AN INVESTIGATION INTO THE BENEFITS OF MUSICAL TRAINING ON COGNITIVE CONTROL AND EMOTIONAL PROCESSING ABILITIES

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A Thesis Submitted for the Degree of PhD
at the
University of St Andrews

2018

An Investigation into the Benefits of Musical Training on Cognitive Control and Emotional Processing Abilities

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This thesis is submitted in partial fulfilment for the degree of PhD

at the University of St Andrews

October 31st, 2017

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Acknowledgements

This work was supported by the University of St Andrews (School of Psychology and Neuroscience) and I am really grateful to have been given this opportunity. I extend a huge thank you to Ines my wonderful supervisor – could not have asked for a better (though, on occasion, slightly terrifying) mentor! A huge thank you to my magnificent friends. Firstly a huge thank you to Lizzie – probably the most supportive and lovely person I have ever had the pleasure of knowing. Thank you to Jennie and Fly dog for entertaining office chat and procrastination. Thanks to my 'bae' Brianna for the ever encouraging "just do it" commentary ;). Thanks to Diana for making me take an unforgettable break! Thank you Alex for always being there. Thanks to David for keeping me alive on protein shakes and to my amazing sister Sophie for too many things to mention. Oh, and Scout.

Thank you all!

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Abstract

Evidence suggests that engagement in musical activity may confer cognitive control advantages though it is not clear why this may be. Here it was explored why such advantages may be observed, exploring a potential underlying mechanism which may be responsible for these enhancements using EEG, behavioural, and self-rating methods. Chapters two and three were unable to replicate previous research which report an association between musical training and enhanced cognitive control, though the results suggest that musical training may heighten emotional responses to errors. Considering that musical performance and training involves active, frequent, and repeated engagement with emotional material, chapters four and five aimed to investigate whether musical training can lead to enhancements in emotional processing abilities using a variety of questionnaires and behavioural tasks. Chapter four found significant associations between musical training and enhanced emotional sound recognition accuracy and empathic abilities, although these effects were not replicated in the subsequent chapter, which detected only similar numerical trends. Chapter six was carried out to investigate if the potential association between musical training and enhanced empathy could be observed in a larger and more diverse sample. Furthermore, activities which use similar higher order processes were included to investigate if they could confer the same potential advantages. This study again failed to find a relationship between musical training and enhanced empathy, though dance and sport were significant predictors of higher empathy levels. Considering that all studies reported in this thesis are cross-sectional, these fragile results could be partially due to individual differences between groups and studies. In sum, the results of this thesis provide limited evidence that musical training may enhance specific emotional processing abilities and affective responses to errors which may lead to both enhanced cognitive control, and improved social awareness and interactions with others.

1. Chapter 1: General Introduction: Musical Training, Cognitive Control, and Emotional Processing

1. Chapter 1 General Introduction: Musical Training, Cognitive Control, and Emotional Processing

In order for a musician to perform successfully, the musician must master a number of cognitively demanding tasks including remembering the score, timing, motor coordination, and coordinating and synchronizing with others (Kraus & Chandrasekaran, 2010). Professional musicians however are not expert only because of these abilities, but also because of their capability in expressing and communicating the emotionality of the music (Sloboda, 2000).

Empirical research in music has mainly focused on the links between musical training and cognitive benefits and while a great deal of evidence demonstrates that musical training does appear to enhance cognitive abilities (e.g. Bergman Nutley, Darki, & Klingberg, 2014; Bidelman & Alain, 2015; Bugos & Mostafa, 2011; Costa-Giomi, 1999; Doi et al., 2017; Geoghegan & Mitchelmore, 1996; George & Coch, 2011; Hars, Herrmann, Gold, Rizzoli, & Trombetti, 2014; Hetland, 2000; Ho, Cheung, & Chan, 2003; Moreno et al., 2011; Pietsch & Jansen, 2012; Rauscher et al., 1997; Rauscher, Shaw, & Ky, 1995; Rideout & Laubach, 1996; Roden, Könen, et al., 2014; Roden, Grube, Bongard, & Kreutz, 2014; Schellenberg, 2004; Vaughn, 2000; Zuk, Benjamin, Kenyon, & Gaab, 2014), relatively little is known about the specific musical underlying mechanisms that are responsible for these improvements. It is suggested that these cognitive benefits may be driven by enhancements in executive functioning abilities, namely cognitive control. A number of research studies reveal that musical training is indeed associated with enhanced cognitive control (Bialystok & DePape, 2009; Jentzsch, Mkrtchian, & Kansal, 2014; Moreno et al., 2011; Moreno, Wodniecka, Tays, Alain, & Bialystok, 2014; Moussard, Bermudez, Alain, Tays, & Moreno, 2016; Palmer & Drake, 1997; Seinfeld, Figueroa, Ortiz-Gil, & Sanchez-Vives, 2013; Travis, Harung, & Lagrosen, 2011) though it is not understood why this might be. This effect could potentially be explained by an emotional response mediating the effect, considering that evidence demonstrates that musical training may be associated with increased responses to the occurrence of errors and conflicts (Jentzsch et al., 2014). This could explain the increased activation of cognitive control, typically observed in individuals with substantial amounts of musical training compared to individuals without musical training. This thesis therefore aims to investigate whether musical training can affect emotional responses to errors.

Furthermore, this thesis aims to explore why musical training may be associated with increased emotional responses to events. A number of research studies demonstrate that music is able to elicit emotions (Bird, Hall, Arnold, Karageorghis, & Hussein, 2016; Blood & Zatorre, 2001; Blood, Zatorre, Bermudez, & Evans, 1999; Brown, Martinez, & Parsons, 2004; Gabrielsson, 2010; Jaquet, Danuser, & Gomez, 2014; Juslin & Laukka, 2004; Koelsch, Offermanns, & Franzke, 2010; Kreutz, Bongard, Rohrmann, Hodapp, & Grebe, 2004; Krumhansl, 1997; Menon & Levitin, 2005; Panksepp & Bernatzky, 2002; Sloboda, 1991) and individuals report using music to modulate their emotions in everyday life (Juslin & Laukka, 2004; Saarikallio, 2010; Saarikallio & Erkkila, 2007). Musicians may therefore have an enhanced understanding of emotion so that they are able to express emotions to a listener, however empirical evidence in this area is tremendously limited. This thesis will consider this comparatively unexplored area by investigating the links between musical training and a number of emotional processing abilities.

1.1. Musical Training and Cognitive Control

Empirical research investigating the benefits of musical activity has generally concentrated on cognitive skills and a plethora of studies have demonstrated that musical activity can enhance a number of cognitive abilities. For example, associations have been reported between musical activity and spatial ability (e.g. Costa-Giomi, 1999; Hetland, 2000; Pietsch & Jansen, 2012; Rauscher et al., 1997; Rauscher, Shaw, & Ky, 1995; Rideout & Laubach, 1996) mathematical skills (e.g. Geoghegan & Mitchelmore, 1995; Vaughn, 2000), verbal ability (e.g. Ho, Cheung, & Chan, 2003; Moreno et al., 2011), working memory (Bergman Nutley et al., 2014; George & Coch, 2011; Roden, Grube, Bongard, & Kreutz, 2013) as well as general cognition (Doi et al., 2017; Hars et al., 2014) and intelligence (Schellenberg, 2004).

Executive functions are defined as control mechanisms that regulate various cognitive processes including set shifting, inhibition, and monitoring and updating (Miyake et al., 2000) and play a role in nearly all cognitive tasks and abilities (Hannon & Trainor, 2007). Musical performance involves activation of a number of executive functions (Jäncke, 2009), therefore Degé, Kubicek and Schwarzer (2011) proposed that enhancements in executive functioning abilities via music may mediate the associations between music lessons and general cognitive abilities.

A number of cross-sectional studies report links between enhanced executive functioning and musical activity in a range of age groups including young children, young adults, and older adults. Degé et al., (2011) reported a number of associations between music lessons and performance on tasks measuring executive functions including set shifting, selective attention, fluency, planning, and inhibition in children aged 9-11 years. In young adults, similar advantages in executive functioning are reported; Moradzadeh, Blumenthal and Wiseheart (2015) tested 18-31 year olds (*n* = 153) across four groups; monolingual musicians, bilingual musicians, monolingual non-musicians and monolingual musicians. While bilingualism did not appear to enhance executive functioning performance, the musicians demonstrated greater efficiency in task switching and dual task performance in comparison to the non-musical groups.

Furthermore, Hanna-Pladdy and MacKay (2011) tested 60-83 year olds (*n* = 70) across three groups: non-musical, low musical (less than ten years of formal training) and highly musical (more than ten years of formal training), on a number of tasks. They found the highly musical group performed significantly better than the non-musical group in measures of naming, nonverbal memory recall, visuomotor speed, visuomotor sequencing, and cognitive flexibility. Supporting the results of these various cross-sectional studies in a randomised control trial, Bugos, Perlstein, McCrae, Brophy and Bedenbaugh (2007) assigned 31 musically naïve older adults (aged 60-85 years) into either a control group (*n* = 15) or an experimental group (*n* = 16). The experimental group received six months of 30 minute weekly individualised piano instruction and were instructed to practice independently for a minimum of three hours per week. Both groups were tested pre-intervention, post-intervention, and three months post-intervention. The researchers observed that piano lessons appeared beneficial to planning, and cognitive flexibility, though enhancements in planning were not sustained after lessons were discontinued. These various studies suggest that musical training can have a beneficial effect on executive functioning abilities though it is still unclear why musical activity in particular would result in these advantages.

1.1.1. Cognitive Control

Playing a musical instrument requires activation of a number of executive functioning abilities such as working memory, timing, planning, control, and inhibition, as well as emotional expression and interaction with others towards reaching a common goal. According to Palmer and Drake (1997) the ability to monitor for future deviations in planned behaviour and subsequently adjust for them is a hallmark of musical performance skill. Moreover, Zhang, Peng, Chen and Hu (2015) suggest that the musical benefits on various executive functioning abilities are the results of enhancements in cognitive control due to the repeated use of control during musical training.

Cogntive control is loosely defined as a construct that proritisises information for goal-driven decision making (Posner & Snyder, 1975). Miller and Cohen (2001) suggest that it is the mechanism responsible for directing our resources which allow us to respond quickly and efficiently. Cognitive control capacity is limited (Posner & Snyder, 1975) therefore depending on demand, cognitive control allocation is adjusted. It is proposed that there are two types of cognitive control: evaluative control which refers to detection in lapses of control which signals the need for more control; and executive control which refers to the recruitment of control. For example, greater cognitive control is recruited during error processing. It is therefore believed that cognitive control can be tested by looking at the ability to detect (evaluative control) and adjust for errors in performance (executive control).

Botvinick, Braver, Barch, Carter, and Cohen (2001) propose the 'conflict monitoring' or 'conflict control loop' theory. This theory suggests that errors are a type of conflict and that a 'conflict monitoring system' is located in the anterior cingulate cortex (ACC). In support of this theory, studies have shown that the ACC appears to be associated with conflict monitoring and consequently the engagement of cognitive control (e.g. Bush, Luu, & Posner, 2000; Kerns, Cohen, MacDonald III, et al., 2004). When the 'conflict monitoring system' identifies conflict, it signals this information to other areas of the brain that are responsible for adjustments of cognitive control. When activated, these other areas increase control thus improving subsequent performance. The theory is widely accepted; a number of studies have found that behavioural and neural expressions of conflict are related to systematic performance adjustments in subsequent trials (see Botvinick et al., 2001; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004).

The action outcome evaluation/reinforcement theory on the other hand suggests that the ACC is not only involved in error detection but it is also involved in determining if actions are worth taking. The ACC decides whether the expected value of a reward means that it is worth acting (including inhibiting erroneous responses) (Rushworth, Walton, Kennerley, & Bannerman, 2004). Evidence for this derives from research which demonstrates that ACC activity is dependent on reward (Gehring & Willoughby, 2002). The ACC might therefore guide action selection based on cost-benefit evaluations.

While these two theories suggest that the ACC is involved in conflict monitoring due to cognitive assessments, the ACC is believed to process both cognitive and emotional information (Bush et al., 2000). Generally, it is assumed that this cognitive and emotional information is processed in two separate sub-divisions of the ACC (see Bush et al., 2000) with suppression of one sub-division observed while the other is activated (Drevets & Raichle, 1998). However, evidence suggests that cognitive control can be affected by emotions (see Mueller, 2011). For example, performance on interference tasks which are used to measure conflict monitoring ability has been found to be influenced by positive affect; the interference effect in the Stroop task was removed if the participants were cued with positive words (Kuhl & Kazén, 1999). Therefore it is suggested that activation of the ACC is due to evaluative self-monitoring along an affective dimension; if participants are distressed by the outcome of an action, the ACC monitors that action and this monitoring has subsequent effects on performance (Luu et al., 2000). Unlike the other theories, this suggests that cognitive control, modulated by the ACC, is associated with affective responses to conflicts or errors.

1.1.2. Music and Cognitive Control

A number of studies have used both behavioural and EEG techniques to investigate whether musical training is associated with enhanced cognitive control. Palmer and Drake (1997) aimed to investigate whether level of musical skill is associated with enhanced abilities in monitoring and planning by investigating errors during piano performance. The researchers tested 6-14 year old pianists; a beginner group, n = 15, M = 3.6 years tuition, an intermediate group, n = 14, M = 5.3 years tuition, and 10 adult advanced pianists (mean age: 27 years; M = 18 years tuition). The participants played pieces on a level of difficulty matched to their own musical experience. There were no differences between groups in the overall mean of errors but there were differences in the types of errors made. Correction errors were defined as one or more consecutive errors which were stopped and re-started correctly. There were no differences in the number of correction errors between the beginner and the intermediate group, though the beginners took longer to detect and correct errors than the intermediates which supports the hypothesis that monitoring improves with musical skill. Interestingly, the adult advanced pianists made very few correction errors. It could be that skilled performers are more efficient in planning and therefore better able to detect any potential deviations from the intended plan and consequently take corrective action before the error takes place in order to ensure a smooth performance.

Other studies have used conflict tasks to measure cognitive control generally finding that musicians appear to display greater cognitive control than non-musicians. For example, Bialystok and DePape (2009) tested young adults (*n* = 95) allocated to one of four groups; monolinguals, bilinguals, instrumentalists or vocalists. The musicians (both instrumental and vocal) outperformed the bilinguals and monolinguals in an auditory conflict task based on pitch (auditory Stroop); being overall faster to respond and resolving the conflict more quickly (i.e. musicians showed a smaller interference effect (incongruent RT minus congruent RT)) than the other groups. Furthermore, the musicians and bilinguals both outperformed their non-musical monolingual counterparts on a spatial conflict task (the Simon arrows task) suggesting that the beneficial effects of musical training on cognitive control are not only limited to auditory tasks. Supporting Bialystok and DePape's (2009) findings, Travis, Harung and Lagrosen (2011) tested the differences between age-matched classical musicians (*n* = 50, range: 27-63 years) (half professional, half amateur) on a Stroop task. They observed that the professional musicians showed smaller interference effects than the amateur musicians suggesting that the professionals were more adept at suppressing the prepotent response during the conflict trials than the amateurs. Furthermore, similar findings have been obtained in a longitudinal study with elderly people; Seinfeld, Figueroa, Ortiz-Gil and Sanchez-Vives (2013) tested two groups (age range 60-84 years); a group who received four months of daily group piano training lasting 90 minutes (*n* = 13) and a control group (*n* = 16) who partook in a range of other leisure activities. Results showed that the musical group displayed signficant improvements on the Stroop colour word task between pre- and post- test scores (score was calculated by summing the number of words named within 45 seconds including congruent and incongruent trials), whereas age-matched controls displayed decreased performance on post- compared to pre-test scores in the Stroop task. As the control group did partake in other activities including painting, computer lessons, physical exercise, and academic lessons among others, this indicates that improvements on the conflict task were indeed specific to invovlement in a musical context. The authors concluded that music may train or at least maintain cognitive control, which worsens as we get older, allowing for quicker conflict detection and faster inhibition of prepotent responses. Note however, that the improvements in the Stroop task performance in this study could have been a result of generally faster response speed rather than a selective benefit for excutive functions. However, not all studies report such benefits of musical activity on cognitive control processes. For example, Slevc, Davey, Buschkuel and Jaeggi (2016) tested university students (n = 96) with varying levels of musical ability (which encompassed both experience and aptitude) using a correlational design and a continuous measure of musical ability. Though the more musical people were faster overall at an auditory Stroop test, they did not show smaller interference effects. Furthermore, no differences were reported for performances on the Simon arrows task.

A range of studies have investigated cognitive control in musicians at the neuronal level. For example, Jentzsch, Mkrtchian, and Kansal (2014) divided young adults into four groups according to self-reported hours of instrumental musical practice (n = 36) (<200; 200-2000; 2000-5000; >5000 hours). Participants completed both a visual Simon and a visual Stroop conflict task. Although the size of the interference effect did not significantly differ between groups, it was observed that following a conflict or an error, amateur musicians were significantly less reactive and more efficient than non-musicians. This was discerned in both the Stroop, and the Simon, conflict tasks as shown by a smaller Gratton effect (interference effects after the experience of conflict in the previous trial), less post-error slowing and greater post-error accuracy.

Furthermore, differences were observed at the neuronal level with increases in amplitude observed in event related potentials (ERPs), thought to index error detection (the error-related negativity (ERN)) and inhibition of prepotent responses (the N200) (these ERPs will be introduced more thoroughly in chapter two), with increasing musical practice time. These results suggest that higher levels of musical practice time might be associated with greater error detection and inhibition abilities. Furthermore, Moussard, Bermudez, Alain, Tays and Moreno (2016) investigated differences between older (mean age: 69 years) musicians (*n* = 17) and non-musicians (*n* = 17) on a go/no-go task. While speed and response accuracy were similar in both groups, the musicians made fewer no-go errors indicating superior inhibitory control and displayed larger amplitudes of the N200 on no-go trials compared to the non-musicians. Moreno, Wodniecka, Tays, Alain and Bialystok (2014), however, tested adult musicians and bilinguals on a go/no go task and while no differences were found behaviourally, the musicians showed a smaller N200 amplitude than the bilinguals. However, these results are in comparison to bilinguals, therefore it could be that the bilinguals simply have even greater inhibitive abilities than the musicians though both groups may display greater amplitude of the N200 during a go/no go task than the general population. However, in an earlier study Moreno et al., (2011) pseudorandomly gave 4-6 year old children (*n* = 48) computerized training in either visual arts or music for two daily one hour sessions, five days a week for four consecutive weeks. The music group outperformed the visual arts group in post-test scores in go/no-go accuracy, however no differences between groups were observed in the N200 component. These four studies have used different samples and comparison groups demonstrating mixed findings in regards to the N200 component. The N200 amplitude has been found to increase with increasing musical training, been found diminished in musicians compared to a bilingual group, while no difference was observed in children receiving 20 days of computerized musical training when compared to a visual arts training group. It is therefore still unclear what the effects of musical training are on brain correlates for conflict and error detection.

However other evidence suggests that musicians may have efficient error detection and adjustment strategies which are mobilised during musical performances. Two studies testing only highly trained musicians found the existence of a pre-ERN during musical production suggesting that musicians can detect and adjust for errors even before an error response has been completed. Ruiz, Jabusch and Altenmuller

(2009) recorded the EEG of pianists during piano performance (n = 19) and Maidhof, Rieger, Prinz and Koelsch (2009) recorded the EEG of 10 pianists while playing scales and patterns. Both studies found differences between ERPs for correct and incorrect responses prior to note onset (increased negativity in pre-error compared to pre-correct responses) indicating the presence of the pre-ERN which suggests that the pianists could detect an error response even before they overtly made a mistake pre-response. Behaviourally, the pianists showed pre-error slowing and a decrease in the velocity of keypress (which results in a quieter note) for incorrect compared to correct responses suggesting that errors were not only detected prior to note onset, but the pianists also attempted to make adjustments to the undesirable response prior to note onset. The authors propose that accuracy in musical production may be due to feed-forward monitoring mechanisms (Ruiz et al., 2009) and/or predictive control processes that detect and adjust for errors before they are made (Maidhof et al., 2009). These results imply that during musical production error detection and subsequent implementation of control adjustments are repeatedly in action and together with Jentzsch et al's (2014) findings, suggests that musical training may enhance the effectiveness of error monitoring processes.

1.1.3. Summary: Musical Training and Cognitive Control

To summarise, a number of past studies support the idea that musicians display greater cognitive control than non-musicians. However, the exact cognitive and brain mechanisms driving these benefits are still not well understood. Some of these advantages might be driven by differences in affective reactions to conflicting and erroneous responses. Activity in the ACC is believed to be involved in cognitive control, and it has been linked to the affective processing of events. Increased brain activation in these regions could be the result of stronger affective responses, and this could explain the diverging results between studies. This stronger affective reaction towards errors may increase activity in the ACC which consequently increases the cognitive response to the error with more cognitive control allocated to the task. This aversive affective response to errors could be because musicians generally process their emotions differently to non-musicians; in order for a musician to perform successfully, they do not only require cognitive control, but also must engage emotional processes in order for the emotional content of a musical piece to be conveyed. Musical training therefore may train emotional processing and change the way in which musicians respond to events emotionally. This is an area which has received much less research interest than the cognitive advantages of musical training and will be outlined in the next section.

1.2. Musical Training and Emotion Processing

Professional musicians are not expert only because of their fine motor and executive functioning abilities, but also because of their capability in expressing and communicating the emotionality of the music (Sloboda, 2000). Despite this, research investigating the effects of musical training on emotional processing remains relatively limited in comparison to research investigating the effects of musical training on cognitive processing. In this section, it will be explored whether repeated engagement with emotional musical material during musical training can affect emotional processing abilities.

1.2.1. Music and Emotions

Emotion is broadly defined as an intensive affective reaction to specific 'objects' lasting for a limited time period (minutes up to a few hours) typically including a number of sub-components such as physiological arousal, subjective feeling, action tendency, and regulation (Clore & Schwarz, 1997; Juslin & Sloboda, 2010; Juslin & Västfjäll, 2008).

Individuals state that one of the main motivations for listening to music is because of its intrinsic emotionality (Juslin & Laukka, 2003) and furthermore report using music as an emotion and mood regulator in everyday life (e.g. Saarikallio & Erkkila, 2007; Saarikallio, 2010). While a large range of studies finds that listeners can reliably recognise emotions in music (see Juslin, 1997), there is some debate regarding whether listeners are able to simply cognitively identify the intended emotion, or whether listeners actually experience the emotion (see Konečni, 2008). A number of studies however do provide convincing evidence that music does elicit emotional reactions in listeners, at least using the emotion definition provided above, at both subjective, and at physiological levels.

1.2.1.1. *Subjective Emotional Responses to Music*

A range of studies using self-report measures has shown that people report emotional reactions to music during music listening. For example, Sloboda (1991) collected data from adult participants (*n* = 83, age range: 16-70 years) who were asked to complete a questionnaire concerning a range of physiological reactions during music listening. Eighty percent of the respondents indicated that they experienced responses typically associated with physiological reactions to non-musical emotions including 'shivers down the spine', 'laughter', 'tears' and 'lumps in the throat'. Furthermore, Krumhansl (1997) demonstrated that music listeners reliably report the 'correct' emotional reactions to music; 40 university students listened to and judged their emotional reaction to six musical excerpts. The six excerpts were chosen by the researcher to evoke three emotions in the listener; sadness, happiness, and fear. The students reported that they experienced the excerpts as invoking responses that matched the intended emotions. Panksepp and Bernatzky (2002) tested 19-23 year old adults (*n* = 16) during two listening sessions in which they listened to self-selected happy or sad music for 40 minutes. They were asked to rate how they felt on a seven point Likert scale on four dimensions: happy, sad, anxiety, and anger and at four time points: pre-listening, immediately post-listening, 10 minutes post-listening, and 20 minutes post-listening. They found that listening to music led to affective changes; happy music increased feelings of happiness while sad music increased feelings of sadness; this effect was greatest immediately post-listening, still significant 10 minutes after but diminished after the 20 minute period. Interestingly, listening to both the happy and sad music led to a short-term decrease in feelings of anger and anxiety (effect significant only immediately post-listening). Koelsch, Offermanns and Franzke (2010) completed a randomised control trial in which participants (*n* = 154; age range = 18-31 years) were allocated to either a musical group (*n* = 81) or a control group (*n* = 73). Both groups completed the profile of mood states (POMS) before and after the experimental session and were presented with 18 pieces, alongside which they were asked to either play using percussion instruments in the musical group, or tap along with using sticks in the control group. The musical group listened to musical pieces of different musical genres (rated as happy by a music psychologist), and the control group listened to and tapped along with computer generated pieces that matched the musical pieces in duration, pitch, and tempo. It was observed that the musical sessions enhanced levels of vigour and decreased levels of anxiety/depression and fatigue, while fatigue and irritability increased and vigour decreased in the control sessions. Using a within-subjects design, Kreutz, Bongard, Rohrmann, Hodapp, and Grebe (2004) recorded scores on the Positive and Negative Affect Schedule (PANAS) before and after amateur choralists (n = 31, age range: 29-74 years) passively listened to music or actively sang the piece in another session (sessions were separated by one week). The results revealed a significant increase in positive and decrease in negative affect post-singing, while no increase in positive, and an increase in negative affect was reported post-listening. This study suggests that both listening and singing can have a short-term effect on our affective state, and active music making has greater and more positive effects than passive music listening. However, it must be noted that this study used a within-subjects design without using counterbalancing, with the listening condition completed one week after the singing condition. These differences in affect could be due to boredom with the music or task and/or irritation at not singing during the session (as all were amateur choralists).

