional impulsivity on IC that this study did not examine. In addition, Patton et al. (1995) further suggest that dysfunctional impulsivity manifests in multiple distinct forms, from the motor to the cognitive level. The BIS-11, currently in its eleventh revised edition, assesses each of these constructs individually or combined to produce a broad score of impulsivity. Musicality, in this study, was not able to predict lower scores on this scale or the DII. This would, therefore, appear to suggest that impulsivity is not affected by musical training or sophistication and is thus not responsible for improved IC. However, this is a position that should be carefully considered. The reliability of the BIS-11 and the DII has been established by research and can therefore be considered accurate measurements of the construct. However, the varying definitions of impulsivity suggested by both inventories represents a broader confusion and inconsistency amongst research as to the definition of the trait (Carillo-de-la-pena and Romero, 1993; Reise et al., 2014). Until this confusion is rectified, it is possible that any relationship – significant or otherwise – between musicality and impulsivity will not be able to be clarified. Furthermore, despite the efficacy of the BIS-11, it has not received any significant revision since 1995. The current accuracy of the items and their ability to assess impulsivity in light of ever-changing social and cultural trends should therefore be considered (Steinberg et al., 2013). The DII, whilst not a method with such commonplace usage amongst research, presents with similar concerns. Thus, if future research were to investigate the effects of musicality on IC using impulsivity as the mechanism of action, it might perhaps be beneficial to adapt the scales to identify with current trends.

As noted by previous research, it is crucial to consider the potential effects of individual differences on the ability for musicality to promote cognitive improvement. As reported by dos Santos-Luiz et al. (2015), positive effects on inhibition were observed when controlling for factors such as socioeconomic status and motivation. This study did not account for such factors, which could explain why comparable results were not observed. Similarly, Schlaug et al. (2005) suggested that motivational levels experienced at the time of learning music is important to how much cognitive improvement can be seen. Dai and Schader (2000) further suggested that learning occurring in childhood is also affected by the levels of parental involvement and support. In the present study, it was difficult to ascertain either of these aspects that participants may have experienced when the initial learning of music first took place. The Gold-MSI allows for the assessment of current active engagement with music, although this factor was not considered in this study. However, for learning that took place in the past, the same measure would not be able to consider their level of motivation. Therefore, it would be advisable for future research to consider these critical factors to determine if they have any notable impact on the ability for musicality to promote changes to impulsivity and thus IC.

Inhibition, as a core executive function, typically presents at the behavioural level. Experimentally, disinhibition can be seen as a delayed response to selective stimuli, as seen in the go/no-go task (Simmonds et al., 2008). It is due to this behavioural presentation that inhibitory control is typically assessed via behavioural paradigms. Positive effects on IC arising as a result of musicality have been seen in abundance by previous research (Dege et al., 2011; Dowsett and Livesey, 2000). In these studies, the experimental methodology employed behavioural paradigms to investigate the relationship. It seems reasonable to assume, therefore, that inhibition is most appropriately assessed using behavioural measures. As this study was principally interested in the trait of impulsivity, it was appropriate to utilise non-experimental, self-report methods as the primary means of data collection. This does not deter from the fact that impulsivity relates to inhibition and is thus can be manifested at the behavioural level, similar to the broader definition of inhibitory control. In future research in this area, an appropriate revision may be to utilise a combination of methodological approaches. In combining self-report measures of impulsivity with behavioural assessments of inhibition, it may be that different results are observed. This may also be the case if participants are tested on measures of impulsivity both before and after musical training to see if a difference arises. If the Gold-MSI were to be used again by future research, it might be pertinent to utilise the full test battery (self-report inventory and musical perception tasks) to gauge the extent to which participants possess musical expertise. It may also be advisable to recruit a larger population sample to capture a broader spectrum of musicality that can be then be applied more generally. Whilst the sample recruited in this study was by no means minimal, a larger pool of participants may have resulted in different conclusions. It is optimistic that a larger sample, in combination with varied methodology, could serve to elucidate the mechanisms underlying the relationship between musicality and IC.

The results observed by this study hold implications for multiple population types. As previously noted, those who could benefit the most from targeted musical training programmes include developing children (Kochanska et al., 1996), elderly patients in cognitive decline (Chao and Knight, 1997) and those suffering from impulsivity disorders (Dawe and Loxton, 2004). Whilst this study was not able to observe a significant relationship between musicality and impulsivity, there are multiple reasons as to why this may have been the case. Thus, musical training programmes, when constructed and applied correctly, should not be considered any less effective on the basis of these findings. As previously established, it is not necessarily the benefits of musical training that are unclear, rather it is the specific mechanisms involved that promote such change. By adapting the methodology in future studies, the role that impulsivity plays in influencing this enhancement could be clarified. If future research were to find a more significant relationship between musicality and impulsivity, existing or future targeted music programmes administered to the aforementioned populations could potentially be enriched by the findings. On this basis, it is clear that future research is critical.

In conclusion, the importance of targeted training programmes designed with the purpose of promoting cognitive improvement in the area of inhibitory control have unquestionable importance in clinical, developmental and rehabilitative settings. Particularly, musical training programmes can be especially effective at such a task. However, to do so requires careful consideration of the individual differences that may influence cognitive change, the extent to which these present in behaviour, and how training programmes can facilitate improvement with these factors considered. The nature of the relationship between musicality and IC is well-established by research. The difficulty is observed when attempting to clearly define this relationship and the mechanisms that facilitate it. This study attempted to clarify whether impulsivity, as a trait manifested by inhibition either at the functional or dysfunctional level, is modified by musicality and contributes to broader IC change. Whilst such a contribution was not able to be found, it is suggested that with methodological adaptations, clarity may be attainable in the future.

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