In sum, these studies using self-report measures of emotional responses to music suggest that both passive and active musical activity can have an effect on affect in the short term. Though self-report measures of emotional responses to music do provide insight on how people respond to music, they may be subject to demand characteristics (Juslin & Västfjäll, 2008). For example, participants may feel they need to choose an emotional response in a forced choice task, and/or report emotional reactions to the music when questioned with leading questions (e.g. which type of emotional reaction did you experience?). However, studies using open-ended descriptive methods also report that music listeners reliably describe emotional responses to music (Gabrielsson, 2010; Juslin & Laukka, 2004) (see also Sloboda, 2010). Furthermore, as mentioned briefly before, there is debate regarding whether people actually experience the emotion or whether they have learned to cognitively recognise the intended emotion and therefore report the cognitive, rather than the emotional, evaluation of the music.

1.2.1.2. Physiological Emotional Responses to Music

According to the definition provided above, for an emotion to be experienced, it requires both subjective feeling, as well as a physiological response. Self-report measures by listeners provide interesting insight on subjective emotional reactions when listening to music. However, alone, they do not fulfil the criteria for a full experience of an emotion. A number of experiments have shown that listening to music does induce autonomic changes associated with emotional processing. Using the same excerpts as described above, in a second experiment Krumhansl (1997) tested the physiological responses to six musical excerpts using 12 physiological measures in a further sample of 38 university students. Here it was found that the presence of music affected all 12 measures and, like with the subjective reactions, the physiological reactions differed in ways specific to the emotions under investigation. Similarly, Nyklicek, Thayer and Van Doornen (1997) recorded cardiorespiratory responses of 18-26 year old participants (*n* = 26) during music listening. Participants listened to 12 musical excerpts intended to convey four different emotions. These emotions were chosen to measure both emotional valence (happy and serenity = positive valence; sad and serenity = negative valence) and intensity (happy and agitated = more intense reactions; sad and serenity = less intense reactions). Differences in respiration rate were observed with the highest respiration rate recorded for the intense emotions. Results supporting these findings were observed by Blood and Zatorre (2001). They recorded heart rate, electromyogram, respiration depth, electrodermal response and skin temperature in adult participants (*n* = 10, age range: 20-30 years) while the participants listened to a self-selected musical piece known by the participant to elicit pleasant emotional responses and 'chills'. The experience of chills was associated with increases in heart rate, electromyogram, and respiration depth. These studies suggest that musical emotion activates similar autonomic responses that are associated with general emotional responses, thus supporting the idea that the listeners actually experience emotions.

Further supporting this idea, it has been shown that musical emotions appear to activate brain regions typically associated with emotional responses. Using EEG, Schmidt and Trainor (2001) played four 60 second musical excerpts to young adults (*n* = 59, age range: 18-34 years). The excerpts differed in both valence (positive and negative) and intensity (high and low). Greater left frontal activity was recorded during the positive (happy, joy) excerpts, while greater right frontal activity was recorded during the negative excerpts (sad, fear). These responses to musical emotions support evidence which suggests that emotions are differentially lateralised in the frontal region of the brain; left frontal activation is involved with positive emotions, while right frontal activation is involved in negative emotions (see Schmidt & Trainor, 2001). These results demonstrate that musical emotions appear to activate similar frontal brain regions to those evoked by emotional stimuli in other modalities. Furthermore, Blood, Zatorre, Bermudez and Evans (1999) used positron emission tomography (PET) to measure cerebral blood flow (CBF) while adult participants (*n* = 10) listened to six versions of an unfamiliar musical excerpt which varied in level of dissonance. Participants were asked to rate the pleasantness or unpleasantness of the excerpts. They found that activity during emotional responses to the excerpts rated as pleasant correlated with activity in paralimbic regions associated with pleasant emotions, while activity during emotional responses to the unpleasant excerpts correlated with activity in paralimbic brain regions typically associated with unpleasant emotions. Supporting these findings, as part of the Blood and Zatorre (2001) study, PET recordings found that during music induced chills CBS activity was observed in brain regions which are typically involved in reward and pleasant arousal. Extending these PET scan findings, Menon and Levitin (2005) used functional magnetic resonance imaging (fMRI) to explore differences in brain activation when young adults (*n* = 13, 19-24 years) listened to music compared to scrambled music. Enhanced connectivity between areas which mediate award, cognitive and autonomic processing (the nucleus accumbens (NAc), the ventral tegmental area (VTA), and the hypothalamus) was found in the music condition but not in the scrambled music condition. This suggests that pleasant emotions can be elicited by music in the same way that pleasant emotions are elicited by reward (see also Brown, et al., 2004).

Together these findings suggest that musical emotions are elicited in much the same way as non-musical emotions supporting the idea that music can induce real emotions. The underlying mechanisms however which allow music to do this are unclear.

1.2.2. Mechanisms of Musical Emotion

A number of theories speculate on what the underlying mechanisms are that allow music to evoke emotions in us. One of the most comprehensive theoretical frameworks in the music literature is the BRECVEM model proposed by Juslin and Västfjäll (2008) which proposes that music elicits emotions via a number of related mechanisms. These mechanisms are not expected to be treated as mutually exclusive, rather emotions may be experienced due to concurrent activation of a number of these mechanisms. Each of these mechanisms will be briefly described before other theoretical suggestions regarding the mechanisms responsible for evoking emotions via music are presented including mimicry and embodied simulation.

1.2.2.1. The BRECVEM Model

The BRECVEM (brainstem reflexes, rhythmic entrainment, evaluative conditioning, emotional contagion, visual imagery, episodic memory, and musical expectancy) model originally proposed six mechanisms that may evoke musical emotions (Juslin & Västfjäll, 2008), but this has since been expanded to seven (Juslin, Liljestrom, Vastfjall & Lundqvist, 2010).

The ‘brainstem reflex’ mechanism suggests that our perceptual systems relentlessly monitor the environment for any important changes that we may need to attend to. Sounds may be one of these important changes, and therefore we respond quickly and automatically to these changes because of a triggered increased activation of the central nervous system. It is suggested that sounds which meet specific criteria such as, for example, fast sounds, loud sounds, and/or sounds that are high or low in frequency, may activate specific physiological changes.

The ‘rhythmic entrainment’ mechanism proposes that the (external) rhythm of the music interacts with the listeners (internal) body rhythm including heart rate and respiration. The internal rhythm eventually synchronizes with the external musical rhythm, evidence for which has been found in a number of studies (e.g. Bernardi et al., 2009). Via proprioceptive feedback from this adjusted rhythm, emotions are evoked in the listener.

The ‘evaluative conditioning’ mechanism is essentially classical conditioning with music though it is more resistant to extinction (Juslin et al., 2010). Listening to a piece of music is often concurrent with other events; if a piece of music is associated with a pleasant event, this piece of music will evoke pleasant emotions when heard without the event (and vice versa for negative emotions). Moreover, supporting this idea, studies have shown that preferences for musical genres can have conditioning effects within a marketing context (e.g. see Schemer, Matthes, Wirth, & Textor, 2008).

‘Emotional contagion’ suggests that when listeners perceive emotions in music, they internally mimic those emotions and therfore experience them as their own. Emotional contagion has been observed when listeners hear speeches manipulated to express either happiness or sadness; the emotional expression conveyed in the speech induced a congruent mood in the listener, furthermore when asked to repeat the speech, participants imitated the emotional expression of the speaker (Neumann & Strack, 2000). Juslin et al., (2010) suggest that we possess a neural mechanism that responds to the ‘voice like’ aspects of music; this mechanism recognises certain features which allows us to mimic the perceived emotion and therefore experience it as our own.

The ‘visual imagery’ mechanism implies that music listeners conjure visual images while listening to music, and emotions are felt because of the interaction between the visual images and the music. Listeners may create an image of the movements in music using spatial representations of the sounds to understand them. For example, research in marketing has demonstrated that sounds and music are associated with visual mental imagery and can affect perceptions of product size (with low sounds associated with greater product size). When visual mental imagery was interfered with (i.e. a picture of the product was shown and participants did not need to rely on visual mental imagery to judge size), perceptions of size were diminshed (Lowe & Haws, 2017).

The 'episodic memory' mechanism advocates the notion that listening to music evokes emotions because it evokes a specific memory with emotional associations. This is different to evaluative conditioning as it relates to the concious recall of a specific autobiographical event. Empirical evidence has shown that listening to music can evoke specific autobiographical memories (e.g. see Janata, Tomic, & Rakowski, 2007). Such musical emotions conjured via episodic memory can be intense; Juslin et al., (2010) suggest that this may due to the physiological responses associated with that specfic memory surfacing along with the music.

Finally, the 'musical expectancy' mechanism suggests that emotions are experienced by violations or confirmations of musical expectations. Music, like language, follows certain rules and musical expectation arises through perception of the musical syntax and whether it is violated or confirmed. This is strongly dependent on learning, and children do not appear able to recognise violations of musical expectancies (see Meyer, 1956 (a great advocate of this theory).

1.2.2.2. The SAME Model

Extending the emotional contagion mechanism offered by Juslin and Västfjäll (2008), the 'Shared Affective Motion Experience Model' (SAME) proposed by Molnar-Szakacs and Overy (2006) proposes that we experience musical emotions because we simulate musical emotions. This simulation occurs via the mirror neuron system (MNS) which is a neural system which allows us to automatically and unconsciously understand and experience the actions, intentions and emotions of another in the same way we experience them ourselves. It is implied that the MNS allows understanding of meaning and intention of a signal by simulating a representation of that signal in the observers or the listeners brain (Molnar-Szakacs & Overy, 2006). Evidence of the MNS was first detected in monkeys; the same visuomotor neurons discharge both when an action is performed and when the experimenter is observed performing a similar action (di

Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Koelsch, 2010; Kohler et al., 2002) as well as in preparation of an action which indicates intention understanding (Fogassi et al., 2005) (see also Rizzolatti & Craighero, 2004). A number of neuroimaging studies have demonstrated activation of similar frontal neuronal networks in humans in both visual (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Iacoboni et al., 1999; Molnar-Szakacs, Iacoboni, Koski, & Mazziotta, 2004) and auditory (Buccino et al., 2005) action observation and imitation, suggesting the existence of a human MNS. These studies suggest that we automatically and unconsciously mimic actions which is the underlying mechanism that the SAME model is founded on.

In the musical domain, a number of studies provide support for the SAME model and the emotional contagion mechanism at both musical auditory and musical visual levels. Koelsch, Fritz, von Cramon, Müller and Friederici (2006) conducted an fMRI study on 11 participants (age range: 20-29 years) aiming to investigate neural correlates of emotion processing during music listening. Participants listened to excerpts of joyful instrumental dance tunes from a variety of musical genres which were used as the pleasant listening condition; these excerpts were electronically manipulated to one tone above or a triton below the original pitch and used as the unpleasant listening condition. Areas of the brain thought to reflect perception-action mechanisms during perception of ‘vocalisable auditory information’ (namely the rolandic operculum) were activated during the pleasant musical condition but not the unpleasant condition. The authors suggest that while perceiving pleasant auditory information, a motor-related circuitry is activated that is responsible for premotor representations for vocal sound production. This suggests that we have a neural mechanism which allows us to respond to the ‘voice like’ aspects of music (even during non-vocal instrumental music); the mechanism recognises certain features which allows us to mimic the perceived emotion and therefore experience it as our own (as described in the emotional contagion mechansims of the BRECVEM model; see also Juslin & Laukka, 2003 for more on emotional reactions to the 'voice like' aspects of music). It must be noted however, that these perception-action mechanisms did not appear to be activated while the participants listened to the unpleasant excerpts. However this could be because the unpleasant excerpts were electronic manipulations of the pleasant excerpts which could imply that the participants did not respond in the same way, not because the excerpts were unpleasant, but because they were not genuine musical pieces. In the visual domain, Livingstone, Thompson and Russo (2009) recorded motion capture and electromyography (EMG) while participants were asked to watch and listen to, then imitate melodic sung phrases. They found that the participants (n = 11, age range: 19-22 years) imitated the facial expressions of the performer during four recorded epochs: while listening to and observing the recordings of the musical phrases, while planning to imitate these phrases, while producing these phrases, and finally after imitating the phrases suggesting that facial expressions of movements lingered beyond the end of production. Together these studies suggest that music activates neurons involved in speech production and neurons involved in facial expression when observing musical performances which provides support for the SAME model of musical emotions.

1.2.2.3. The Embodied Simulation Account of Aesthetic Experiences

Similar to the SAME model, typically focused in other non-musical domains, the 'embodied simulation account of aesthetic experiences' suggests that aesthetic emotions are experienced due to simulation of actions, emotions, and corporeal sensations (Freedberg & Gallese, 2007). This theory suggests that activation of sensorimotor areas of the brain is critical to the experience of aesthetic emotions (Cross, Kirsch, Ticini, & Schütz-Bosbach, 2011). If this is the case, it is therefore of interest to consider whether expertise in the sensorimotor system can enhance emotional responses to aesthetic experiences.

1.2.3. Does experience modulate emotional responses?

The emotional contagion mechanism of the BRECVEM model, the SAME model, and the embodied simulation account of aesthetic experiences suggest that emotional response is based on embodied simulation. A number of research articles have investigated whether experience with movements can modulate affective experience and understanding. Certainly, studies have shown that people are better at identifying their own actions compared to that of others (e.g. Cañal-Bruland, Balch, & Niesert, 2015; Sevdalis & Keller, 2009, 2010, 2011) and perceptual accuracy is enhanced in domain specific activities (hence musicians, athletes and dancers etc. are used as expert judges (see Pizzera & Raab, 2012)). Christensen, Gomila, Gaigg, Sivarajah and Calvo-Merino (2016) suggest that expertise in the bodily expression of emotion (via repeated proprioceptive and exteroceptive feedback) can heighten sensitivity to the emotion conveyed in the movement of others. They conducted an empirical study to investigate this, asking female undergraduates (*n* = 24, age range: 18 -32 years) and female ballet dancers (*n* = 20, age range: 20-36 years) to watch 48 ballet dance video clips of solo performers lasting 5-6s played both forwards and backwards. The 48 clips were selected based on valence ratings; 24 happy and 24 sad clips with either low or high arousal were used (balanced across conditions). While galvanic skin response (GSR) was recorded, participants were asked to rate how sad or happy the movements made them feel. All participants were able to accurately identify the intended emotion but the dancers were better able to identify the happy and sad movements (greater differences in ratings). Dancers GSR was higher for the happy movements than for the sad movements but only in the videos presenting typical forward movements; this difference was not observed in the non-dancers. The authors conclude that these results suggest that motor expertise specific to the movement can modulate both behavioural and physiological sensitivity during the observation of affective body movements in dance.

Supporting these findings, fMRI studies have reported stronger activations in premotor areas when dancers observe movements within their own dance repertoire compared to those they had not yet attempted (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2004; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006). In addition, Kirsch, Snagg, Heerey, & Cross, (2016) used facial electromyography (EMG) to record responses while 25 dancers (at least one year of weekly regular dance practice) (mean age: 24 years) and 26 non-dancers (mean age: 21 years) watched video clips of dance movements. Participants were asked to rate how much they liked or disliked the clips. While no difference in liking ratings between the groups was observed, an interaction between liking category, EMG, and dance experience was observed with associations between the affective ratings and facial muscles only seen in the dancing group. The authors suggest that prior sensorimotor experience does affect affective responses and evaluations of dance movements. These studies generally suggest that trained dancers experience stronger affective reactions to dance than non-trained dancers at both subjective and physiological levels. While many studies have investigated the effect of dance training on appreciation of expressions of emotion in dance, other studies have shown similar effects in other domains. For example, van Paasschen, Bacci, and Melcher (2015) investigated the effects of art expertise on emotional and preference judgements. Forty novice and twenty art experts (consisting of artists and art teachers) were asked to view 100 abstract artworks, and 50 portraits and rate the pieces along four dimensions (valence: happy-sad; arousal: calm-exciting; beauty: ugly-beautiful; liking: do not like-like). While no differences were observed in the valence or the arousal dimensions, the experts rated the artworks as more beautiful and overall reported greater liking for the artworks than the novices. These results suggest that, as with dance, appreciation of artworks increases with expertise.

Sevdalis and Raab (2016) further suggest that highly trained motor skills in one domain may have far-transfer effects to the appreciation of movements and performance in other domains. Hence, they investigated whether sporting experience was associated with judgement accuracy of expressive movements in dancers. The researchers asked young adults (n = 46, age range: 19-31) with varying levels of sporting experience to watch point-light displays of individual dancers performing either in an expressive or non-expressive way. Participants were asked to rate expressive intensity of the displays (i.e. expressive or non-expressive). Results demonstrated that years of sports training could predict judgement accuracy. These results imply that training of actions in sports appears to enhance judgement accuracy of dance movements thus supporting their prediction that highly trained motor skills in one domain can enhance appreciation and possibly simulation of movements in another domain.

In summary, these results suggest that sensorimotor training can affect emotional responses during performance evaluation. Furthermore, evidence suggests that motor skills trained in one domain may have far-transfer effects to the emotional responses experienced during performance evaluation of other domains.

1.2.4. Does musical experience modulate emotional response?

A variety of studies have investigated whether musical expertise has an impact on experiencing musical emotions with somewhat mixed findings. For example, Bigand, Vieillard, Madurell, Marozeau and Dacquet (2005) conducted three experiments asking adult participants to group 27 musical excerpts according to their emotional similarity. Musical expertise only weakly influenced emotional responses to music with both groups consistently separating the excerpts into approximately seven emotional groupings though in the first experiment the musically trained participants were more consistent with their groupings than the non-musically trained. Robazza, Macaluso, & D'urso, (1994) found no effect of musical expertise on the ability to label musical pieces according to an emotion (happiness, sadness, anger or fear) in adults and children. However, the musical pieces were chosen only because they held titles which referred to typical emotional content which somewhat limits the ecological validity of these findings. In comparison, using a set of 40 musical excerpts previously validated to express two positive and two negative emotions (happiness; peacefulness; sadness; fear/threat), Castro and Lima (2014) asked adult listeners of various ages and musical expertise (n = 80) to rate to what extent each excerpt expressed these four emotions along a 10 point scale; when the highest rated emotion matched the intended emotion, this was rated as an accurate response. Castro and Lima (2014) found that although no differences in accuracy were observed between the young musicians (73%) (18-30yrs) and the young non-musicians (70%), middle-aged musicians (40-60yrs) were more accurate (73%) than their non-musical counterparts (61%). Using both self-report and physiological measures Dellacherie, Roy, Hugueville, Peretz and Samson (2011) tested differences in response to dissonance between participants with low musical experience (n = 15) and participants with high musical experience (n = 13) (age range: 19-31 years) (participants differed in both musical listening and musical practice experience).

Participants were asked to rate emotional valence (unpleasant – pleasant) and arousal (relaxing – stimulating) towards ten 7 second musical excerpts (original musical pieces were used for the consonant excerpts; the dissonant excerpts consisted of electronically manipulated versions of the original pieces: tones of the leading voice received a shift in pitch either upwards or downwards) while heart rate, skin conductance response (SCR) and EMG were recorded. While no differences between groups in arousal rating were reported, dissonance induced more unpleasant feelings in the highly musical group compared to the group with low musical experience. Furthermore, SCR recordings showed greater differences between consonant and dissonant music listening in the musical group than in the non-musical group and EMG activity was greater in the musical group compared to the non-musical group during the dissonant excerpts. From these findings, the authors suggest that musical experience increases emotional reactions to dissonance and this could be due to sustained associative learning linking unpleasant emotions with dissonance. These studies suggest that musicians may recognise emotions with slightly more accuracy than non-musicians and that they may experience musical emotions with more intensity than non-musicians.

1.2.5. Does musical experience modulate emotional response in non-musical domains?

Evidence suggests that experience can modulate emotional understanding both specific to the domain in which the individual is experienced, as well as in domains unspecific to their area of experience or expertise. The far-transfer effects of emotional musical experience however appears to not yet have been extensively studied.

In the auditory domain, researchers have demonstrated that music lessons appear to enhance the ability to identify emotions in speech prosody in both adults and children. Lima and Castro (2011) asked 40 highly trained musicians and 40 untrained controls to judge the emotional expression of short sentences using only the prosody of the sentence. The highly trained musicians were found to be more accurate than the non-musicians across age groups (18-30; 40-60 years) and emotions. Dmitrieva, Gel'man, Zaitseva and Orlov (2006) investigated the differences between 48 young musicians and 46 age-matched school children (age range: 7-17years) on perceptions of emotional information (either joy, anger or no emotion) contained in speech. They found that the young musicians were better and more efficient at perceiving the emotions than their non-musical counterparts. Thompson, Schellenberg, and Husain (2004) conducted two experiments with musically trained and untrained adult participants. In the first experiment 20 participants were asked to identify the emotion (happy, sad, fearful or angry) of tone sequences manipulated to mimic the pitch and temporal structure of spoken phrases. In the second experiment 56 participants were asked to identify one of these four emotions plus a neutral emotion option but on semantically neutral utterances spoken with emotion. Results revealed that musicians were generally better at identifying the emotions in the tonal experiment and better at recognising fear, anger and the neutral emotions in the spoken utterances experiment. Thompson et al. (2004) conducted a further experiment with 43 six year olds who were randomly assigned to one year lessons of either keyboard, vocal, drama or no lessons. The children were tested using a similar method as described above; the keyboard group performed equivalently to the drama group and they were better at recognising anger and fear than the group that received no lessons. Based on these findings, the authors concluded that musical training may enhance our sensitivity to vocal expressions of emotion and that this benefit presides both in childhood and in adulthood. Overall, these studies suggest that musical training can enhance emotion recognition in auditory domains.

1.2.6. Summary: Musical Training and Emotional Processing

To summarise, the literature suggests that musical training can enhance emotional responses and emotion recognition in music, and in auditory domains. Surprisingly however it does not appear to have been investigated whether musicians can better understand or recognise emotions beyond auditory domains. This is an interesting area for research as research in other areas (such as sport and dance) suggests that emotion recognition and emotional understanding can be enhanced with training; moreover training may be able to transcend domains.

1.3. General Aims, Research Questions and Specific Aims of Thesis Chapters

In order for a musician to perform successfully, the musician must master a number of cognitively challenging skills, as well as, repeatedly engage with, understand, and convey the emotionally of a musical piece. Musical training may therefore not only train cognitive skills as the majority of research has focussed on, but it may also train emotional processing abilities which may subsequently affect how events are responded to emotionally. The anterior cingulate cortex (ACC) is linked to both emotional and cognitive responses. A stronger emotional response in the ACC may increase cognitive activity, thereby increasing cognitive control. Some evidence subtly suggests that musical training is associated with increased reactiveness to errors, which may consequently explain why they display increased cognitive control during interference tasks, when compared to non-musicians. This thesis aims to explore whether musical training is associated with stronger affective responses to conflict and error during cognitive control tasks. Moreover, this thesis examines whether musical training can lead to enhanced emotional processing abilities, and whether these potential advantages are specific to musical activity alone.

Research Questions

Can evidence suggesting that musical training enhances cognitive control be replicated?

Does musical training affect how we respond to error or conflict on an affective level?

Does musical activity confer an advantage in emotion processing abilities beyond the musical domain?

Are these potential emotion processing benefits specific to musical activity? Can other artistic or non-artistic activities, that are cognitively and/or emotionally similarly demanding, result in similar benefits?

Overview and Aims of each Chapter

Chapter two uses EEG and interference tasks to explore whether enhancements in cognitive control observed with musical training, are due to heightened affective responses to errors. Potential affective differences are investigated using self-evaluation measures. Chapter two was unable to support findings in the literature that musical training is associated with enhanced cognitive control. However, results suggest that musical training is associated with more affective responses to errors in performance.

Chapter three explores why results in chapter two differ to those reported in the literature. The design of the study in chapter two differed from studies reported in the previous literature in a number of important ways including stimulus presentation and response configuration. Furthermore, a speed/accuracy trade off observed in the musical group in chapter two made analysis of the ERP components of interest problematic. The study reported in chapter three therefore manipulates both response configurations and instructions (focus on speed or accuracy) to explore why the results in chapter two differed to the general reported findings in the literature.

Chapter four uses both behavioural and self-report measures to investigate whether musical training can affect emotional processing abilities. If so, the effects of musical training on emotional processing may help explain the results reported in chapter two; that musical training may affect how individuals react to errors emotionally. Chapter four therefore systematically explores whether musical training is associated with enhanced emotional processing abilities using a battery of tests.

Chapter five explores interesting findings reported in chapter four; an association between musical training and empathy. As the study in chapter four appears the first to report associations between musical training and empathy in adults, chapter five investigates whether such effects can be replicated using a new sample, as well as, whether scores on another empathy measure can confirm the association between music and empathy reported using a single measure of empathy in chapter four.

Chapter six investigates if the associations between empathy and music could be replicated in a larger and more diverse online sample. Furthermore, chapter six explores whether the advantages observed are specific to musical activity or whether other activities, which use similar higher order processes, can confer the same advantages.

2. Chapter 2: The Effect of Musical Training on Cognitive Control and Affective Responses to Errors

2. Chapter 2: The Effect of Musical Training on Cognitive Control and Affective Responses to Errors

2.1. Introduction

Literature suggests that musical training may be associated with enhancements in cognitive control (see section **1.1.2**), however it is unclear why this may be. As discussed in the general introduction, cognitive control is linked with the ability to detect and adjust to errors and/or conflict. However, the ability to do this is dependent on how much value is given to the error and possibly due to affective responses to the error or conflict. Differences between musicians and non-musicians have been reported in these abilities however it is unclear why these differences occur. The current study aims to investigate whether results in the literature can be replicated, and why this may be; do musicians have different affective responses to conflict or error? Tasks and EEG components which can be effectively used to measure cognitive control will be discussed before the hypotheses for the current study are presented.

2.1.1. Tasks for measuring cognitive control

Two essential features of cognitive control include the ability to suppress irrelevant interfering information and the ability to inhibit incorrect/inappropriate prepotent responses (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002). According to Carter and van Veen (2007), the ability to detect and respond to conflict occurring between simultaneous, competing and mutually incompatible representations is a technique of measuring cognitive control capacity; when a conflict is detected, control processes are activated to overcome the conflict and improve future performance. Interference tasks present information from two competing dimensions and require both suppression of irrelevant information and inhibition of prepotent responses (i.e. response to the irrelevant dimension) which make interference tasks good candidates for measuring cognitive control (Bunge et al., 2002). For example, in the Stroop task, the participant must suppress the semantic meaning of word and inhibit the prepotent response which is to read the word, as reading is faster and more automatic than the slower controlled response of attending to and processing the colour of the font (Miller & Cohen, 2001; Travis et al., 2011). The Stroop task is a relatively simple task but with well-known interference effects; people are generally accurate in this task but tend to show increased reaction times during incongruent trials. Interference tasks such as the Stroop are also particularly helpful when investigating behavioural adjustments following a conflict which could indicate increased or decreased cognitive control (see Kerns et al., 2004). In the current study both the Stroop and the Simon task will be used to explore inhibitory abilities and post-conflict behavioural adjustments as measures of cognitive control.

2.1.2. Electroencephalogram (EEG) and Event-Related Potential (ERP) components of interest

Prior research has shown that, in some tasks, different groups of participants (e.g. younger versus older) may produce very similar behavioural results in data, but examination of processes at the neural level can demonstrate clear differences in how information is processed. For example, Tays, Dywan, Mathewson and Segalowitz (2008) found that both younger and older adults displayed similar accuracy in attentional control in a working memory task though EEG recordings revealed significant differences in neural responses (including both timing and areas of activation). These research findings demonstrate that whilst cognitive control can be measured with behavioural responses, differences in the ability to detect and adjust for conflict can also be seen clearly at the electrophysiological level, and thus recording data at both a behavioural and neural level will allow further understanding of processes utilised by different individuals when undertaking tasks.

Electroencephalography (EEG) is a non-invasive technique which records voltage changes in the brain using electrodes placed along the scalp. EEG provides a continuous temporal measurement of electrical activity in the brain which can deliver timings of neurocognitive processes in real time. Event-related potentials (ERPs) allow researchers to focus on electrical activity which is time locked to specific events such as stimuli presentation and responses to stimuli. ERPs consist of a number of components which describe the latency and the amplitude of voltage changes in relation to an event. While recording, event markers indicate presentation of stimuli and responses to stimuli. Epochs are marked out to identify ERPs. As ERPs are small relative to the EEG signal, the data from multiple trials are recorded and averaged to reduce electrical noise. Additionally, eye movements and blinks can lead to the presence of false artefacts, therefore electrodes are placed around the eye area and are controlled for in analysis.

ERPs are useful for measuring cognitive control as they can be time locked to conflicting and non-conflicting stimuli and to correct or incorrect responses. Averaging across a number of trials can explore whether there are any reliable differing characteristics such as differences in latency and/or amplitude where ERP components may occur earlier or later or have increases in amplitude when looking at differences between comparison conditions, e.g. conflicting trials compared to non-conflicting trials and post-error/post-correct responses in the Stroop and the Simon task.

Two ERP components are particularly of interest when investigating cognitive control. A number of studies investigating error processing have observed a negative ERP component appearing 50-100ms following an error response on speeded response tasks (see Botvinick et al., 2001; Yeung, Botvinick, & Cohen, 2004). This component was named the ‘Error-Related Negativity’ (ERN) and is believed to be an index of error detection (Holroyd & Coles, 2002; Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001) and is thought to be generated by the anterior cingulate cortex (ACC) (Dehaene, Posner, & Tucker, 1994). The ACC is connected to the limbic and the paralimbic areas of the brain and responds to both cognitive and affective information (Bush et al., 2000). It is proposed that the ERN may be elicited in two different ways; the cognitive evaluation of the value placed on an error and the emotional responsiveness to an error which will now be discussed.

Evidence suggests that if an error is deemed important, the amount of cognitive control allocated to that error is increased, and therefore a greater ERN amplitude will be elicited. Gehring, Goss, Coles, Meyer and Donchin (1993), and Falkenstein, Hoorman, Chrust and Hohnsbein (2000) found the ERN to be diminished if an error response was not deemed as greatly aversive; both found a significantly smaller ERN when participants were instructed to respond as quickly as possible compared to when they were instructed to respond as accurately as possible. Furthermore, Tucker, Hartry-Speiser, McDougal, Luu and deGrandepre (1999) observed a difference in ERN amplitude when responding to differing feedback, with a greater ERN provoked for negative compared to positive feedback which they suggest demonstrates that the amplitude of the ERN is based on evaluations of the importance of errors.

On the other hand, given that it is thought the ERN is activated by the ACC, and the ACC is active during pain or distressed states, Luu, Collins and Tucker (2000) proposed that the ERN may be elicited by an affective response to an error. Dehaene et al., (1994), for example, found that the ERN was not elicited when participants were unaware of a mistake suggesting that it is dependent on a conscious reaction to the error. Likewise, Luu, Flaisch and Tucker (2000) demonstrated that as participants became increasingly aware of an incorrect response (in a timed task where late responses were also deemed incorrect), the amplitude of the ERN also increased. Clinically, positive correlations between the amplitude of the ERN and high negative affect (high levels of subjective distress) have been found (Luu, et al., 2000) and Gehring, Himle and Nisenson (2000) reported that the amplitude of the ERN was correlated with symptom severity in participants with obsessive compulsive disorder (OCD), supporting the theory that OCD is related to pathologically hyperactive error signals. Supporting these findings, Hajcak, Mcdonald and Simons (2004) reported that high general negative affective experience (using PANAS) was associated with significantly greater ERN amplitudes. In summary, the ERN may be sensitive to the emotional evaluation of an erroneous response and/or how much value is placed on an erroneous response.

Moreover, Gehring et al., (1993) propose that the ERN is associated with a number of compensatory adjustment behaviours. Indeed a number of studies have found associations between the ERN and behavioural measures, with a larger ERN amplitude predicting more post-error slowing (Gehring et al., 1993; Holroyd, Yeung, Coles, & Cohen, 2005; Kerns et al., 2004; Wessel & Ullsperger, 2011), less error force (Gehring et al., 1993), and a greater probability for post-error accuracy (Carp & Compton, 2009; Gehring et al., 1993). The assumption that the ERN is associated with both affective reactions to errors and compensatory behavioural adjustments coincides with the 'attentional control theory'. This theory posits that although anxiety can impair performance, it also has the potential to facilitate the detection of threat to the goal and improve performance effectiveness by implementing compensatory mechanisms (Eysenck, Derakshan, Santos, & Calvo, 2007). The ERN may be a particularly interesting component to analyse when investigating cognitive control, and emotional responsiveness towards an error made and/or the value placed on that error.

In addition to the ERN, the N200 component which is a component with a negative polarity, occurring around 200ms following a conflict stimulus, is of interest when investigating cognitive control as it is thought that it reflects a response to the detection of conflict. For example, Azizian, Freitas, Parvaz, and Squires (2006) found that stimuli which cue conflicting responses appear to increase the amplitude of the N200. It is also thought that the N200 is sensitive to overcoming habitual prepotent responses. Using go/no-go tasks, it has been demonstrated that the N200 is augmented when participants are asked to respond to stimuli presented with low frequency regardless of which response (go or no-go) is required suggesting that it is involved in inhibiting habitual prepotent responses rather than necessarily only conflict detection (Donkers & van Boxtel, 2004; Falkenstein, Hoormann, & Hohnsbein, 1999; Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003). Thus, the N200 is a component of interest when investigating differences in detection conflict and subsequent response suppression.

2.1.3. Rationale for Current Study

Previous literature, as discussed in the general introduction, suggests that musicians and non-musicians respond to error and conflict in different ways, with musicians generally found to display greater cognitive control than non-musicians

(Bialystok & DePape, 2009; Jentzsch et al., 2014; Palmer & Drake, 1997; Seinfeld et al., 2013; Travis et al., 2011) (see section **1.1.2**). Furthermore, musical training appears to be associated with increased ERN amplitude (Jentzsch et al., 2014) which has previously been linked to greater emotional responses to errors (Dehaene et al., 1994; Gehring et al., 2000; Hajcak et al., 2004; Luu et al., 2000; Luu et al., 2000). The current study therefore aims explore whether the difference between musicians and non-musicians in cognitive control performance and ERN amplitude may be due to differential affective responses to errors. This will be investigated using EEG, behavioural performance measures and finally, in addition to methods used in other studies, a subjective performance evaluation measure.

2.1.4. Design of Current Study

Using a similar study design to Jentzsch et al., (2014) two conflict tasks are used including the Stroop task and the Simon task. While a number of studies have used the Stroop task to examine whether musicians differ to non-musicians in their ability to resolve conflict, the above mentioned studies have used a variety of different ways to test the Stroop effect. Typically studies have used a horizontal Stroop task in which participants are asked to respond by pressing either a left or right key (e.g. press right when font is red and left if font is blue) (e.g. Bialystok & DePape, 2009; Jentzsch et al., 2014). However, other studies have asked participants to vocalise their answers (e.g. Seinfeld et al., 2013), while others ask participants to select the correct colour or word from a selection beneath the stimuli (e.g. Travis et al., 2011). In the current study, a further variant of the task is used (the spatial Stroop task) to add to this body of literature.

2.1.5. Hypotheses

1. With increasing hours of musical practice an overall reduction in reaction time will be observed as demonstrated in the literature.
2. It is predicted that the more musical training individuals have, the less post-error and post-conflict interference there will be as shown by reduced post-error and post-conflict slowing and error rates.
3. The amplitude of the ERN will increase with more musical training indicating greater emotional reactiveness to errors and/or more value placed on the error.
4. Despite mixed findings in the literature regarding the N200, as the study design most closely aligns with that of Jentzsch et al., (2014) it is expected here that an increase in the amplitude of the N200 will be observed with increased musical training.
5. Musical training will increase affective responses to errors as indicated by happiness ratings on the performance evaluation questionnaire.

2.2. Methodology

2.2.1. Participants

Sixty young adults (mean age: 20.8 years, range: 17-29 years, 38 female) were divided into three groups based on self-reported accumulated hours of musical practice: low (<500h), medium (501-3000h) and high (>3000h). All participants provided informed consent, were tested in one 90 minute testing session and received reimbursement of £8.

2.2.2. Materials

Conflict Tasks: Participants completed two tasks which required participants to attend to the stimulus information, while ignoring its spatial location. Stimuli was presented either above or below a fixation point displayed in the mid-point of the screen (0.8 degrees visual angle). In the 'Stroop' task participants were presented with the words 'Above' or 'Below' and were asked to respond to the semantic meaning of the word; see **Figure 1**. In the Simon task participants were presented with an arrow pointing either upwards or downwards and asked to respond to the direction of the arrow; see **Figure 2**. A final 'mixed task' combined these two tasks.

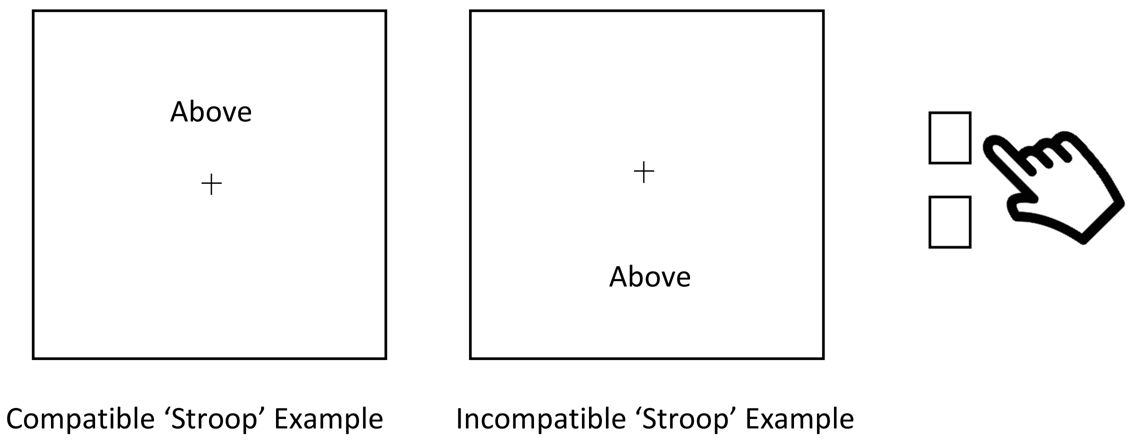
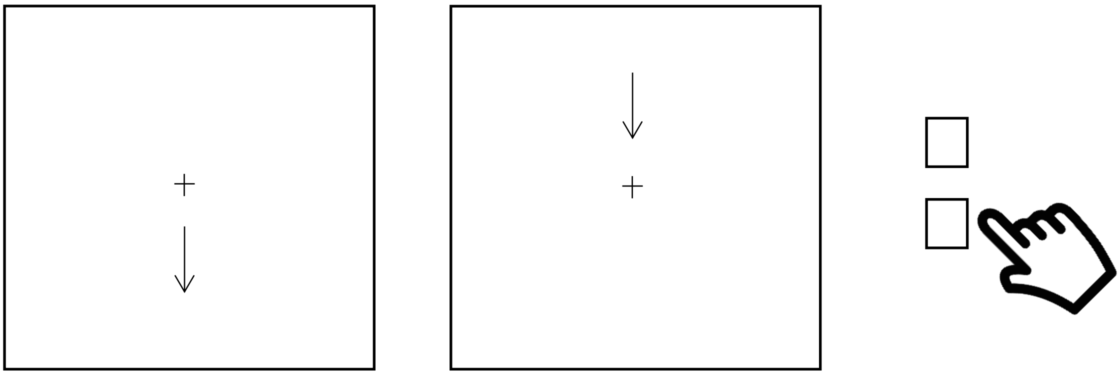


Figure 1: Compatible and incompatible 'Stroop' examples with correct response



Compatible Simon Example   Incompatible Simon Example

Figure 2: Compatible and incompatible Simon examples with correct response

Performance Evaluation Questionnaire: Participants were verbally asked to predict how many errors they made to measure their ability to detect errors. They were also asked how confident they were about their error detection ability, on a four point scale ranging from 'Not confident at all' to 'Very confident'. This was to test how musical training affected how people feel about their error detection ability. Participants were also asked how happy they were about their performance taking into account both speed and accuracy, again along a four point scale: 'Not happy at all' to 'Very happy'; this was asked to provide insight into how people may feel emotionally about their performance and to subsequently analyse if musical training has an effect on emotional reactions to performance. Answers were noted by the experimenter. These questions were asked following each of the 16 blocks with a maximum score of 4 for each question resulting in maximum total score of 64 for confidence and a maximum total score of 64 for happiness.

Musical Experience Questionnaire: Participants were also asked to complete a questionnaire regarding musical experience. This self-report questionnaire developed by Jentzsch et al., (2014), includes questions relating to accumulated practice time, number of years played, grades achieved and general musical knowledge. It also enquires about non-music related hobbies, hours spent listening to music and demographical information (see **Appendix 1**).

2.2.3. Apparatus

Stimulus presentation and data collection was conducted using 'Experimental Run-Time Software' (ERTS). The stimuli were presented at a viewing distance of 80cm on a 17-inch CRT monitor. Responses were recorded using two response key pads with keys set 10cm vertically apart.

A BIOSEMI Active-Two amplifier system with 72 Ag/AgCI electrodes was used to record the EEG. A Common Mode Sense active electrode was used as a reference electrode and a driven right leg passive electrode as a ground electrode. EEG was recorded at a sampling rate of 256Hz. Four electrodes were used to record electro-occulographic activity and trials which contained horizontal eye movements and blinks were corrected using the adaptive artefact correction method of Brain Electromagnetic Source Analysis Software (BESA).

2.2.4. Procedure

Firstly, the cap, gel and electrodes were attached for EEG recording outside of the testing booth. Participants were then asked to move into the darkened testing room and be seated in front of the computer monitor. Participants were asked to use the index finger of each hand to press their response; the position of the hands (i.e. left or right at top) was counterbalanced between participants.

Participants completed all three tasks, the single Stroop and Simon tasks were administered first and the order counterbalanced across participants. Participants completed four blocks in the Simon task and four blocks in the Stroop task: each block included 64 trials resulting in a total of 256 trials for each task completed. The mixed task was the last task completed and consisted of eight blocks, again in each block there were 64 trials: half of which were Simon trials and half Stroop trials (total of 256 Stroop trials and 256 Simon trials in the mixed task). Compatible and incompatible trials were presented randomly and with equal probability across the three tasks.

The stimuli were presented for a maximum of 2000ms or until a response was recorded. Following this, a blank interval of 1200ms was administered before the beginning of the next trial. Prior to each task (Stroop, Simon and mixed), instructions were included and participants completed 10 practice trials. After each block an interval was given. During this interval, participants were verbally questioned to judge their performance as described above, thus they completed the performance evaluation questions 16 times. Finally, participants completed the questionnaire regarding musical activity.

2.3. Results

2.3.1. Participant Characteristics

Statistical analyses were conducted to investigate possible confounds between the three musical groups. Chi-square analyses showed no statistically significant differences between the participants in the three musical groups for sex: χ^2 (2, n = 60) = 1.374, p = .503, or for handedness: χ^2(2, n = 60) = 0.735, p =.692. Please see **Table 1** for participant numbers and the results of one way ANOVAs to test for differences between the groups.

Table 1: Participant Characteristics Chapter two

	Musical Group				
	Low (n=18)	Medium (n=23)	High (n=19)	F(linear)	η_p^2
Sex (female; male)	11:7	13:10	14:5	-	-
Handedness (right; left)	16:2	20:3	18:1	-	-
Age [years]	21.9	20.8	19.9	2.75(*)	-
Years of Education [years]	16.1	15.7	15.3	0.52	-
Accumulated Practice Time [h]	116.5	1407	6377	**75.17*** **	**0.706**
Total Years Played [years]	1.8	8	13.5	**68.9*** **	**0.633**
Musical Knowledge Score	9.1	11.4	16.7	**31.5*** **	**0.489**
Listening to Music [h/week]	15.6	16.6	12.6	0.66	-
Physical Activity [h/week]	3.8	3.6	5.2	1.01	-
Computer Gaming [h/week]	3.4	2.4	0.3	1.9	-
Non-musical Artistic Activity [h/week]	0.3	1.1	1.4	1.43	-

(*)p < .1 *p <.05; ***p < .001

	Main musical instrument played
Musical Group	
Low	6 Strings, 2 Wind, 1 Percussion, 1 Voice, 4 Piano (4 n.a.)
Medium	7 Strings, 3 Wind, 3 Voice, 10 Piano
High	8 Strings, 3 Wind, 3 Voice, 5 Piano

2.3.2. Behavioural Performance

To explore group differences in reaction times and error rates, two mixed measures ANOVAs with three within-subjects factors: task type (Stroop/Simon), compatibility (compatible/incompatible trials) and task condition (single/mixed task), with music group (low/medium/high) as the between-subjects factor were run for both reaction times and error rates. Linear ANOVAs were conducted with musical groups to investigate linear trends across the dependent variables.

2.3.2.1. Overall Performance

Reaction Times: There was a significant effect of compatibility: $F(1, 57) = 543.140$, $p < .001$, $\eta_p^2 = .905$. It took participants longer to respond to incompatible (M = 431ms) than to compatible trials (M = 390ms). A main effect of task type was found: $F(1, 57) = 7.698$, $p = .007$, $\eta_p^2 = .119$; it took participants significantly more time to react to stimuli in the Stroop task (416ms) than in the Simon task (405ms). There was a main effect for task condition; $F(1, 57) = 31.575$, $p < .001$, $\eta_p^2 = .356$, with participants responding more quickly in the single task condition (M = 402ms) than in the mixed task condition (M = 419ms). There was also a main effect of musical group: $F(2, 57) = 11.495$, $p < .001$, $\eta_p^2 = .287$ with the low musical group taking significantly longer to respond than the other two groups: M = 448ms compared to M = 394ms for the intermediate group and M = 390ms for the highly musical group.

There was a significant interaction between compatibility and condition; $F(1, 57) = 10.027$, $p = .002$, $\eta_p^2 = .150$, with a greater compatibility effect (incompatible minus compatible trials) in the single task (M = 45ms) than in the mixed task (M = 38ms). There was a significant interaction between task and condition $F(1, 57) = 38.551$, $p < .001$, $\eta_p^2 = .403$; stimuli in the mixed condition took longer to respond to than stimuli in the single condition in the Stroop task (30ms) but there was not a sizeable difference between single and mixed conditions in the Simon task (4ms). There was an interaction between task condition and music group: $F(1, 57) = 4.507$, $p = .015$, $\eta_p^2 = .137$, with the difference in response time between single and mixed conditions decreasing with increasing levels of musical practice: low musical group: *M* = 30ms; intermediate: *M* = 14ms; high: *M* = 7ms, see **Figure 3**. No other effects reached significance levels; all *p*'s > .05.

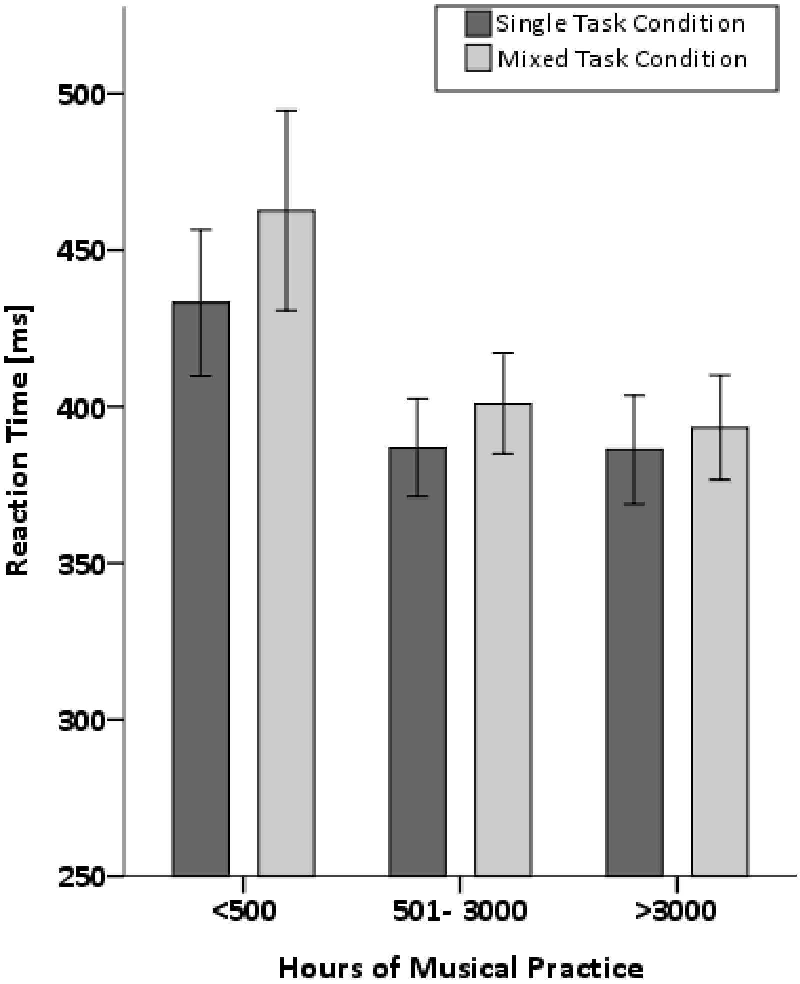


Figure 3: Mean RT's for Single and Mixed Task Conditions across Musical Groups with 95% confidence intervals

Error Rates: As in RT's, a main effect of compatibility was observed: F (1, 57) = 206.868, p < .001, η_p^2 = .784. More errors were made in incompatible (*M* = 11.8%) than in compatible trials (*M* = 3.8%). A similar main effect of task type was observed in the error rates as reported in reaction times: *F*(1, 57) = 5.381, *p* = .024, η_p^2 = .086; significantly more errors were made in the Stroop task (*M* = 8.4%) than in the Simon task (*M* = 7.3%).

A main effect of condition was observed with more errors made in the mixed condition (*M* = 8.4%) than in the single condition (*M* = 7.2%); $F(1, 57) = 10.441$, $p = .002$, $\eta_p^2 = 0.155$. There was a main effect of musical group: $F(2, 57) = 4.806$, $p = .012$, $\eta_p^2 = .144$ with an increase in errors as musical experience increases: low musical group: *M* = 5.8%; intermediate: *M* = 7.6%; high: *M* = 10.1%. Please note that this effect is opposite to was found in RT's which suggests a potential speed-accuracy trade off. There was an interaction between compatibility and musical group $F(2,57) = 5.515$, $p = .006$, $\eta_p^2 = .162$, due to an increase in the interference effect (incompatible minus compatible) with increased musical experience: low: 5.8%; intermediate: 7.6%; high: 10.1% which is opposite to the pattern predicted, see **Figure 4**. No other effects reached significance levels; all *p*'s >. 05.

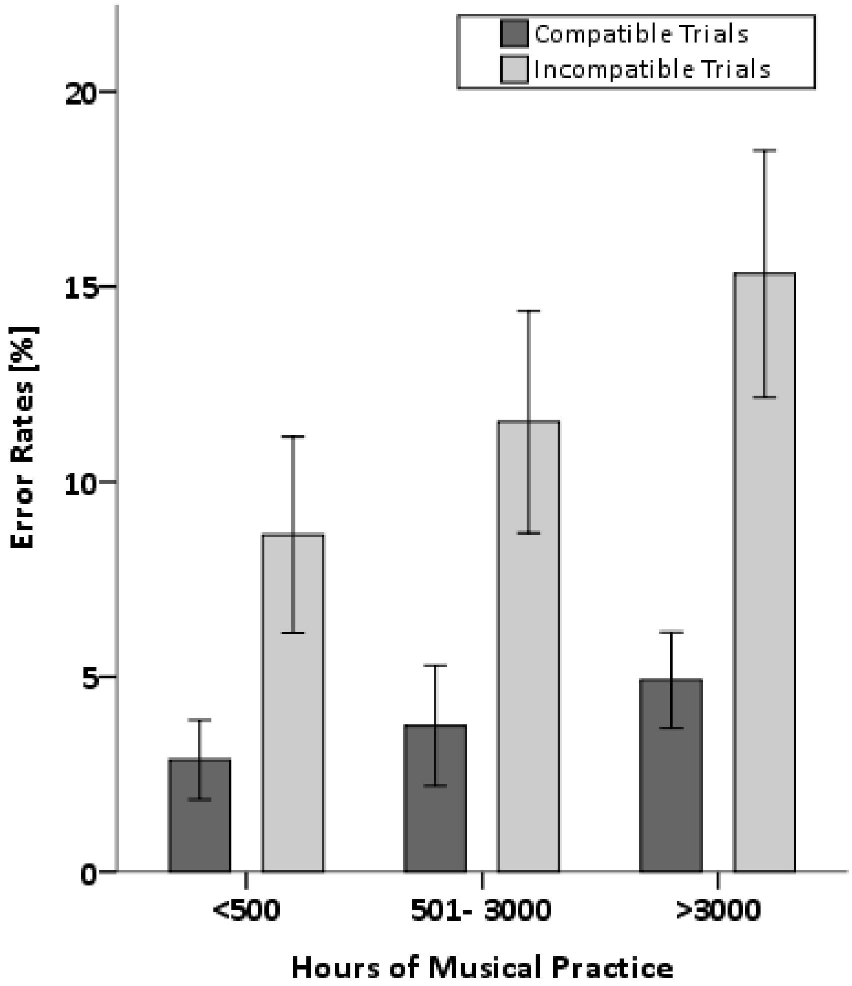


Figure 4: Compatible and Incompatible Error Rates [%] across Musical Groups with 95% confidence intervals

2.3.2.2. Sequential Effects

To investigate group differences in behavioural conflict adjustments and post-error behaviour, only the results of the single task condition were included to ensure a sufficient number of trials for analysis. For behavioural conflict adjustments, two further mixed ANOVAs were conducted with three within-subject factors including previous compatibility (compatible/incompatible), current compatibility (compatible/incompatible), and task (Stroop/Simon), with musical group as the between-subjects variable for both RT's and error rates. For this analysis, only correct trials and trials preceding correct trials were considered.

Reaction Times: There was a significant interaction between previous and current compatibility: $F(1, 57) = 478.33$, $p < .001$, $\eta_p^2 = .894$, indicating the presence of the Gratton effect of 80ms ([C-IC (M = 436), minus C-C (M = 353)] minus [IC-IC (M = 398) minus [IC-C (M = 395)]), which demonstrates that the compatibility effect was smaller after incompatible trials (3ms) than after compatible trials (83ms). There was a significant three-way interaction between current compatibility, previous compatibility and task: $F(1, 57) = 17.55$, $p < .001$, $\eta_p^2 = .235$; with the Gratton effect found to be significantly larger in the Simon task (90ms) than in the Stroop task (70ms). No other effects reached significance levels: all p's > .05.

Error Rates: There was a main effect for previous compatibility with more mistakes made when previous stimuli was incompatible (M = 4.3%) than when compatible (M = 2.0%); $F(1, 57) = 92.83$, $\eta_p^2 = .620$. There was an interaction between previous and current compatibility: $F(1, 57) = 186.57$, $p < .001$, $\eta_p^2 = .766$ with a Gratton effect ([C-IC (M = 8.0%) minus C-C (M = 0.5%)] minus [IC-IC (M = 1.8%) minus IC-C (2.2%)]) of 7.9% present which indicates that as with RT's, the compatibility effect on error rates was smaller following incompatible trials (-0.4%) than when trials followed compatible trials (7.5%). A three-way interaction between previous and current compatibility, and music group was observed: $F(2, 57) = 3.60$, $p = .034$, $\eta_p^2 = .112$; this was due to an increasing Gratton effect with increasing hours of musical practice: low (5.6%), medium

(8.9%) and high (9.1%), (see **Figure 5**). No other effects reached significance levels: all *p*'s > .05.

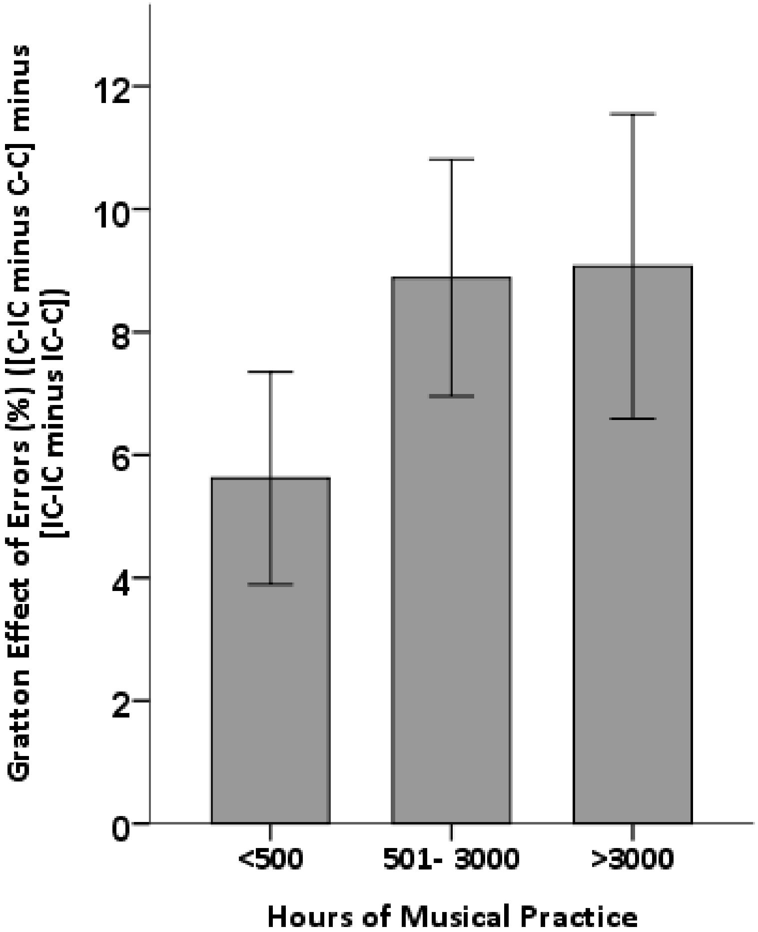


Figure 5: Group Differences in Gratton Effects in Error Rates (%) with 95% confidence intervals

2.3.2.3. Post-error effects

To explore musical group differences in post-error behaviour, two mixed ANOVAs were conducted using the within-subjects factors task (Stroop/Simon) and trial type (post-error/post-correct), again with musical group as the between-subjects factor.

Reaction Times: Post-error trials were significantly slower (M = 465ms) than post-correct trials (M = 393ms), $F(1, 57) = 130.59$, $p < .001$, $\eta_p^2 = .696$ indicating a post-error slowing effect. This however, was not modulated by music group: F(linear: 1,59) = 0.73, $p = .396$. There was an interaction between type of task and trial type $F(1, 57) = 4.958$, $p = .03$, $\eta_p^2 = .080$, due to the post-error slowing effect (post-error minus post-correct) being smaller in the Stroop task (60ms) than in the Simon task (83ms). No other effects reached significance levels: all *p*'s > .05.

Error rates: No effects reached significance levels: all *p*'s > .05.

2.3.3. Electrophysiological Performance

The continuous EEG recording was segmented into stimulus- and response-locked epochs, each of which lasted for 1000ms, beginning 200ms before stimulus onset (stimulus-locked epoch) or keypress response (response locked epoch). Trials were removed from the analysis if they contained amplitudes larger than 100 uv, a gradient larger than 75 uv and/or a signal lower than 0.032 uv. One participant's data is not included due to a recording fault resulting in a sample size of 59.

The N200 latency and amplitude were analysed using two mixed measures ANOVAs with two within-subjects factors: task (Stroop/Simon) and task condition (Single/Mixed) and one between-subjects factor: musical practice level (low/medium/high). To explore group differences in the amplitude and latency of the ERN, single and mixed task conditions and tasks were combined to provide a sufficient number of trials for analysis. Linear ANOVAs were conducted in both the N200 and ERN latencies and amplitudes to investigate linear trends with increasing levels of musical practice.

2.3.3.1. N200

The mean amplitude of the N200 was analysed in difference waves (incompatible minus compatible trials) at the FCz electrode 250-350ms post stimulus onset in a 50ms time window around the peak latency of the grand mean.

Latency: No effects reached significance levels: all *p*'s > .05.

Amplitude: The N200 amplitude was significantly larger in the Simon task (M = -1.96 µV) than in the Stroop task (M = -1.38 µV), F(1, 56) = 13.599, p = .001, η_p^2 = .195. There were no significant differences between music groups for either task. A linear trend can be observed between musical groups with latency shortening and the amplitude increasing as musical practice increased but only in the Single Stroop task; see **Table 2** for means and F linear values and **Figure 6** for ERP waveforms.

Table 2: Latency and amplitude N200 in single and mixed tasks by musical group: results of linear ANOVAs

			Musical Group			
N200			Low *M (SD)*	Medium *M (SD)*	High *M (SD)*	*F*(linear)
Latency[ms]	Single	Stroop	513(37)	505(28)	493(34)	3.601(*)
		Simon	504(31)	496(23)	503(25)	0.015
	Mixed	Stroop	510(30)	508(30)	501(35)	0.720
		Simon	499(34)	496(31)	500(33)	0.020
Amplitude[μV]	Single	Stroop	-1.09(1.2)	-1.78(1.8)	-1.92(1.2)	3.078(*)
		Simon	-1.89(1.6)	-1.98(1.3)	-2.21(1.8)	0.401
	Mixed	Stroop	-0.74(1.2)	-1.37(1.5)	-1.36(1.4)	1.822
		Simon	-1.42(1.7)	-2.3(1.6)	-2(1.7)	1.158

(*) $p < .10$

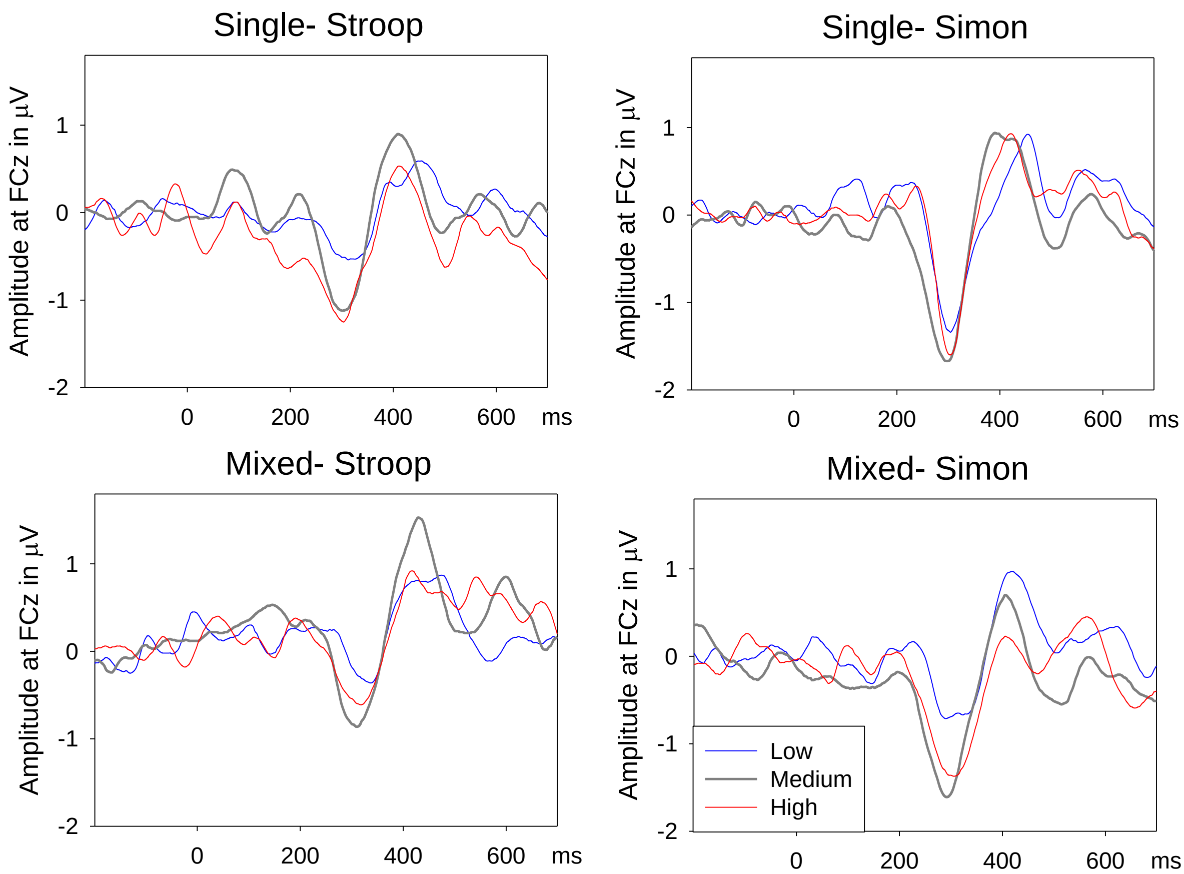


Figure 6: Stimulus-locked ERP waveforms depicting the N200 component (FCz electrode) across each single and mixed task using the difference waveforms averaged across musical practice level

2.3.3.2. ERN

ERN peak amplitudes were measured in difference waves (errors minus correct response) at the FCz electrode in a search window 0-100ms after response onset. The amplitude and the latency of the ERN did not significantly differ between musical groups, see **Table 3** for the results of the linear ANOVAs.

Table 3: Results of linear ANOVAs for ERN amplitude and latency (Ms) across musical groups

	Musical Group			
ERN	Low	Medium	High	
	M (SD)	*M (SD)*	*M (SD)*	*F*(linear)
Latency [ms]	256(15)	253(21)	262(19)	0.713
Amplitude [µV]	-7.8(0.8)	-9.23(0.8)	-8.2(0.9)	0.105

2.3.4. Explicit Performance Monitoring

Pearson correlations were performed between the total number of errors made and the total number of predicted errors to measure whether participants are able to evaluate their own performance accurately. Indeed, the Pearson correlation revealed that total errors correlated strongly with predicted errors: r = .800, n = 60, p < .001, suggesting that participants could predict their own performance with accuracy. Furthermore happiness with performance correlated negatively with number of errors r = -.324, n = 60, p = .011, and more importantly happiness with performance correlated negatively with number of predicted errors r = -.436, n = 60, p < .001, suggesting that participants were negatively affected by a poorer predicted performance. To test differences in correlation strength between the musical groups, standardised scores within the groups were calculated and using the 'split file' function in SPSS, Pearson correlations within groups were tested. The correlation between happiness with performance and number of predicted errors was not significant in the low musical group: r = -.178, n = 18, p = .479, while it was significant in the intermediate group: r = -.560, n = 23, p = .023, and a trend was observed in the highly musical group: r = -.401, n = 19, p = .089. This suggests that happiness with performance was most affected by a higher number of predicted errors in the intermediate group, while individuals in the low musical group were not significantly affected.

There was a significant difference between the groups for total confidence in the ability to detect errors: F(linear: 2, 57) = 6.394, p = .014, η_p^2 = .095; those in the low musical group were significantly more confident in their error detection than the intermediate or highly musical groups. No significant differences were observed in error detection accuracy (error prediction accuracy was calculated by subtracting the number of predicted errors from the number of actual errors and converting them into absolute difference scores), though numerically error predicition progressively worsened with increasing musical training. There was also no significant difference in overall happiness with performance ratings between musical groups. See **Table 4**.

Table 4: Results of linear ANOVAs for Error Evaluation Questionnaire across musical groups

	Musical Group			
	Low	Medium	High	
	M (SD)	*M (SD)*	*M (SD)*	*F(linear)*
Error Prediction Accuracy	12.11 (22.7)	16.22 (32.7)	18.90 (24.9)	0.561
Happiness with Performance	46.39 (6.4)	44.26 (6.6)	44.63 (5.0)	0.781
Confidence in Error Detection	55.17 (7.4)	47.74 (8.9)	48.63 (6.9)	**6.394***

*p < .05

2.4. Discussion

Previous research reports that musical training appears to augment the ERN during conflict tasks, which potentially suggests greater emotional reactiveness to errors. The aim of the current study was to investigate whether musical training differentially affects emotional reactions to errors using behavioural, neuronal, and explicit performance evaluation measures. If so, this may explain why previous research suggests that musical training is associated with greater cognitive control abilities.

It was predicted that reaction time across tasks would decrease alongside increasing hours of musical practice and the results support this prediction. As in previous studies (e.g. Bugos et al., 2007; Gruhn, Galley & Kluth, 2003), an increase in musical practice appears to be associated with faster speed of processing. However, in this study, speed was traded for accuracy with an increase in error rates observed alongside increasing hours of musical practice, therefore this result must be regarded with caution.

It was further predicted that people with more musical training would show less post-error and post-conflict reactiveness. However this was not supported. In fact an opposite trend is observed in error rates with an increasing Gratton effect with increasing hours of musical practice. There were no differences between the musical groups in post-error reaction times or error rates. This contrasts with the results of Jentzsch et al., (2014) who observed a decrease in the Gratton effect, reduced post-error slowing and improved post-error accuracy with increasing hours of musical training. The results here suggest that the more musical training people had, the more reactive they were to conflict though the same cannot be concluded for post-error error rates or post-error slowing. This could suggest that post-conflict behaviour is affected differently by musical training than how it affects post-error behaviour though this does not concur with the previous literature.

There were no differences between groups observed for amplitude of the ERN, rejecting the third prediction that the more musically trained would display a larger ERN amplitude than the non-musically trained. These findings do not support those observed by Jentzsch et al., (2014) who found the amplitude of the ERN to increase with increasing musical practice levels suggesting that musical training affects how we monitor and compensate for errors. However, as mentioned above, there was a speed/accuracy trade off with people with higher levels of musical training performing more quickly but compromising accuracy for this speed. This causes a problem when analysing the ERN results as it is thought that the ERN may not only be related to action monitoring and adjustment, but it may also be related to the evaluation of the importance of an error. Importantly for the present results, and as discussed in the introduction, studies have found the amplitude of the ERN to be augmented when errors were considered more aversive (in an accuracy compared to in a speed condition) (Falkenstein et al., 2000; Gehring et al., 1993). It is therefore not surprising that no differences between the musical groups in ERN amplitude were observed as the highly musical group appeared to place less value on accuracy than on speed in contrast to the groups with less musical training. This may have diminished the ERN amplitude in the highly musical group, which may have otherwise been greater than the less musical groups, as reported in the previous literature.

Based on previous literature, it was predicted that musical training would increase the amplitude of the N200; the results do not support this hypothesis showing no significant differences between musical groups. However, there was a trend for the single Stroop task which showed a shorter latency and an increase in the amplitude of the N200 with increases in musical training. The single Stroop task is the task most closely aligned to tasks used in previous literature that also found an increasing N200 amplitude with musical training (Jentzsch et al., 2014). The N200 is thought to be an index of conflict detection and suppression of habitual prepotent responses and these results suggest that the type of task (Simon or Stroop) targets different types of conflict which subsequently has differential effects on conflict detection and response suppression. These results suggest that musical training may differentially affect the N200 and differences in the types of conflict tasks used (e.g. Stroop, Simon, or go/no-go tasks) in the previous literature may explain why the literature reports differing effects of musical training on the N200. This is an ERP component that therefore requires more study.

A negative correlation between happiness with performance and number of predicted errors was found suggesting that participants are able to accurately monitor their own performance. A subjectively rated weaker performance resulted in less happiness with performance which suggests that participants are somewhat negatively affected by erroneous responses. The strength of the negative correlation between a poorer performance and happiness was predicted to increase with increasing hours of musical training. The strongest correlation was observed in the intermediate group, while a trend was observed in the highly musical group, and no correlation was observed in the low musical group. This suggests that even small amounts (from 500 hours) of musical training may have an effect on how errors are affectively responded to, which may explain Palmer and Drake's (1997) results which found that small amounts of musical training appeared to affect the way in which errors were committed. Differences between groups in error confidence were observed; the group with minimal hours of musical practice were significantly more confident in their error prediction accuracy than both the intermediate and the high musical group. Interestingly, this confidence was numerically supported by prediction accuracy with the low musical group being more accurate in their error prediction abilities than the other groups, and the highly musical group being least accurate though this difference was not significant. These differences are interesting as they suggest that musical training appears to have an effect on error evaluation performance and affective response to an error. These findings may provide insight into why musical training appears to be associated with greater cognitive control and ERN amplitude (as shown in the previous literature); these may be modulated by affective responses to errors. As the ACC is active during affective responses and it activates areas of the brain responsible for cognitive control (Bush et al., 2000), effects of musical training on affective responses to errors may subsequently increase cognitive control, thereby enhancing future performance.

2.4.1. Limitations

There are a number of important limitations to the current study which will now be addressed. Many studies which investigate differences in people who are musically active and those who are not, compare professional musicians to non-musicians (e.g. Bialystok & DePape, 2009; Palmer & Drake, 1997). In the current study, amateur musicians are compared to non-musicians, therefore it could be that the musical group were not substantially different musically to the non-musical group. However, other studies compare musically trained children with no or less musical training with quite minimal differences in years or hours of training (e.g. Palmer & Drake, 1997). Furthermore, the current study used the same technique as used by Jentzsch et al., (2014) recruiting young adult amateur musicians and non-musicians and differences were observed in Jentzsch's study between the groups.

The design differed to other studies as the stimuli was presented vertically to add to the existing body of literature which has generally used horizontal stimuli and response configurations. This could partly explain the differences in findings in the current study compared to the previous literature. Previous research has shown that horizontal stimuli appear to elicit greater interference effects (Mückschel & Beste, 2015), and although interference effects with the vertical stimuli were also observed here, perhaps the effects were not great enough to elicit differences at the electrophysiological level as shown by no significant differences between groups in the ERN or in the N200. A study which investigates differences between horizontal and vertical key placement may be of interest to investigate if this could contribute to the differences in findings.

Moreover, in a study conducted by Grützmann, Endrass, Klawohn and Kathmann (2014) it was shown that response accuracy ratings can have an effect on performance monitoring at the behavioural and at the neuronal response level. Reaction times of correct responses and post-error slowing were reduced and the ERN increased in a rating compared to a non-rating condition in a conflict (Flanker) task. The authors suggest that the accuracy ratings may be associated with greater attention to response accuracy which would explain the increase in the ERN which is thought to be related to the value placed on errors. Although accuracy ratings were completed after each trial in Grützmann et al's (2014), and in the current study response accuracy was only questioned after each block of trials, these ratings may have had an effect on the behaviour and neuronal response and could explain the differences in findings compared to those in the previous literature.

A major limitation to this study is the speed/accuracy trade off. The more musical training people had, the faster they responded, though accuracy was compromised. This is specifically a problem when analysing the ERN data; as discussed the ERN is typically attenuated when speed is emphasized over accuracy (Falkenstein et al., 2000; Gehring et al., 1993). Therefore, it could be that the participants with more musical training placed more value on speed than accuracy in comparison to the groups with less musical training, which may have consequently diminished any potential differences between groups in ERN amplitude. A further study investigating the difference in performance when asked to respond either with speed or accuracy would be of interest.

A further limitation regarding the conclusions that can be made from these results is the design of the study. Considering that the study is cross-sectional, no claims can be substantiated in regards to cause and effect (this will be discussed more thoroughly in the general discussion).

2.4.2. Conclusions

The aim of the current study was to investigate why musical training is associated with increased cognitive control as the literature suggests. Chapter two aimed to explore whether musical training affects emotional responses to errors which is believed to be linked to cognitive control. Previous behavioural effects observed in the literature could not be replicated, however differences were observed between musical groups when explicitly asked to evaluate their own performance. This findings suggests that musical training may be related to increases in negative affective reactions towards erroneous responses. This adverse reaction may subsequently increase activation in the ACC which consequently increases cognitive control. However, unfortunately, although differences in cognitive control were observed electrophysiologically with trends observed in the N200 component (an ERP thought to index inhibition of prepotent responses), the current study could not replicate behavioural findings reported in the literature which suggest that musical training increases cognitive control.

The current study has a number of limitations which must be addressed in order to substantiate any conclusions. The results contrast those in the literature, but there were a number of differences in design of the current study compared to previous studies. The main difference which could be because of task instructions, was the finding of the speed/accuracy trade off making analysis of errors and specifically the ERN problematic. It would therefore be of interest to include a manipulation of instruction in a further study to overcome this limitation (respond either as quickly or as accurately as possible). Additionally, in contrast to other studies the stimuli and keys were mounted vertically. It would therefore be of interest to compare conditions which use horizontal or vertical keys. Lastly, different to other studies, participants were asked to provide response accuracy ratings which has been shown to have differential effects on behavioural and ERP correlates of performance monitoring, therefore a future study could either eliminate this task or compare conditions with and without response accuracy ratings.

3. Chapter 3: The Effect of Musical Training on Cognitive Control

3. Chapter 3: The Effect of Musical Training on Cognitive Control

3.1. Introduction

Chapter two found that musicians were faster at responding to the conflict tasks overall, though this speed was traded for accuracy. This speed/accuracy trade off presented a problem when analysing the ERN as discussed above. Furthermore, the design used by chapter two differed to the design used in a number of previous studies in the literature. Firstly, the stimuli-response configurations were presented vertically in contrast to the traditional horizontal presentation of stimuli and response keys. Secondly, participants were asked to rate their response accuracy which has been shown to affect ERP and behavioural correlates of performance monitoring. These differences will be taken into consideration while discussing the rationale for the design of the study in chapter three.

3.1.1. Horizontal versus Vertical Response Sets

Mückschel and Beste (2015) argue that although we process information from different spatial dimensions in everyday life, most empirical studies investigate performance only along the horizontal right-left dimension. Therefore very little is understood about the behavioural and neuronal responses to information from other spatial dimensions. They conducted a study in which they tested two spatial dimensions (horizontal and vertical) using a spatial conflict task (the Flanker task), investigating both behavioural and neuronal differences. They found a larger compatibility effect (incongruent RT minus congruent RT) in the horizontal task compared to the vertical task. Furthermore, a greater N200 amplitude was elicited during incongruent trials in the horizontal task than during the incongruent trials in the vertical task, suggesting that more resources are expended inhibiting prepotent responses in the horizontal task than in the vertical task. The authors suggest that this greater level of interference is experienced during the horizontal task due to the ‘right-left prevalence effect’ which is an effect which exists because we have more practice in right-left discriminations in everyday life than top-down discriminations. This therefore leads to greater automation in the right-left dimension, resulting in inhibition of this response being more difficult. While musicians read musical notation from left to right, the musical notation system maps pitches onto vertical locations (higher notes are placed spatially higher on the musical staff). Research suggests that musicians are subject to a 'SMARC' effect (spatial musical association of response codes) in which the cognitive system maps pitch height along a spatial dimension which can affect motor performance when response alternatives are either horizontal or vertical even when the dimension is irrelevant to the task at hand (Rusconi, Kwan, Giordano, Umiltà, & Butterworth, 2006). Furthermore, Stewart, Walsh and Frith (2004) found that musical expertise modulated performance on a spatial mapping task with pianists responding more quickly during a stimulus – response mapping task when stimuli presenting a rightward response were presented in vertically higher locations and vice versa; the opposite pattern was found for non-musicians. The authors concluded that vertical-horizontal visuomotor mapping learned through piano training may generalise beyond the musical context. It is therefore of interest whether musical experience could have modulated the performance to the vertical stimuli-response sets in chapter two as these results differed to the literature which previously used horizontal response sets. In the current study therefore, two conditions comparing performance on horizontal and vertical response sets will be included.

3.1.2. Speed versus Accuracy

As discussed previously, the value placed on an error can have an effect on the ERN, with the ERN typically diminished if more emphasis is placed on speed than on accuracy (Falkenstein et al., 2000; Gehring et al., 1993). The musical group in chapter two appeared to compromise speed for accuracy which may have diminished potential differences in ERN amplitude between the musical groups. Therefore in the current study, emphasis on speed and accuracy will be manipulated by including two conditions with different response instructions: respond either as quickly or as accurately as possible.

3.1.3. Effects of Response Accuracy Ratings

The second design difference to previous studies investigating performance monitoring in musicians was the use of response accuracy ratings after each experimental block. Previous research reports that response accuracy ratings can have an effect on both behavioural and neuronal correlates of performance monitoring (Grützmann et al., 2014); reaction times and post-error slowing appeared to be reduced while the amplitude of the ERN increased in a rating condition compared to a non-rating condition. The current study therefore, will not ask participants to evaluate their performance.

Furthermore, as a spatial Stroop task was used in chapter two, which again differed from that used in previous literature, in the current study the classic Stroop task will be used.

3.1.4. Current Study

In the current investigation, seeing that a speed/accuracy trade off was observed in the highly musical group in chapter two, and as emphasis on speed over accuracy can attenuate the amplitude of the ERN, participants will take part in two conditions: accuracy and speed focus. Response hands will be manipulated as evidence has shown that response mappings can affect performance: unlike in chapter two, in which vertical stimuli was used, differing from previous literature, in the study in chapter three, participants will complete two conditions: one horizontal and one vertical. Manipulating these two variables will ideally provide insight into why the results in chapter two differed from those in the previous literature. The ERN and the N200 appear to become decreased with increasing levels of fatigue (e.g. Boksem, Meijman, & Lorist, 2006). Therefore, as the current design includes two manipulations each with two conditions and each of which need a substantial number of trials for ERP analysis, the Simon task will not be used here.

3.1.5. Hypotheses

1. Musicians will respond more quickly than non-musicians.
2. Musicians will be less reactive to post-error and post-conflict interference than non-musicians as shown by less post-error and post-conflict slowing error rates.
3. Musicians will be better able than non-musicians to detect conflict and errors at the electrophysiological level as shown by greater increases in the ERN amplitude, and the N200.
4. Overall, the horizontal condition will create greater interference effects than the vertical condition, and there will be differences between the low musical, and the high musical group.
5. People will respond more quickly in the speed condition and more accurately in the accuracy condition. This will produce differences in the ERN; the ERN will be diminished in the speed condition when compared to responses in the accuracy condition.

3.2. Methodology

3.2.1. Participants

Thirty-six young adults (mean age: 22.2 years, range: 18-34 years, 30 female) were divided into two groups based on self-reported hours of musical practice: low (<500h) (*n* = 15), and high (>3000h) (*n* = 15). Six participants did not fall into either of these groups, therefore their data was not further analysed. All participants provided informed consent, were tested in one 90 minute session and received reimbursement of £8.

3.2.2. Materials

The Stroop Task: Participants completed a 'Stroop task' which required participants to attend to the colour of a word while ignoring the semantic meaning of that word. 'Red' and 'Blue' were the two stimulus words used. The word meaning and word colour could be either compatible or incompatible, see **Figure 7**.

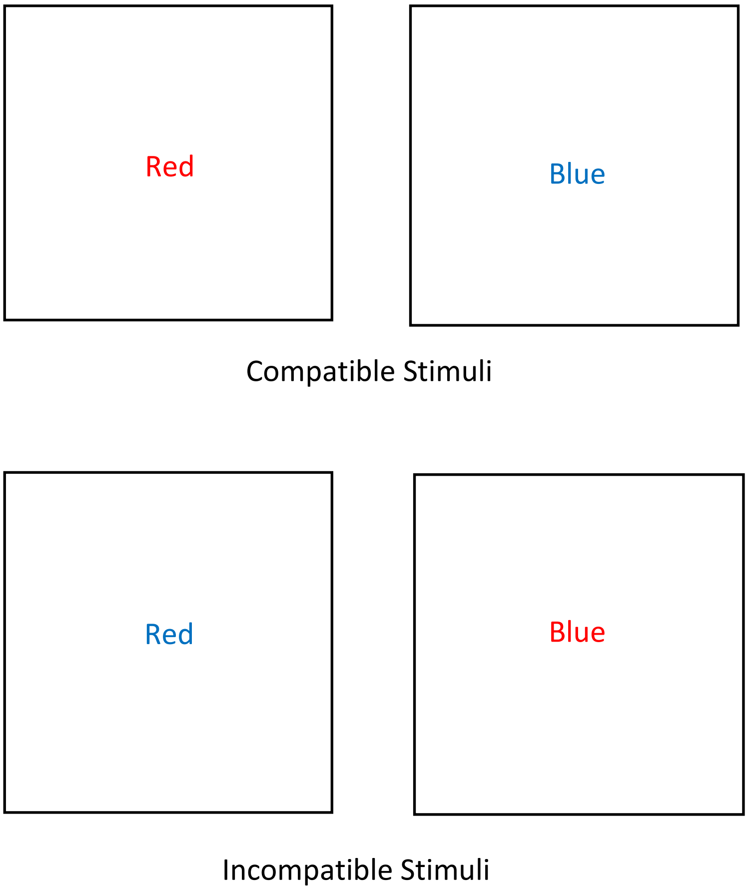


Figure 7: Compatible and Incompatible Stroop Stimuli

Musical Experience Questionnaire: Participants completed the musical experience questionnaire as described in section **2.2.2.**

3.2.3. Apparatus

The same EEG set up was used as in chapter two; see section **2.2.3**. Responses were recorded using two response key pads with keys set 10cm apart either horizontally or vertically.

3.2.4. Procedure

Firstly participants were fitted with the EEG cap and asked to sit in a darkened booth (same procedure described in section **2.2.4.**). Participants were asked to use the index finger of each hand to press their response. Participants then completed four conditions. In condition one, keys were mounted horizontally and participants were asked to respond as accurately as possible to the task. In condition two, keys were mounted horizontally, but participants were asked to respond as quickly as possible. In condition three, keys were mounted vertically and asked to respond as accurately as possible. In condition four, keys were vertically mounted and participants were asked to respond again as quickly as possible. Each of the four conditions contained four blocks, each with 80 trials; compatible and incompatible trials were presented with equal probability totalling in 320 trials for each condition. The order of conditions was counterbalanced across participants however two vertical or two horizontal conditions were always completed in succession.

Before the beginning of each condition, instructions were displayed and participants completed 10 practice trials. The stimuli were presented for a maximum of 1000ms or until a response was recorded. Following this, a blank interval of 1200ms was administered before the beginning of the next trial. Each block was followed with a minimum break of 12 seconds. Participants were provided feedback during this break which included mean reaction time and number of errors for the previous block. The participants received new instructions following each block. After two conditions were completed (either vertical or horizontal with speed and accuracy), the experimenter changed the orientation of the keys for the remaining two conditions (either vertical or horizontal with speed and accuracy).

After completion of the Stroop tasks, participants completed the musical experience questionnaire.

3.3. Results

3.3.1. Participant Characteristics

Statistical analyses were conducted to investigate possible confounds between participants in the two musical groups. Chi-square analyses showed no statistically significant differences between the participants in the two musical groups for sex: χ^2 (1, *n* = 30) = 0.833, *p* = .651, or for handedness: χ^2(1, *n* = 30) = 0, *p* = 1. As can be seen in **Table 5** one-way ANOVAs revealed significant differences in age: *F*(1, 29) = 8.110, *p* = .008, η_p^2 = 0.223, and in years of education: *F*(1, 29) = 8.119, *p* = .008, η_p^2 = 0.226, with participants in the low musical activity group being significantly older and therefore unsurprisingly (in this student population) possessing more years of education than participants in the highly musical group. There were no differences between participants in hours spent listening to music or in other non-musical activities.

Table 5: Participant Characteristics Chapter three

	Musical Group			
	Low (*n*=13)	High (*n*=13)	*F value*	η_p^2
Sex (female; male)	13; 2	11; 4	-	-
Handedness (right; left)	14; 1	14; 1	-	-
Age [years]	24.0	20.4	**8.110****	**0.223**
Years of Education [years]	17.6	15.3	**8.119****	**0.226**
Accumulated Practice Time [h]	153.5	5640.7	**83.433*****	**0.749**
Total Years Played [years]	2.8	13.3	**65.557*****	**0.701**
Musical Knowledge Score	7.1	16.5	**136.975*****	**0.830**
Listening to Music [h/week]	27.3	29.3	0.025	-
Physical Activity [h/week]	4.0	3.8	0.017	-
Computer Gaming [h/week]	0.6	0.3	0.225	-
Non-musical Artistic Activity [h/week]	2.2	2.5	0.022	-

**p* <.05; ****p* < .001

	Main musical instrument played
Musical Group	
Low	2 Strings, 3 Wind, 1 Voice, 5 Piano (4 n.a.)
High	4 Strings, 4 Wind, 2 Voice, 5 Piano

3.3.2. Behavioural Performance

3.3.2.1. Overall Performance

To explore group differences in Stroop task performance in reaction times and error rates, two mixed measures ANOVAs with three within-subjects factors: compatibility (compatible/incompatible trials), key orientation (horizontal/vertical) and instruction (accuracy/speed) with music group (low/high) as the between-subjects factor were run for both reaction times and error rates.

Reaction Times: RT's were found to be affected by musical practice with the low musical group taking significantly longer (M = 333ms) to respond than the high musical group (M = 308ms): $F(1, 28) = 7.064$, $p = .013$, $\eta_p^2 = 0.201$. See **Figure 8**.

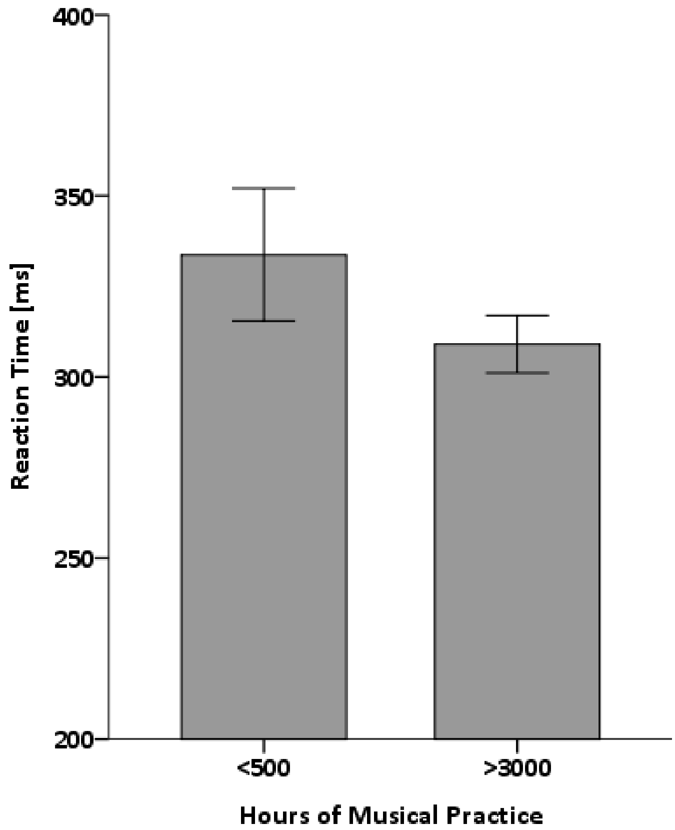


Figure 8: Mean RT's for each Musical Group with 95% confidence intervals

There was a significant effect of compatibility: $F(1, 28) = 10.650$, $p = .003$, $\eta_p^2 = .276$. It took participants longer to respond to incompatible (M = 324ms) than to compatible trials (M = 318ms). There was a significant main effect of key orientation: $F(1, 28) = 8.684$, $p = .006$, $\eta_p^2 = .237$ with responses significantly faster when the keys were mounted horizontally (M = 315ms) compared to vertically (M = 328ms).

There was a significant main effect of task instruction: $F(1, 28) = 41.441$, $p < .001$, $\eta_p^2 = .597$ with participants following the instructions and responding significantly quicker in the speed condition (M = 308ms) than in the accuracy condition (M = 335ms). No other effects reached significance levels; all p's > .05.

Error Rates: A significant main effect of compatibility was observed with more mistakes made on incompatible trials (M = 9.5%) than on compatible trials (M = 8.5%): $F(1, 28) = 4.878$, $p = .036$, $\eta_p^2 = .148$. A main effect of task instruction was also observed here: $F(1, 28) = 59.847$, $p < .001$, $\eta_p^2 = .681$, with more errors made when instructed to respond as fast as possible (M = 12.2%) compared to when instructed to respond as accurately as possible (M = 6.1%). Although there was not a significant main effect for the orientation of keys, an interaction between orientation of keys and compatibility was observed with a larger compatibility effect (incompatible minus compatible errors) when the keys were mounted vertically (1.6%) than horizontally (0%): $F(1, 28) = 4.965$, $p = .034$, $\eta_p^2 = 0.151$. No other effects reached significance levels; all p's > .05.

3.3.2.2. Sequential Performance

To explore sequential performance, two mixed measures ANOVAs with four within-subjects factors: key orientation (vertical/horizontal); instruction (accuracy/speed) previous compatibility (compatible/incompatible trials), and current compatibility (compatible/incompatible trials) with music group (low/high) as the between-subjects factor were run for reaction times and error rates. For this analysis, only correct trials and post-correct trials were considered.

Reaction Times: There was a main effect of previous compatibility on reaction times: $F(1, 28) = 5.578$, $p = .025$ $\eta_p^2 = .166$, with participants reacting faster when the previous trial was incompatible (M = 312ms) than compatible (M = 316ms). Although no main effect for orientation of keys, there was an interaction between key orientation and previous compatibility $F(1, 28) = 16.401$, $p < .001$, $\eta_p^2 = .369$; participants took longer when the previous trial was compatible than when incompatible with a larger difference when the keys were mounted vertically (8ms) than horizontally (1ms). No other effects or interactions with previous compatibility reached significance levels; all p's > .05 which was surprising as this demonstrates the absence of the Gratton effect.

Error Rates: There was an interaction between previous and current compatibility: $F(1,28) = 8.934$. $p = .006$, $\eta_p^2 = .242$, due to larger compatibility effects when the previous trial was compatible (M = 1.8%) compared to when the previous trial was incompatible (M = -0.2%) indicating the presence of the Gratton effect in error rates. No other effects reached significance levels; all p's > .05.

3.3.2.3. Post-error Effects

For post-error analyses, the data from four participants was excluded due to low numbers of errors, resulting in a sample of 13 for each musical group. Furthermore, only the speed condition trials were analysed and the accuracy condition excluded due to low error numbers in the accuracy condition. To explore post-error effects, two mixed measures ANOVAs with three within-subjects factors: previous compatibility (compatible/incompatible trials), current compatibility (compatible/incompatible trials) and trial type (post-correct/ post-error) with music group (low/high) as the between-subjects factor were run for reaction times and error rates.

Reaction Times: Analyses revealed a significant main effect of trial type: $F(1, 24) = 23.922$, $p < .001$, $\eta_p^2 = .499$, with participants reacting faster on post-correct trials (M = 300ms) than on post-error trials (M = 333ms) indicating the presence of the typical post-error slowing effect. There was an interaction between trial type and previous compatibility: $F(1, 24) = 6.905$, $p = .015$, $\eta_p^2 = .223$, which showed that there was a greater effect of previous compatibility (IC minus C) on post-error trials (12ms) than on post-correct trials (-3ms). No other effects reached significance levels; all *p*'s > .05.

Error Rates: There was a main effect of trial type: *F*(1,24) = 9.397, *p* = .005, η_p^2 = .281, with less errors made on post-error (*M* = 12.3%) than post-correct trials (*M* = 17.5%) demonstrating an increase in accuracy following an error. There was also a three way interaction between trial type, previous compatibility and current compatibility: *F*(1,24) = 6.817, *p* = .015, η_p^2 = .221, due to a greater Gratton effect ([C-IC minus C-C] minus [I-C minus IC-C]) of 1.53% errors in the post-error trials than in the post-correct trials (-2.1%). No other effects reached significance levels; all *p*'s > .05.

3.3.3. Electrophysiological Performance

EEG was segmented as described in section **2.3.3.**

3.3.3.1. N200

As in chapter two, the mean amplitude of the N200 was analysed in difference waves (incompatible minus compatible trials) at the FCz electrode 250-350ms post stimulus onset in a 50ms time window around the peak latency of the grand mean. One participants EEG data was not included due to a recording fault, therefore *n* = 29 with 14 in the highly musical group, and 15 in the low musical group. Two ANOVAs were conducted on both the N200 latency and amplitude with one within-subjects variable instruction (speed/accuracy) and a between subjects variable of musical group (low/high).

Latency: There was no main effect of task instruction on the N200 latency, though there was a main effect of musical group: F(1,27) = 4.557, p = .042, η_p^2 = .144, with participants in the high musical group (M = 291ms) showing a shorter overall N200 latency than the low musical group (M = 311ms) supporting the trend identified in chapter two. As can be seen from **Table 6** this is driven by the differences in latency seen mainly in the speed condition. No other effects reached significance levels; all p's > .05.

Amplitude: No effects of N200 amplitude reached significance levels. See **Table 6** for means and **Figure 9** for ERP waveforms for speed and accuracy.

Table 6: Latency and amplitude of N200 in the low and the highly musical groups

		Musical Group		
N200		Low *M (SD)*	High *M (SD)*	F
Latency [ms]	Speed	319 (35)	291 (34)	**4.757***
	Accuracy	303 (35)	290 (37)	1.045
Amplitude [µV]	Speed	-0.65(0.6)	-0.67 (0.7)	0.004
	Accuracy	-0.72 (0.8)	-0.90 (0.5)	0.590

*$p < .05$

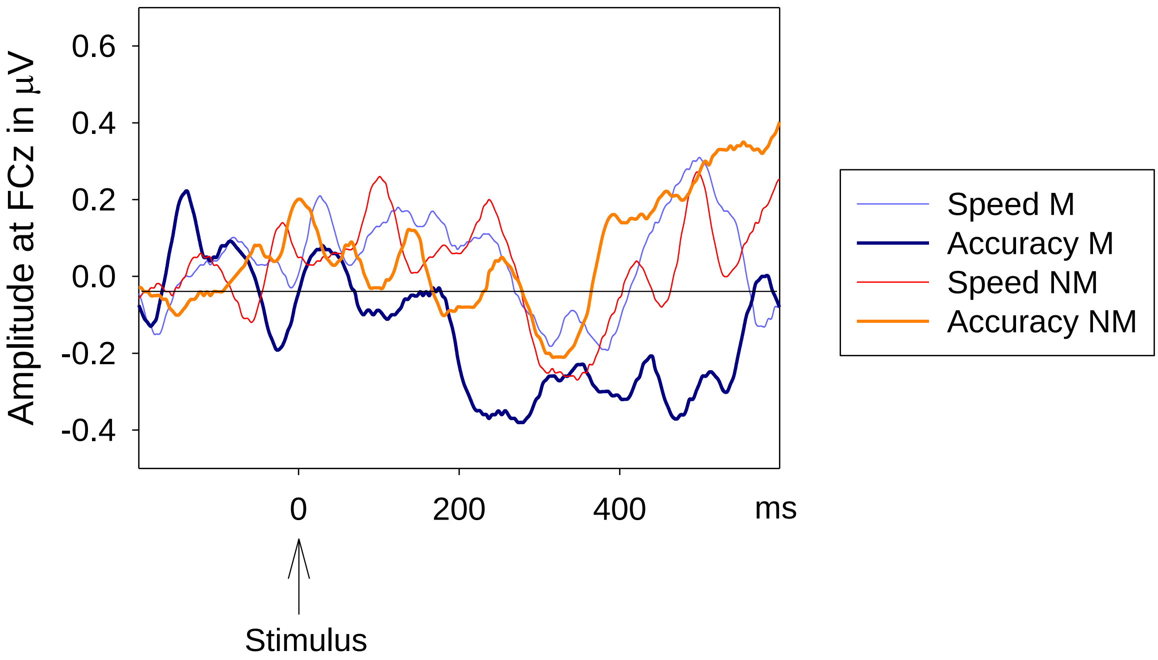


Figure 9: Stimulus-locked ERP difference waves (incompatible minus compatible trials) depicting the N200 for the FCz electrode with the two musical practice levels (Musicians and Non-musicians) and Conditions (Speed and Accuracy) superimposed

3.3.3.2. ERN

ERN peak amplitudes were measured in difference waves (errors minus correct response) at the FCz electrode in a search window 0-100ms after response onset. Three participants were excluded from ERN analyses because they had less than eight EEG-artefact free error trials; *n* = 13 for both low and high musical groups. Two ANOVAs were conducted on both the ERN latency and amplitude with one within-subjects variable instruction (speed/accuracy) and a between subjects variable of musical group (low/high).

There were no main effects or interactions for either amplitude or latency of the ERN for task instruction or for musical groups. Please see **Table 7** for means and F values of the ERN by musical group and **Figure 10** for ERN latency and amplitude differences for speed and accuracy conditions across music groups.

Table 7: Latency and amplitude of ERN for speed and accuracy in the low and the highly musical groups

		Musical Group		
ERN		Low *M (SD)*	High *M (SD)*	F
Latency [ms]	Speed	51 (29)	57 (32)	0.273
	Accuracy	50 (26)	54 (22)	0.222
Amplitude [µV]	Speed	-5.63 (3.0)	-5.73 (3.5)	0.006
	Accuracy	-5.45 (3.6)	-6.98 (4.6)	0.906

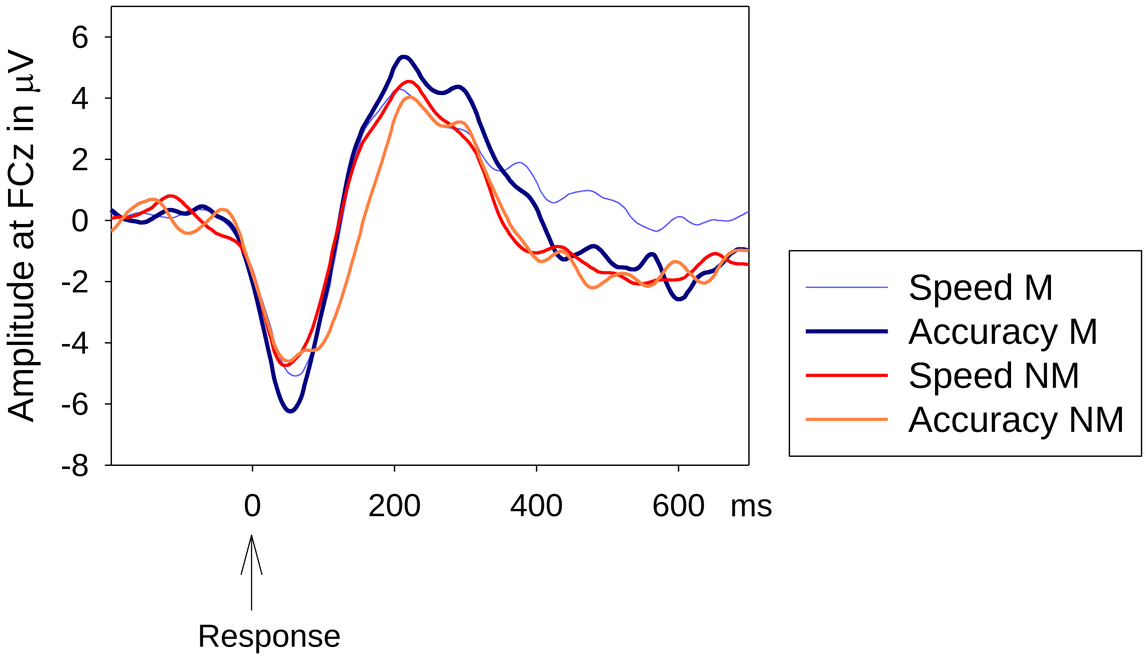


Figure 10: Response-locked difference waves (error minus correct trials) with the two musical groups (musicians and non-musicians) and conditions (speed and accuracy) superimposed

3.4. Discussion

The aim of the current study was to investigate why the results in chapter two differed to those reported in previous research: musical training is found to be associated with increases in cognitive control. Importantly, as the highly musical group appeared to place more value on speed than on accuracy which can attenuate the amplitude of the ERN, a speed condition and an accuracy condition were included. Literature suggests that musicians may be differentially affected by spatial mappings, and as a vertical response set was used in chapter two in comparison to the typically used horizontal response sets in other studies, here both vertical and horizontal response sets were incorporated and subsequently compared.

The first prediction stated that musicians will perform faster than non-musicians and the results supported this prediction. Furthermore despite being faster, the musicians did not make more errors than the non-musicians, in contrast to findings reported in chapter two but in support of the previous literature. This supports a range of studies which have shown that musicians do appear to respond more quickly than non-musicians (e.g. Bugos et al., 2007; Gruhn et al., 2003). However, it must be noted that in the current study, the two groups were not age-matched and participants in the musical group were significantly younger than those in the non-musical group which could account for the differences in response times.

The behavioural results do not support the second prediction that musicians would display less interference effects than non-musicians which contrasts the findings of a number of studies discussed above, which found that people with musical training appeared to have reduced reactiveness to trials post-error or post-conflict compared to people with less musical training (Jentzsch et al., 2014; Palmer & Drake, 1997). The results reported in chapter two, on the other hand, found an opposite effect in post-conflict behaviour with more musical training associated with greater reactiveness to preceding conflict trials. In the current study no effect was found. This suggests that the effects of post-conflict interference in musicians is potentially reflecting individual differences of participants across studies, or may suggest that this effect is weak, resulting in these mixed or null findings that have been observed.

Prediction three stated that differences between ERN amplitude between the musical groups would be observed. No significant differences were observed between groups in ERN amplitude. Nevertheless, a numerical difference between the musical groups can be observed with the highly musical group displaying a numerically greater average ERN amplitude than the non-musical group in the accuracy condition (see **Figure 10**) which would support the previous findings in the literature (Jentzsch et al., 2014). However, as mentioned, the groups were not age matched and the musicians were significantly younger than the non-musicians. Older groups tend to show smaller ERNs than younger groups in choice reaction time tasks (e.g. Band & Kok, 2000; Dywan, Mathewson, Choma, Rosenfeld, & Segalowitz, 2008; Hoffmann & Falkenstein, 2011; Koelsch et al., 2009; Kolev, Falkenstein, & Yordanova, 2005; Mathewson, Dywan, & Segalowitz, 2005; Nieuwenhuis et al., 2002; Schreiber, Pietschmann, Kathmann, & Endrass, 2011) which could be the cause of the numerical differences in ERN amplitude. Surprisingly no differences were seen in the ERN amplitude between the speed and accuracy conditions though a number of studies (e.g. Falkenstein et al., 2000; Gehring et al., 1993) have shown that the ERN is typically diminished during a speed condition when compared to an accuracy condition. Furthermore, studies have demonstrated that older people tend to show greater ERN differences between speed and accuracy than younger people (e.g. Endrass, Schreiber, & Kathmann, 2012). However, this was not observed here, in fact, numerically a greater difference in the amplitude of the ERN between speed and accuracy conditions was observed in the younger musical group compared to the older non-musical group. However, it must be noted that the difference in age, though significant, was minimal (average 3.6 years difference) and the studies mentioned typically compare 18-30 year olds (younger adults) to 55-85 year olds (older adults). These results suggest that the ERN amplitude was not differentially affected by the speed and accuracy conditions and no differences in ERN amplitude were observed between groups in the current study.

Though no differences were observed between the musical groups in N200 amplitude, the musicians did have a shorter N200 latency; this was shown numerically in the results of chapter two, and this difference was significant in the current study. It is thought that the N200 is sensitive to overcoming prepotent responses (Azizian et al., 2006). Though this was not shown with differences in interference effects, this may explain how musicians were faster than non-musicians at responding overall; they may be faster at inhibiting the prepotent response. Previous literature investigating the effects of musical training on the N200 amplitude have been somewhat mixed with two studies finding a greater amplitude in groups with higher levels of musical training (Jentzsch et al., 2014; Moussard et al., 2016) and another finding the amplitude in a musical group diminished compared to a bilingual group (Moreno et al., 2014), while another found no difference between a musical and visual arts group after 20 days of training (Moreno et al., 2011). In both the current study and in chapter two, no differences in N200 amplitude between music groups were observed. Overall, these results suggest that musical training may differentially affect the N200 which is thought to be an index of inhibition of prepotent responses. However, due to the mixed findings in the literature, further investigation is needed to clarify the differential effects of musical training on the N200.

It was predicted that overall participants would find the horizontal condition more difficult than the vertical condition. This was based on previous literature which found horizontal stimuli-response configurations to elicit greater reaction times and interference effects than vertical stimuli-response configurations (Mückschel & Beste, 2015). The authors suggested that their results were due to a 'right-left prevalence effect' which is a phenomenon that occurs because we practice right-left discriminations in everyday life (e.g. reading left to right) which are therefore more automatic than top-down discriminations that are practiced with much less frequency. However, in musicians, pitch height is spatially represented which may be because pitch is vertically positioned in musical notation (Rusconi et al., 2006) and evidence suggests that musical training may affect visuomotor mapping (Stewart et al., 2004). The results here suggest that all participants found the horizontal condition less difficult than the vertical condition, displaying shorter reaction times and reduced interference effects than the horizontal condition. In keeping with this, there was also a larger Gratton effect in the vertical compared to the horizontal condition. In the current study the classic Stroop task was used which does not require the processing and suppression of spatial dimensions which may explain why no right-left prevalence effect is observed as was also reported by Proctor, Vu and Nicoletti (2003) in Simon tasks when the stimulus spatial location was irrelevant. Furthermore, the stimuli was presented centrally in the current study, while only the response keys were presented either horizontally or vertically.

3.4.1. Limitations

The main limitation for the current study is that the two groups differed in age. The musical group was significantly younger than the non-musical group which presents a major confound when investigating differences in Stroop response times and EEG. A number of studies have shown that older people respond more slowly on the Stroop task (e.g. Bugg, DeLosh, Davalos, & Davis, 2007; Verhaeghen & De Meersman, 1998) and the Stroop interference effect also increases with age and could be due to reduced inhibitory processes (e.g. Bugg et al., 2007). However, in the current study no differences in interference effects were observed despite the musical group being significantly older than the non-musical group.

The current study was unable to replicate differences in ERPs as reported in the literature. Firstly, no differences between the musicians and non-musicians were observed. Furthermore no differences in the amplitude of the ERN were observed between the speed and accuracy conditions or between the younger and the older group which is surprising given the overwhelming evidence which suggests that these effects are robust. It could be that the tasks used in both the current study and in chapter two do not elicit the same ERP effects as observed in other similar studies. However, in the current study, the same stimuli and task were used as used by Jentzsch et al., (2014) who did find differences in both the N200 and the ERN across groups with differing levels of musical training. Therefore, the null results in regards to ERP differences could simply be due to the recruitment of an unusual non-representative sample.

Finally, as in chapter two, this study uses a cross-sectional design which limits any causal conclusions; this limitation will be discussed more thoroughly in the general discussion chapter.

3.4.2. Conclusions

The current study found that the vertical stimuli produced greater interference effects than the horizontal stimuli but the low musical group did not differ in this when compared to the high musical group. These results therefore cannot explain why the findings in chapter two differed to those in the literature. Furthermore, speed and accuracy instructions did not differentially affect the ERN which is surprising given the overwhelming literature which provides good evidence for this. Therefore, again, differences between chapter two's findings and previous literature in regards to the ERN cannot be explained here. The highly musical group appeared to respond faster than the non-musical group overall though this result must be treated with caution due to significant differences in age between groups with musicians being significantly younger than non-musicians. The highly musical group did show a shorter N200 latency than the low musical group which supports the numerical trend observed in chapter two. The N200 is believed to be an index of inhibition of prepotent responses therefore this may explain why musical training appeared to be associated with faster speed of processing overall and suggests greater cognitive control, this however was not reflected behaviourally in neither chapter two nor in the current study. Though the literature and the results of the study in chapter two suggest that musical training appears to affect how errors are evaluated, this was not shown to subsequently influence behavioural adjustments. The question regarding the effects of musical training on control processes therefore remains open and requires further investigation.

4. Chapter 4: The Effect of Musical Training on Emotional Processing Abilities

4. Chapter 4: The Effect of Musical Training on Emotional Processing Abilities

4.1. Introduction

The results from chapter two suggest that affective responses to errors may be modulated by musical training. It is, however, unclear why that might be. The second part of this thesis explores whether musical training can affect emotional processing abilities. As discussed in section **1.2.1**, research has shown that music can both induce emotions and affect emotional arousal in the short-term (Blood & Zatorre, 2001; Blood et al., 1999; Brown et al., 2004; Gabrielsson, 2010; Juslin & Laukka, 2004; Juslin, 1997; Koelsch et al., 2010; Kreutz et al., 2004; Krumhansl, 1997; Menon & Levitin, 2005; Nyklicek et al., 1997; Panksepp & Bernatzky, 2002; Schmidt & Trainor, 2001; Sloboda, 1991, 2000). It is less clear however what the effects of engaging in musical activity may be for emotional processing in the long term and whether these effects transfer to other non-musical domains. In this chapter a number of emotional processing measures will be explored and research in these areas will be presented before a rationale for the current study design is introduced.

4.1.1. Emotion Recognition

As discussed in sections **1.2.4** and **1.2.5** of the general introduction, a number of studies have demonstrated that musical training appears to have a positive effect on our ability to recognise musical emotions and emotions in speech across a wide span of ages (Dmitrieva et al., 2006; Lima & Castro, 2011; Thompson et al., 2004; White-Schwoch, Anderson, Strait & Kraus, 2013). However, it is unclear whether these enhancements in recognising emotions in speech are due to enhanced auditory perceptual abilities as shown in a number of studies (see Kraus & Chandrasekaran, 2010 for a review) or if this may be due to generally superior emotion recognition abilities. In other words, does this superior emotion recognition performance transfer to non-auditory domains?

Research investigating musical expression in performers demonstrates that musicians use both facial and bodily expressions to communicate the emotional, structural, and narratives of a musical piece (Davidson, 2012). Moreover, if movements in musicians are constrained, this results in a less expressive performance compared to when the musician can move freely (Davidson, 1995). This suggests that musicians use not only sound to express musical emotions, but also bodily gestures or movements, and facial expressions.

Indeed, a number of studies have shown that musical experiences can be heavily influenced by the facial and gesture expressivity of a performer. Thompson Russo, and Quinto (2008) asked participants to judge the emotion of a piece when listening to and watching recordings of sung intervals; the auditory and visual information was manipulated to have congruent or incongruent emotional connotations. The researchers found that the facial expressions did indeed influence judgements concerning the emotion in music. While perceiving the audio and visual information, sung major thirds (regarded as ‘happy’ in the literature) were assigned significantly higher ratings (1 = very sad; 5 = very happy) than sung minor thirds (regarded as ‘sad’); however, when the audio and visual information was incongruent (sung major third with sad facial expression), ratings were neutral for both happy and sad congruent trials indicating that both the audio and visual information played an important role in the ratings of the intervals.

Further to these findings, research has also shown that viewing a musician during a performance can enhance the reaction of the listener/viewer to the music. Thompson, Graham and Russo (2005) aimed to investigate whether visual aspects of musical performance contribute to the way in which listeners perceive the music. In an experiment looking at the perception of dissonance, 26 participants were split into two groups; an audio only or audio and visual condition. Both groups listened to 20 musical excerpts lasting from three to six seconds long. In the audio-visual condition, 10 of the excerpts exhibited a performer displaying visual dissonance (e.g. wincing eyes to express dissonance) and in the remaining 10, the same performer acted in a more neutral manner. Participants were asked to rate the level of dissonance (described as music that is conflicting or negative). In the audio-visual condition, participants rated dissonance in the visually dissonant performances as significantly more dissonant than in the visually neutral performances. This difference was not observed in the auditory only condition. The authors suggest that visual information of a performer does affect how dissonance is perceived.

In a further experiment, Thompson et al., (2005) investigated whether visual information also had an effect on the perception of changes in melodic interval size. Fifteen participants judged changes in interval size (from small to large differences) of a musical piece while viewing videos of the performer with either congruent (facial expressions and physical gestures emphasising differences in intervals matched the music) or incongruent (mismatch) conditions. It was found that the visual information did affect how differences in interval size were perceived: ratings of nine semitone interval differences were much lower when accompanied with the incongruent visual stimuli with only a two semitone difference (and vice versa). The authors suggest that these experiments illustrate that musical perception is influenced strongly by visual information (see also Thompson & Russo, 2007; Vines, Krumhansl, Wanderley, Dalca, & Levitin, 2005). Supporting these conclusions, Tsay (2013) reported that both novice and professional musicians state that when evaluating a musical performance, sound is the most important element. Despite this belief, both the novices and the musicians could not identify the winners of a live music competition when hearing only the sound or indeed hearing the sound and watching the video. Both groups could however reliably choose the actual winners based on the silent videos only. These two studies suggest that when watching performers we are very aware and influenced by both the sound of the music as well as the facial and gestural emotional expression of the performer.

Interestingly, although numerous studies have shown that engaging in musical activity can have a positive effect on the ability to recognise musical emotions and emotions in speech, it has not been investigated whether musical engagement enhances the ability to recognise emotions beyond the auditory domain. As discussed, visual expressivity of musical emotions during performance appears to play a highly important role in how music is experienced. As mentioned in section **1.2.3** of the general introduction, motor skills trained in one domain can be of assistance when observing movements in another domain; training may allow for action simulation to occur which aids understanding (Sevdalis & Raab, 2016). Given the experience of musicians with musical emotions, they may develop motor training in the ability to express musical emotions using facial expressions and gestures; this training could then enhance the ability to recognise facial and gestural emotions beyond the musical domain. Thus, the relationship between musical training and the ability to recognise emotions in non-musical visual domains will be explored here.

4.1.2. Affect and Emotion Regulation

Many studies have investigated the short term effects of musical engagement on subjective and physiological emotional and affective responses to music as discussed in sections **1.2.1.1** and **1.2.1.2**. However, fewer studies have explored the long term effects of long-term musical engagement on emotion and affect. Some studies have however investigated the effects of music on emotional well-being in a number of different groups including the elderly, psychiatric patients, and children. As mentioned in the general introduction, Seinfeld et al., (2013) gave a group (*n* = 13) of older adults four months of daily piano training, while an aged-matched control group participated in a range of different leisure activities (painting, physical exercise, computer and language lessons among others) (*n* = 16). Important for the present literature review, significant decreases in depression symptoms were observed in both groups, but decreases in fatigue and psychological distress and increases in physical and psychological health were observed only in the piano group. In another study, a group of elderly people listened to their favourite music for 30 minutes per week for four weeks; significant decreases from pre to post testing scores on the 'Geriatric Depression Scale' and increases in sleep quality were found (Chan, Chan, & Mok, 2010). For further studies investigating musical activity among older people, please see a review conducted by Creech, Hallam, McQueen and Varvarigou (2013).

Choi, Lee and Lim (2008) gave psychiatric patients 15 one hour 'music intervention' sessions, aimed at improving self-awareness, reducing anxiety and depression, increasing self-esteem and improving cooperation and collaboration through encouraging expression through playing a musical instrument of their choice, listening to live music, and improvising with the music therapists. A marked improvement was observed in depression, anxiety and relationships as measured by the 'Beck's Depression Inventory', the 'State Trait Anxiety Inventory' and the 'Relationship Change Scale'. In children, it has been reported that musical lessons can have a positive effect on self-esteem; Costa-Giomi (2004) conducted an experiment on 9-10 year old children (n = 117). Costa-Giomi discovered that, after three years of weekly piano lessons, the experimental group (n = 63) demonstrated higher levels of self-esteem than those in the control group (n = 54) who did not receive any formal musical education, as measured by the 'Coppersmith Self-Esteem Inventory'.

Overall, these findings suggest that musical activity can have positive effects on well-being in a diverse range of participant groups including older people, psychiatric patients, and children. Given these findings, the current study will investigate whether musical activity in adults can also confer such advantages in general well-being.

4.1.3. Empathy

As discussed in the general introduction in section **1.2.2** a number of theories attempt to explain the mechanisms that allow music to elicit emotions in listeners. The three models (the BRECVEM model, the SAME model, and the embodied simulation account of aesthetic experiences) presented had one thing in common; musical emotion might be experienced via simulation. Theories of empathy also suggest that we understand and experience emotions of others via embodied mimicry (e.g. Decety & Jackson, 2006).

Empathy has not often been the focus of studies investigating the benefits of musical activity though anecdotally the relationship between music and empathy is often highlighted. Indeed, Benzon goes so far as to say that "music is a medium through which individuals brains are coupled together in shared activity" (p23, Benzon, 2008). Greenberg, Rentfrow and Baron-Cohen, (2015) suggest that perceptions, interpretations and emotional reactions to music are connected with empathy. Cross, Laurence and Rabinowitch (2012) present an interesting discussion of how musical activity can promote empathy with reference to communication, imitation, entrainment and emotional contagion (which are reminiscent of the mechanisms for experiencing musical emotion described in the BRECVEM model, see section **1.2.2.1**). The similarities between how musical emotions are experienced and how empathy is experienced are many. Therefore, it could be that people who engage with musical material and experience musical emotions using simulation mechanisms, may also be able to use this training for simulating emotions beyond the musical domain, such as experiencing empathy for others.

A handful of experimental studies have shown that musical activity is associated with enhanced empathy in children. Rabinowitch, Cross and Burnard (2012) randomly divided school children (n = 52) into either a group which would receive a musical group interaction programme over a year-long period or an interaction programme without a musical element. Both programmes encouraged interactive games and consisted of empathy-promoting components such as imitation and entrainment; the only difference was the musical element in one group, and not in the other. The researchers found that empathy scores significantly increased in the music group but not in the control group (using a self-report measure and an implicit 'matching faces' task). Similarly, Krischner and Tomasello (2010) divided four year olds (n = 96) into two groups that engaged in a joint task; either with a musical element or without. The authors found that the children in the musical condition displayed significantly more spontaneous cooperative and helpful behaviour than the children in the non-musical condition. A number of other studies have also shown that musical activity with a focus on interaction and empathy enhancement can indeed promote empathy in children (see Hietolhti-Ansten & Kalliopuska, 1990; Kalliopuska & Ruokonen, 1986, 1993). In an online music listening study with 3164 adults, Egermann and McAdams (2013) asked participants to rate how much empathy they felt towards the musician after hearing a musical excerpt. Amateur and professional musicians reported feeling more empathy than non-musicians. The authors suggest that the musician listeners may have identified more with the musician players, and with their superior knowledge about performing music, it could also be that they more able to imitate and therefore understand the musicians' movements.

Together, these studies suggest that musical engagement may be linked with empathy levels, though no behavioural study has yet tested this potential association in adults. The current study therefore aims to investigate if musical activity can enhance empathy in adults.

4.1.4. Rationale of Current Study

A number of studies have demonstrated the near transfer effects of musical activity with advantages observed in recognising musical emotions and emotions in speech. The current study aims to investigate these auditory near transfer effects as well as the potential far-transfer effects of musical activity on emotional processing in other domains. It has been shown that music has short-term positive effects on our emotions and affect; in this study, it is investigated whether repeated engagement with music can have positive benefits on our emotional processing abilities and emotional well-being in the long-term. Furthermore, some research has found that musical interaction programmes can promote empathy in children (Hietolhti-Ansten & Kalliopuska, 1990; Kalliopuska & Ruokonen, 1986, 1993; Kirschener & Tomasello, 2010; Rabinowitch et al., 2012); the study in the current chapter aims to investigate whether adults with typical musical training (without emphasis on interaction or empathy) also show higher empathy levels than their non-musical counterparts.

The effects of active musical activity will be explored as there appears to be greater emotional effects during active music making than passive music making (e.g. Kreutz et al., 2004). Furthermore people are included who are still actively making music as well as people who may have now stopped with active music making as research shows that some benefits gleaned during a time of musical activity do seem to be long-lasting (e.g. White-Schwoch et al., 2013). Accumulated hours of musical practise will be used as a measure of musical activity seeing that diary based studies investigating the practise habits of musicians have shown that accumulated hours are the best predictor of differences in skill (Ericsson, Krampe, & Tesch-Römer, 1993; Sloboda, Davidson, Howe, & Moore, 1996).

4.1.5. Hypotheses

1. Based on the previous literature, it is predicted that active engagement with music will be associated with greater abilities in recognising emotions in both auditory and in visual domains.
2. Considering that active musical engagement appears to have positive benefits on our short-term emotional well-being, it is predicted that long-term active engagement with musical training will have a positive effect on long-term general emotional well-being measures.
3. Due to previous literature reporting a positive relationship between musical engagement and empathy in children, it is hypothesised that long-term engagement in musical training will be positively associated with empathy levels in adults.

4.2. Methodology

4.2.1. Participants

100 young adults, mean age 21.3 years, range: 17-34, 79 female, were recruited from the University of St Andrews subject pool. According to self-reported hours of musical practice, participants were divided into three groups for analyses: low (0-500h), medium (501-3000h) and high (over 3000h). All participants provided informed consent, were tested in one 90 minute session, and received reimbursement of £8.

4.2.2. Stimuli and apparatus

All computerised tasks were administered via a laptop with the dimensions 28.7cm X 22.9cm which was placed approximately 40cm away from the participant, however participants were permitted to move the laptop to a preferred position.

The Reading the Mind in the Eyes Test: 'The Reading the Mind in the Eyes Test' was developed by Baron-Cohen, Wheelwright, Hill, Raste, and Plumb (2001). Participants were presented with 36 equally sized (15cm x 6cm) black and white photographs on the laptop. The photographs individually displayed 36 pairs of eyes and the surrounding facial area. Four words describing different emotions were displayed around the eyes and participants were asked to choose one of these four words that best described the mental state of the person in the photograph. Participants were provided with an answer sheet and asked to circle their answer. A glossary containing examples and meanings of all of the words was provided and could be used before and during the task. All participants completed the task in the same sequence. A final score (maximum 36) was calculated for each participant which reflects the summation of all correct answers.

Facial Emotion Recognition: For the Ekman 60 Faces test, photographs of the faces of 10 people (6 female, 4 male) were selected from the Ekman and Friesen (1976) series; for details see the handbook of the FEEST – Facial Expressions of Emotion: Stimuli and Tests (Young, Perrett, Calder, Sprengelemeyer, & Eckman, 2002). For each face, there were 10 poses corresponding to each of six emotions (happiness, surprise, fear, sadness, disgust, and anger), totalling 60 photographs. These were shown one at a time in random order on a computer screen, each for an unlimited time until a response was made. On each trial, the participant decided which of the emotion names best described the facial expression shown. The names of the six emotions were given at the bottom of the screen and were available throughout the test. There were six practice trials and 60 test trials, leading to an accuracy score for each participant of maximal 60 (maximum of 10 for each of the six emotions).

Emotional Gesture Recognition: In the emotional gesture recognition task, participants judged body movements (no facial or other cues are visible) and decided which of five emotions (happiness, sadness, fear, anger or disgust) best described the emotion of the movement. The point light stimulus set developed by Atkinson, Dittrich, Gemmell and Young (2004) was used in the current study. Participants watched short videos of individual actors, both male and female, which lasted between 5 and 10 seconds long. Participants verbally relayed their answers to the experimenter and no feedback was provided. There was one practice video, followed by 50 test trials, which included ten repetitions of each of the five basic emotions tested. The emotion conditions appeared randomly and participants completed the set in the same order. A final score (maximum of 50) was calculated for each participants by summation of the correct answers.

Emotional Sound Recognition: This task tests the ability to recognise emotions in sound. Participants were played audio files (10 practice trials, 50 test trials, lasting between 5 and 10 seconds each) of male and female actors reading out numbers with emotional intonation. The test included 10 trials for each of the five emotions:

happiness, sadness, fear, disgust and anger. The stimuli used here were originally developed by Calder, Keane, Lawrence and Manes (2004). The five emotion words were written on a card, and this card was available for inspection throughout the test. Participants were asked to verbally relay which emotion word best described the emotional intonation heard. Responses were not timed and no feedback was provided during the test or the practice trials. A final score (maximum of 50) was calculated for each participants by summation of the correct answers.

Difficulties in Emotion Regulation Scale: The Difficulties in Emotion Regulation Scale (DERS) is a self-report questionnaire developed by Gratz and Roemer (2004). This scale consists of 36 items which assess difficulties in emotion regulation. Participants answered by scoring statements, e.g. *"When I am upset, I feel like I am weak"* on how often they feel that way on a five point scale (1: Almost Never…, 5: Almost Always). Approximately half of the items were reverse-coded. See **Appendix 2**. The higher the score, the poorer a person is at regulating their emotions, with the highest achievable score being 180.

Empathy Quotient: The 'Empathy Quotient' designed by Baron-Cohen and Wheelwright (2004) is a self-report measure of empathy. There are 40 statement items. Participants read each statement and then decided how strongly they agreed or disagreed with each item, e.g. *"It doesn't bother me too much if I am late meeting a friend"* along a four point scale (strongly agree to strongly disagree). See **Appendix 3**. A final score was calculated for level of empathy by awarding two points for a strongly empathic response, one for a less strongly empathic response and zero for a non-empathic response. The highest score achievable was 80.

Self-Positivity Bias: This is a shortened version of the self-positivity test developed by Watson, Dritschel, Jentzsch and Obonsawin (2008). Participants were asked to rate on a five point scale the self-referential content (1: not like me…., 5: like me) of 20 negative words, e.g. *'worthless'*; *'anxious',* and 20 positive words, e.g. *'bright'*;

'capable'. Participants then rated the emotional content of the same set of 40 words in the same order, using a five point scale (1: negative…., 5: positive). The mean scores for both the positive and negative words were calculated for both the self-evaluation and the emotion rating task. The self-positivity bias 'score' was gained from the self-evaluation task, with the mean of the 20 negative words being subtracted from the mean of the 20 positive words. A score of zero indicates no emotional bias. The emotion rating task was used as a control to check that participants understood the emotional content of the words. See **Appendix 4**.

Hospital Anxiety and Depression Scale: The Hospital and Anxiety Depression Scale (HADS) was developed by Zigmond and Snaith (1983). This scale has seven items relating to depression and seven to anxiety, both with a maximum score of 21. The participants read statements and cross one of four options which changed to suit each question, e.g. *'I feel tense or wound up'* could be answered on a scale ranging from *'most of the time'* (3 points) to *'not at all'* (0 points). See **Appendix 5**. On each question, the highest score achievable was 3 and the lowest score achievable is 0; the greater the score, the more depressive or anxious the answers provided were.

Musical Experience Questionnaire: Participants completed the musical experience questionnaire as described in section **2.2.2.**

4.2.3. Procedure

Participants completed all tasks in the same order: 1. Empathy Scale; 2. Emotional Sound Recognition Task; 3. The Reading the Mind in the Eyes Test; 4. Self-positivity Scale; 5. Emotional Gesture Recognition Task; 6. Difficulties in Emotion Regulation Scale; 7. Hospital Anxiety and Depression Scale; 8. Facial Emotion Recognition Task; 9. Musical Activity Questionnaire.

4.3. Results

4.3.1. Participant Characteristics

Statistical analyses were conducted to investigate any possible demographic differences between participants in the three musical groups. Chi-square analyses showed no statistically significant differences between the participants in the three musical groups for sex: χ^2 (2, n = 100) = 3.316, p = .191, or for handedness: χ^2(2, n = 100) = 1.515, p = .469 (participant numbers can be seen **Table 8**). As can also be seen in **Table 8**, one-way ANOVAs showed no differences in age, years of education, physical activity or computer gaming. A difference between groups was observed between accumulated practice time, number of years played, musical knowledge score and hours of listening to music weekly.

Table 8: Participant Characteristics Chapter four

	Musical Group				
	Low (n=30)	Medium (n=34)	High (n=36)	*F(linear)*	η_p^2
Sex (female; male)	22; 8	25; 9	32; 4	-	-
Handedness (right; left)	27; 3	32; 2	35; 1	-	-
Age [years]	21.5	20.8	21.5	0.001	-
Years of Education [years]	16.0	15.4	16.0	0.007	-
Accumulated Practice Time [h]	106	1680	5853	**140.360*** **	**0.558**
Total Years Played [years]	1.8	8.6	13.2	**207.363*** **	**0.680**
Musical Knowledge Score	6.9	12.9	15.8	**147.499*** **	**0.596**
Listening to Music [h/week]	11.7	19.6	18.6	**4.954* **	**0.047**
Physical Activity [h/week]	5.0	3.8	4.8	0.042	-
Computer Gaming [h/week]	1.0	0.6	0.4	0.782	-

*p <.05; ***p < .001

	Main musical instrument played
Musical Group	
Low	11 Strings, 4 Wind, 1 Percussion, 2 Voice, 6 Piano (6 n.a.)
Medium	11 Strings, 10 Wind, 4 Voice, 9 Piano
High	8 Strings, 1 Wind, 1 Percussion, 7 Voice, 17 Piano, 2 Brass

4.3.2. Construct Validity of Measures Used

Analyses were carried out to confirm that the measures used demonstrate construct validity. **Table 9** displays the results of the Pearson correlations. There were significant positive correlations between anxiety, depression and difficulties in emotion regulation. In addition, self-positivity bias significantly negatively correlated with these three measures. In other words, the less strong the self-positivity bias, the stronger the levels of depression, anxiety, and difficulties in emotion regulation.

Table 9: Pearson Correlations across levels of anxiety, depression, difficulties in emotion regulation and self-positivity bias

Pearson Correlations across Anxiety, Depression, Difficulties in Emotion Regulation and Self-Positivity Bias (n = 100)

	1. Anxiety	2. Depression	3. DERS	4. Self-Positivity Bias
1.	-	.528***	.328***	-.386***
2.	-	-	.493***	-.565***
3.	-	-	-	-.552***

*p < .05, ** p <.01, ***p <.001

Figure displays the means of the self-referential words (positive/negative) and the means of the emotional ratings (positive/negative) in the self-positivity bias measure. A paired samples t-test showed a significant difference between the mean of the positive word emotion ratings, M = 4.43 (SD = 0.31) and the mean of the negative word emotion rating, M = 1.6 (SD = 0.22), t(99) = 70.92, p < .001. This suggests that participants were able to understand the emotional valence of the positive and negative words. It can also be seen in the figure that generally participants attributed positive emotions more than negative emotions to themselves.

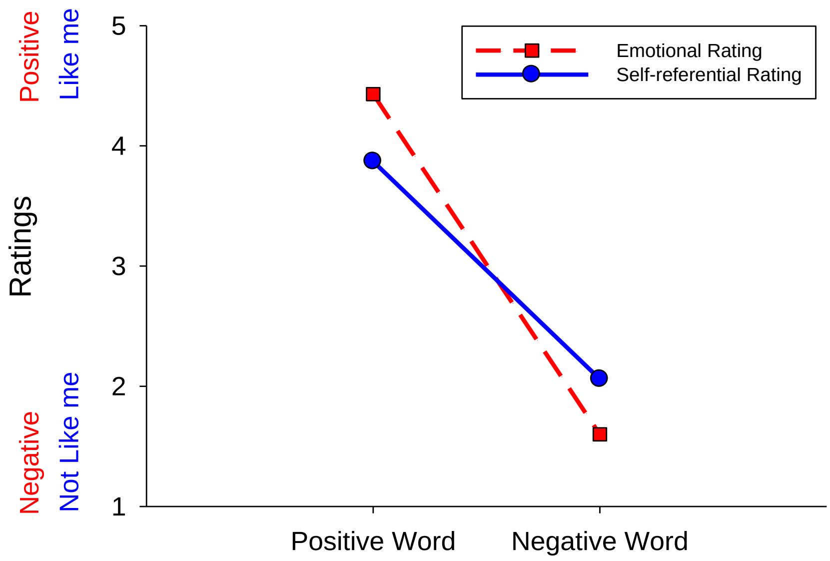


Figure 11: Mean Ratings of Self-Referential and Emotional Content of Words (Positive & Negative)

4.3.3. Data Analyses

Linear trend analyses were conducted on all dependent variables with three group levels, dependent on self-reported hours of musical training; low (0-500h), medium (501-3000h), and high (>3000h). Linear trend analyses were carried out because the potential effects were predicted to be systematically related to hours of musical practice. In addition, in order to ensure that possible significant effects are not the results of the somewhat artificial choice of group boundaries, Pearson correlations between the dependent variables and hours of musical practice were conducted on all effects that reached significant levels in the linear analyses.

Linear trend analysis revealed a linear association between the ability to recognise emotions in sound and increasing levels of musical practice: F(linear: 1,97) = 4.29, p = .041 η_p^2 = 0.042. Similarly, levels of empathy were found to linearly increase with increasing levels of musical practice: F(linear: 1,97) = 5.56, p = .020, η_p^2 = 0.054. No other significant trends were uncovered in any of the other emotion recognition tasks, in levels of anxiety, depression, self-positivity, or in the emotion regulation scale (see **Table 10** for an overview of the results).

Table 10: Means (M), Standard Deviations (SD), and outcomes of the statistical analysis on emotion processing measures for Chapter four

	Musical Group			
	Low	Medium	High	
	M (SD)	*M (SD)*	*M (SD)*	*F*(linear)
Depression	4.2 (4.0)	4.5 (2.8)	4.0 (3.5)	0.041
Anxiety	9.0 (4.3)	9.1 (3.7)	8.6 (4.1)	0.155
Empathy Quotient	42.5 (12.3)	46.1 (13.1)	49.7 (11.4)	**5.564***
Self-Positivity Bias	1.8 (0.8)	1.8 (0.7)	1.8 (1.0)	0.052
Diff. in Emo. Reg.	91.2 (21.1)	86.9 (23.2)	93.9 (19.9)	0.252
Mind In The Eyes	27.9 (3.6)	26.8 (3.8)	27.64 (3.8)	0.061
Facial Emo. Recog.	51.3 (4.3)	48.0 (5.2)	51.6 (3.7)	0.067
Gesture Emo. Recog.	35.7 (3.8)	35.5 (4.0)	36.0 (3.7)	0.100
Sound Emo. Recog.	34.2 (3.7)	34.6 (6.4)	36.9 (5.2)	**4.289***

*p < .05

To confirm the significant results obtained above are not an artefact of the specific group split, Pearson correlations were performed. Confirming the above results, a significant correlation between empathy and reported hours of musical practice was revealed: $r = .213$, $n = 100$ $p = .034$. The correlation for recognition of vocal emotions with musical practice levels was also significant: $r = .287$, $n = 100$, $p = .004$.

In the recognition of emotion for sound task, five different emotions were tested. The above analyses report just the result using the overall score. In order to evaluate whether the emotion in sound recognition advantage found in musically trained participants is specific only to a subset of these emotions, a more detailed analysis was conducted, analysing the effects of musical training on each of the five emotions tested separately. Interestingly, as illustrated in **Table 11**, people with more musical training appeared to be significantly better specifically in the recognition of happy sounds, $F(\text{linear: } 1,97) = 6.24$, $p = .014$ $\eta_p^2 = 0.063$, but not for the other emotions.

Table 11: Breakdown of the five separate emotions within the emotional sound recognition task with report of Means, SDs and results of the statistical analysis

	Musical Group			
	Low	Medium	High	
	M (SD)	*M (SD)*	*M (SD)*	*F*(linear)
Overall Sound Recog.	34.2 (3.7)	34.6 (6.4)	36.9 (5.2)	**4.289***
Sad	7.5 (1.4)	7.6 (2.1)	8.2 (1.4)	2.851
Happy	6.5 (1.2)	7.3 (1.6)	7.4 (1.4)	**6.239***
Fear	6.6 (1.6)	6.9 (1.6)	6.9 (1.2)	0.535
Disgust	5.8 (2.4)	5.1 (2.7)	6.1 (2.6)	0.339
Anger	7.9 (1.6)	7.7 (1.6)	8.4 (1.5)	1.550

*$p < .05$

4.4. Discussion

The aim of the current study was to investigate whether musical training is associated with enhanced emotional processing abilities.

The first prediction stated that active musical engagement would be associated with better emotion recognition abilities in both the auditory and in the visual domain. Musical training was associated with enhanced auditory emotion recognition which concurs with research which suggests that music can train auditory abilities; see Kraus and Chandrasekaran (2010) for a review. Thus, it could be that amateur musicians may have a slight advantage in auditory perceptual abilities, which in turn may increase the ability to recognise emotions in sound. This is supported by a number of studies which suggest that musical training can lead to structural changes in areas involved in auditory processing. For example, the auditory cortex, the left planum temporale, and the anterior corpus callosum have been found to be larger in musicians compared to non-musicians (Schlaug, 1995; Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995; Schneider et al., 2002). On the other hand, Juslin and Västfjäll (2008) suggest that we possess a neural mechanism which responds automatically to the 'voice like' aspects of music which allows us to mimic the emotion and therefore experience it as our own. It may be that those who engage more with musical material may be more apt at recognising emotions in music and in voices. Alternatively, it may be that people with a natural given sensitivity for sound perception are more engaged in music as it is more rewarding for them.

Surprisingly, results from this study demonstrated that musical training was *not* associated with visual emotion recognition on any of the visual measures (eyes, faces, or gestures). This finding suggests that people with musical training do not demonstrate far-transfer effects in emotion recognition abilities. This is surprising given the importance of visual emotional expressivity during musical performance as discussed in section **4.1.1.** Emotion Recognition and research which suggests that motor expertise in one domain can have far-transfer effects to perceptual judgements in other domains (Sevdalis & Raab, 2016).

The second prediction stated that active long-term musical engagement would have a positive effect on long term emotional well-being. Surprisingly, the present findings do not support this prediction. No significant relationships between self-reported hours of musical activity and levels of anxiety, depression, emotion regulation ability and self-positivity were observed. This is an unexpected finding given the intrinsic emotionality of music and the research which suggests that both passive and active musical activity can lead to positive increases in emotional arousal (see Koelsch et al., 2010; Kreutz et al., 2004). The results suggest that musical activity does not result in long-term emotional benefits which could imply that the changes to emotions are indeed limited to short-term changes in affect.

The third prediction stated that based on previous findings which suggest a positive relationship between active musical activity and empathy in children, long-term active musical engagement would be positively associated with empathy levels in adults. This third prediction was supported with a positive correlation between EQ scores and self-reported hours of musical training observed. This concurs with the evidence from a number of studies which have reported that musical activity does appear to promote empathy in children (e.g. Hietolhti-Ansten & Kalliopuska, 1990; Kalliopuska & Ruokonen, 1986, 1993; Kirschner & Tomasello, 2010; Rabinowitch, Cross, & Burnard, 2012), though this is the first study to show such an effect in adults with musical training. As briefly mentioned in regards to emotional sound recognition, it could be that people who are naturally empathetic are drawn to musical engagement because engagement with emotional material is more rewarding for them compared to someone with less empathy. This is an important and interesting finding, however it must be noted that this study was exploratory and is the first to establish a correlation between musical training and empathy in adults; therefore, in the next study reported in chapter five, a different participant sample will be used to further explore this result and to ascertain whether this effect can be replicated.

5. Chapter 5: The Effect of Musical Training on Emotional Processing: A Replication Study

5. Chapter 5: The Effect of Musical Training on Emotion Processing: A Replication Study

5.1. Introduction

The aim of the current study was to investigate whether the effects uncovered in chapter four can be replicated considering that it was the first study to show correlations between the empathy quotient (EQ) and musical training. In this study, only the tests which showed significant effects in the previous study were included for testing; the emotional sound recognition task and the EQ questionnaire. A second measure of empathy, the Interpersonal Reactivity Index (IRI), was included to verify that musical training is associated with empathy, and not only specifically with items on the EQ. Again, a cross-sectional design was used to investigate whether the effects could be replicated using a different sample.

5.1.1. Hypotheses

1. A positive correlation between hours of musical training and empathy scores on both empathy measures (EQ and IRI) will be observed.
2. A positive correlation between hours of musical training and emotional sound recognition abilities will be observed.

5.2. Methodology

5.2.1. Participants

A new sample of 103 participants recruited from the University of St Andrews participant pool completed the study. The mean age of participants was 22.6 years, age range 17-62, 56 female. As in previous studies, participants were split by self-reported hours of musical practice (low: 0-500h; medium: 501-3000h; and high: > 3000h).

5.2.2. Stimuli and Apparatus

Interpersonal Reactivity Index: The 'Interpersonal Reactivity Index' (IRI) (Davis, 1980; 1983) is a multi-dimensional self-report measure of empathy which measures four distinct but related empathy domains. These include 'perspective taking', e.g. "I try to look at everybody's side of a disagreement before I make a decision", 'fantasy', e.g. "I really get involved with the feelings of the characters in a novel", 'empathic concern', e.g. "Sometimes I don't feel very sorry for other people when they are having problems" and 'personal distress', e.g. "I sometimes feel helpless when I am in the middle of a very emotional situation". Each of these subscales contained seven items and for each item participants answer by indicating how well a statement describes him- or her-self. The five point answer scale ranges from "does not describe me well" to "describes me very well". See **Appendix 6**. Participants could score between 0 and 4 along this scale. The maximum score for each subscale was 28.

The Empathy Quotient: The empathy quotient developed by Baron-Cohen and Wheelwright (2004) was used, as described in section **4.2.2.**

Emotional Sound Recognition: The emotional sound recognition task developed by Calder et al., (2004), as previously described and used in chapter four, was again used here. In addition, participants were recorded while verbally relaying their answers.

Musical Experience Questionnaire: As used in the previous studies the musical experience questionnaire was used, see section **2.2.2.**

5.2.3. Procedure

All participants completed the measures in the same order beginning with the EQ, followed by the emotional sound recognition task, before completing the IRI, and finally the musical experience questionnaire.

5.3. Results

5.3.1. Participant Characteristics

Statistical analyses were conducted to investigate possible demographical differences between participants in the three musical groups. Chi-square analyses showed no statistically significant differences between the participants in the three musical groups for sex: χ^2 (2, n = 103) = 1.148, p = .563, or for handedness: χ^2(4, n = 103) = 3.583, p = .465 (participant numbers can be seen in **Table 12**). One-way ANOVAs did not reveal any differences between the musical groups for age, years of education, listening to music, physical exercise, computer gaming, or artistic activities, please see **Table 12**.

Table 12: Participant Characteristics: Chapter five

	Musical Group				
	Low (n=31)	Medium (n=44)	High (n=28)	*F(linear)*	η_p^2
Sex (female; male)	18; 13	28; 16	20; 8	-	-
Handedness (right; left)	27; 3	36; 8	25; 2	-	-
Age [years]	22.9	21.2	24.5	1.009	-
Years of Education [years]	17.3	15.6	18.1	0.476	-
Accumulated Practice Time [hrs]	175	1540	7214	**75.668*** **	**0.407**
Total Years Played [years]	2.2	8.5	17.4	**104.846*** **	**0.510**
Musical Knowledge Score	8.5	12.1	16.3	**104.577*** **	**0.154**
Listening to Music [hrs/week]	19.1	14.9	19.1	0.000	-
Physical Activity [hrs/week]	5.3	4.7	5.0	0.071	-
Computer Gaming [hrs/week]	1.0	1.2	1.0	0.000	-
Artistic Activities [hrs/week]	2.0	1.8	2.0	0.000	-

***p < .001.

Main musical instrument played	
Musical Group	
Low	7 Strings, 6 Wind, 2 Brass, 1 Percussion, 1 Voice, 11 Piano (3 n.a.)
Medium	15 Strings, 7 Wind, 4 Brass, 4 Percussion, 3 Voice, 11 Piano
High	9 Strings, 1 Wind, 1 Brass, 5 Voice, 12 Piano

5.3.2. Questionnaire Performance

Linear trend and Pearson correlational analyses were performed. Linear analyses were conducted but revealed no significant effects; results are presented in **Table 13**.

Table 13: Means (M), Standard Deviations (SD), and outcomes of the statistical analysis on the various emotion processing measures for Emotion Study

	Musical Group			
	Low	Medium	High	
	M (SD)	*M (SD)*	*M (SD)*	*F(linear)*
Empathy Quotient	43.6 (13.3)	45.9 (10)	47.7 (10.3)	2.005
Interpersonal Reactivity Index				
Perspective Taking	18.5 (4.4)	17.8 (4.6)	19.7 (4.0)	1.148
Fantasy	18.8 (5.9)	17.6 (6.8)	18.4 (8.2)	0.051
Empathic Concern	19.4 (5.5)	21.2 (4.1)	21.3 (3.4)	2.729(*)
Personal Distress	13.1 (5.5)	12.1 (4.4)	12.3 (4.0)	0.371
Sound Emo. Recognition	34.3 (5.3)	35.6 (5.2)	35.4 (5.2)	0.619

(*) $p < .10$

After conducting Pearson correlations, no correlations were found to be significant with hours of musical practice and the EQ: $r = .15$, $n = 103$, $p = .13$; or in emotional sound recognition: $r =.09$, $n = 103$, $p = .368$. The EQ significantly inter-correlated with all aspects excluding personal distress on the interpersonal reactivity index, see **Table 14**.

Table 14: Pearson Correlations across the Empathy Quotient and the Interpersonal Reactivity Index Sub-scales

Pearson Correlations across the Empathy Quotient and the Interpersonal Reactivity Index Sub-scales (n = 103)

	1.Empathy Quotient	2.Perspective Taking	3. Fantasy	4.Empathic Concern	5.Personal Distress
1.	-	.482***	.277**	.651***	.184(*)
2.	-	-	.401***	.365***	-.079
3.	-	-	-	.359***	.179(*)
4.	-	-	-	-	.329**

(*) $p < .10$ *$p < .05$, ** $p <.01$, ***$p <.001$

5.4. Summary of findings chapter five

The study in chapter five was conducted to investigate whether the effects in chapter four could be replicated using a different sample and a second empathy measure to test for external validity. While a numerically similar relationship between EQ scores and hours of musical practice as seen in chapter four was detected, this effect did not reach significance levels. A linear trend however between increasing musical training and increasing scores on the empathic concern subscale of the IRI was observed. This subscale correlated most strongly with the EQ suggesting that the items on the EQ and the empathic concern subscale of the IRI are more closely aligned than the items in the perspective taking, fantasy, or personal distress subscales.

No significant relationship was detected between hours of musical training and the ability to recognise emotional vocal sounds. This is surprising given the effects observed in chapter four and the literature which presents overwhelming evidence that musical training is typically associated with increased auditory perceptual abilities.

Due to the inconclusive findings of both studies, to further explore the data a combined analysis of both independent data sets is conducted.

5.5. Combined Analysis

5.5.1. Method/Analysis

The measures that were used both in chapter four and in chapter five were analysed (i.e. the EQ questionnaire and the emotional sound recognition task). For both measures a two-way between-subjects ANOVA with factors music group (low/medium/high), and study (chapter four/chapter five) was conducted. Using both 'music group' and 'study' as factors allows it to be determined whether performance differs significantly between the samples in the two studies and/or between music groups.

5.5.2. Results

5.5.2.1. Participant Characteristics

Table 15 reveals the participants characteristics when the samples from studies in chapters four and five are combined. Chi-square analyses showed no statistically significant differences between the participants in the three musical groups for sex: χ^2 (2, n = 203) = 4.512, p = .105, or for handedness: χ^2(4, n = 203) = 3.937, p = .415 (participant numbers can be seen in **Table 15**). As can also be seen in **Table 15** one-way ANOVAs did not show any differences between musical groups for age, years of education, physical activity or computer gaming. There was a significant difference between groups for hours spent listening to music: with the intermediate group reporting that they listened to more music on average weekly than the two extreme groups.

Table 15: Participant Characteristics Combined Analyses

	Musical Group			*F(linear)*	η_p^2
	Low (n=54)	Medium (n=68)	High (n=60)		
Sex (female; male)	40; 21	53; 25	52; 12	-	-
Handedness (right; left)	54; 6	68; 10	60; 3	-	-
Age [years]	22.2	21.0	22.8	0.480	-
Years of Education [years]	16.6	15.5	16.9	0.188	-
Accumulated Practice Time [h]	140.8	1601	6448.6	**181.783*** **	**.450**
Total Years Played [years]	2.0	8.6	15.0	**235.030*** **	**.540**
Musical Knowledge Score	7.7	12.4	16.1	**244.849*** **	**.550**
Listening to Music [h/week]	11.7	19.6	18.6	**4.954***	**.047**
Physical Activity [h/week]	5	3.8	4.8	0.042	-
Computer Gaming [h/week]	1	0.6	0.4	0.782	-

*p<.05 ***p < .001.

5.5.2.2. Results of Between-Subjects ANOVAs and Correlational Analyses

Empathy Quotient: There was no significant main effect of study, F(1, 197) = 0.049, p = .825. Importantly, there was a significant main effect of music group, F(2, 197)

= 3.583, p = .030, η_p^2 = .035, but no significant interaction between music group and study F(2, 197) = 0.262, p = .770.

Emotion Sound Recognition: There was no significant main effect of study, F(1,197) = 0.033, p = .770. Importantly, there was a significant main effect of music group, F(2, 197) = 1.340, p = .047, η_p^2 = .020, but no significant interaction between music group and study F(2, 197) = 1.005, p = .368.

5.5.2.3. Results of Linear ANOVAs and Correlational Analyses

Results of both ANOVAs show, that there was no difference in outcome between the samples used in studies outlined in chapters 4 and 5. There was a significant linear trend between the musical groups for both the EQ questionnaire and for scores on the recognition of emotional vocal sounds task. See **Table 16** for the group means and linear analyses results.

Table 16: Means (M), Standard Deviations (SD), and outcomes of the statistical analysis on the EQ and emotional sound recognition (combined analyses)

	Musical Group				
	Low *M (SD)*	Medium *M (SD)*	High *M (SD)*	*F*(linear)	η_p^2
Empathy Quotient	43.1 (12.7)	46 (11.4)	48.8 (10.9)	**7.613****	**0.037**
Sound Emo. Recognition	34.3 (4.7)	35.2 (5.7)	36.25 (5.2)	**4.478***	**0.022**

*p < .05; **p < .01

For the correlational analyses, participants from chapters four and five were pooled. The Pearson correlation between hours of musical practice and the EQ was significant: r = .175, n = 203 p = .013. The Pearson correlation between hours of musical practice and emotional sound recognition scores was also found to be significant: r = .172, n = 203, p = .014, see **Figure 12**.

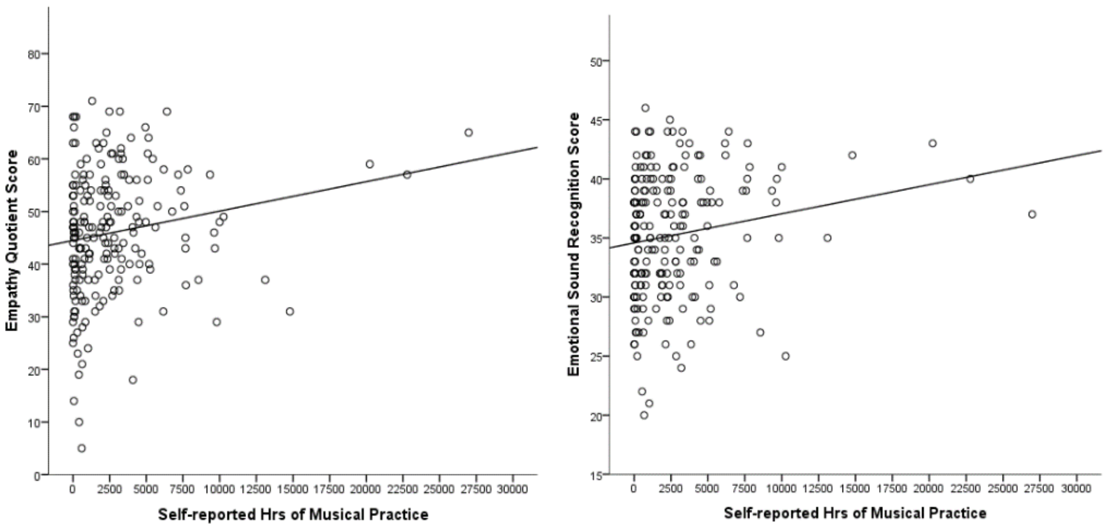


Figure 12: Scatterplots showing the relationship between self-reported hours of musical practice and empathy (left) and emotional sound recognition (right), including all participants from both studies

As can be seen on the scatterplot, only six participants reported a total of over 10,000 hours of musical practice which may have inflated the correlation. Pearson correlational analyses after excluding these six participants were therefore conducted. The correlation was still found to be significant between both hours of musical practice and empathy: $r = .159$, $n = 197$, $p = .025$, and between hours of musical practice and emotional sound recognition: $r = .164$, $n = 197$, $p = .022$, see **Figure 13**.

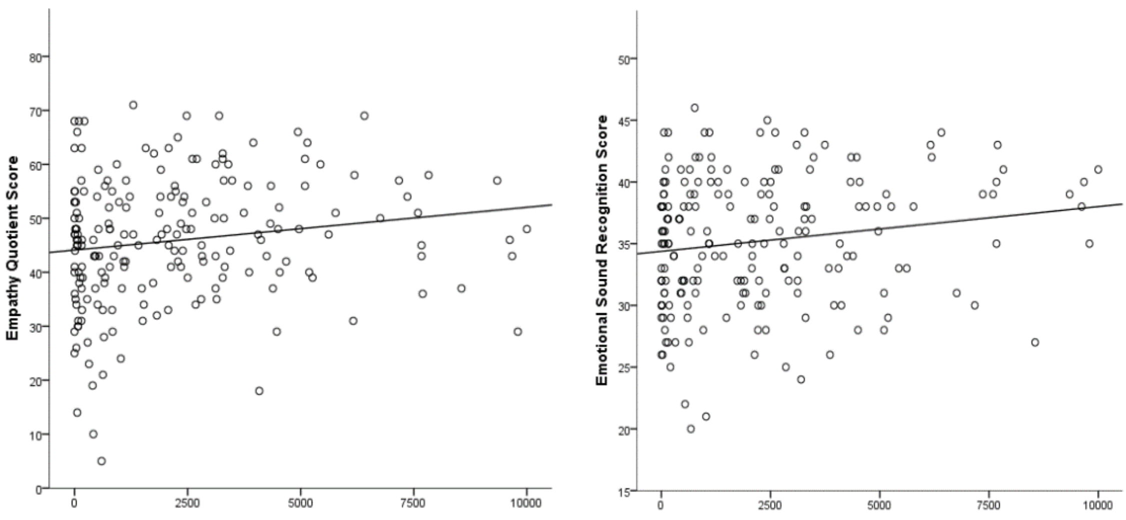


Figure 13: Scatterplots showing the relationship between self-reported hours of musical practice and empathy (left) and emotional sound recognition (right) excluding 6 participants with over 10,000h of musical training

5.6. Discussion

The aim of chapter five was to investigate whether the effects observed in chapter four, including correlations between musical training and empathy and musical the ability to recognise emotions in sound, could be replicated and if another measure of empathy could confirm the effect.

The first prediction stated that a positive correlation between hours of musical training and two measures of empathy would be observed. Although the effects did not reach significance levels in the study in chapter five, a numerical linear trend was detected between more musical training and higher empathy quotient (EQ) scores and the 'empathic concern' subscale of the interpersonal reactivity index (IRI). Considering that the two studies used different samples but from the same population, a combined analysis was conducted and positive correlations were revealed between musical training and the EQ.

There are a number of speculations regarding the mechanisms behind how music may affect emotions and these may also explain why there appears to be a relationship between musical activity and EQ scores. The 'Shared Affective Motion Experience' (SAME) model proposed by Molnar-Szakacs and Overy (2006) suggests that musical emotion is conveyed via our mirror neuron systems (MNS). The MNS has been associated with a number of higher order processes including theory of mind, empathy, imitation and intention understanding (Overy & Molnar-Szakacs, 2009). If musically trained individuals are continually using their MNS to convey emotion via music, perhaps this MNS training can then be used for the other higher order processes associated with activation of the MNS such as empathy and intention understanding. Support for the mechanisms in this theory comes from an fMRI study by Gazzola, Aziz-Zadeh and Keysers (2006). They identified that the left hemispheric temporo-parieto-premotor circuit was activated during both a motor execution task, and when participants were simply asked to listen to the sound of the same action. Interestingly, Gazzola et al., also found that individuals who scored highly on the IRI had a higher than average activation in this 'mirror-neuron area' during emotion perception.

Another explanation for this possible link between musical activity and empathy is that when people engage with musical material, they may try to infer the intentions/perspective of the composer. Evidence suggests that when listening to music, people attempt to understand what an artist or a composer is intending to communicate. Steinbeis and Koelsch (2008) reported that activations typically seen in the cortical network during mental state attribution were observed in participants when they believed that they were listening to a composer written musical piece, but not when they believed they listened to a computer generated piece. It is likely that musicians will engage in similar behaviours when learning or performing music and thus may be better trained in empathising. Interestingly, in a study conducted by Wöllner (2012) it was found that people with higher empathy scores were more accurate at estimating musicians' intentions after observing and listening to a musical piece than people with lower empathy scores. Furthermore, Egermann and McAdams (2013) found that empathy appears to moderate the difference between perceived emotion and 'felt' emotion when listening to musical excerpts; those with higher empathy levels were more likely to experience the emotion as their own. From a number of studies it appears that empathy is linked to the susceptibility of feeling emotions in music (see also Vuoskoski & Eerola, 2012; Vuoskoski, Thompson, McIlwain, & Eerola, 2012). This could suggest that people with more empathy feel emotions in music more so than those without empathy and therefore may be drawn to begin and to continue with active musical activity.

Another explanation for a possible association between musical training and empathy is that active music playing may increase socialisation opportunities, seeing that it is frequently carried out in groups such as ensembles, bands, or orchestras. Music players therefore must interact with others which they may otherwise not experience if not actively taking part in musical activity. Musical practice and/or performance within a group requires social awareness; the players must interact with each other (regularly without using words) and be able to indicate meaning, tempo, and timing to others, as well as, synchronize movements, and anticipate the actions of others. Thus, this practice in social awareness might heighten the ability to understand and empathise with others beyond a musical context. However, data was not collected regarding how many hours of musical practice included playing in a group, therefore it is unclear what type of musical activity the participants engaged in. This may explain the differences in results between chapter four and the current chapter. For example, participants in the highly musical group in chapter four may have engaged in more group musical activity than the participants in the highly musical group in chapter five. This will be discussed in the limitations section and could be a variable that future research could consider.

The second prediction stated that, as in chapter four, and based on the findings from previous literature, there would be a positive correlation between hours of musical training and the ability to recognise emotions in sounds. The combined analysis provided evidence supporting this prediction. As discussed in study number three, this could be because musical activity trains auditory abilities rather than specifically emotional auditory abilities. Furthermore, it could be that those with better auditory perception of emotional sounds are more captivated by music and are therefore more attracted towards engaging in musical activity. Coupled with the empathy correlation however and with the theories discussed in relation to the empathy findings, it could be that people who engage with musical material are more adept at understanding the emotional tones by imitating and simulating the tones themselves. It would be of interest to investigate whether those with musical training are better at emotion imitation and whether this then relates to emotional sound recognition ability and furthermore whether this relates to empathising abilities.

5.6.1 Limitations

The present findings indicate that musical training might have the potential for improving levels of empathy and our ability to recognise emotions in sound. However, conclusions regarding the causality of this effect cannot be attributed to music without further investigation. The present studies were cross-sectional which cannot substantiate any causal claims; this will be discussed more in the general discussion.

Differences in the type of musical engagement participated in could potentially explain why results between the two samples tested in chapters four and five differed.

It could be that the highly musical group in chapter four contained more individuals who are, or were, actively involved in musical groups, whereas individuals in the same group with the equivalent number of hours in chapter five may have been more active in solo musical pursuits. While data was collected regarding the instruments the participants played, and the main instrument of each individual (the instrument played the most) were compared, no differences were observed. However, the sample sizes for each instrument were very small, consequently these analyses are not incredibly powerful, and were therefore not reported in the results section. While the type of main instrument played may provide some insight into the type of musical engagement participated in (for example, a pianist may be more likely to play alone than a drummer), data was not collected regarding whether music was mainly practised in groups or alone.

It is unclear what may be 'driving' the empathy effect, therefore it would be interesting firstly to investigate whether it is something intrinsically musical or if this may be due to other processes involved in musical activity such as social interaction, engagement with emotional materials, imitation and synchronization, and/or motor control. It would be of interest to test other groups with individuals who engage in another activity with comparable hours spent for learning a musical instrument such as dancing or sport. There is also discussion in the current literature regarding in what way music listening and empathy inter-relate and particularly what kind of music listening relates with empathy (Clarke, DeNora, & Vuoskoski, 2015; Greenberg et al., 2015). There may be variability in empathy according to the musical genres individuals engaged with as suggested by the literature on music listening and which may explain the differences in results between chapters four and five.

5.6.2 Conclusions

The present studies investigated the relationship between musical activity and important emotional processing abilities. Surprisingly, although music is intrinsically emotional, no evidence that sustained musical activity results in generally enhanced emotion recognition abilities or long-term emotional benefits was found. However, potential selective advantages in the ability to recognise emotions in vocal sounds and the capacity to empathise were observed in one sample, although these effects could not be replicated in a second sample. Despite this, the latter finding might have potential implications for encouraging musical activity to improve empathising abilities in both clinical and non-clinical populations. However, since this study is cross-sectional, results of a causal link between musical activity and empathy levels remain speculative and necessitate further research.

6. Chapter 6: Empathy, Music and other Activities

6. Chapter 6: Empathy, Music and other Activities

6.1. Introduction

The previous chapters uncovered a potential relationship between musical activity and EQ scores in adults with varying levels of musical training. As discussed in section **5.6.** there are a number of processes involved in musical activity which could foster empathic tendencies, such as motor control, engagement with emotional material, understanding other people's perspectives, and imitating and synchronising movements. A number of other non-musical activities also engage such processes and it is unclear whether the association between music and empathy is something intrinsically musical, or if it may be due to processes which other activities engage and which can therefore confer the same advantages in empathy. Hence the aim of the current study is to investigate whether other activities which engage similar processes to musical activity are also associated with empathy levels.

A number of research studies have investigated whether empathy is related to engagement in a variety of leisure activities and these will be briefly introduced before a rationale for the current study design is presented.

Acting: Similar to musical activity, acting involves engaging with emotional material, and understanding perspectives of other people.

Actors are required to imagine and adopt other people's emotions, intentions and perspectives. It could therefore be argued that acting training may train empathic understanding, and a number of studies have investigated the links between empathy, perspective taking and acting. Goldstein, Wu and Winner (2009) used a cross-sectional design to test whether adolescent actors (n = 68) showed enhanced empathy and sensitivity to facial expressions when compared to their non-acting counterparts (n = 43). Using the 'reading the mind in the eyes test', Goldstein et al., (2009) found that 16 year old adolescents with acting experience outperformed their non-acting counterparts at reading the mental states of others. Similarly in young adults, those with acting experience (n = 23) were more capable at understanding motivations behind social interactions than young adults without acting experience (n = 21) when completing the 'Movie for the Assessment of Social Cognition', which entails watching clips of four people interacting and answering questions regarding the characters' motivations, intentions, beliefs and emotions. Interestingly, neither adolescent nor young adult actors outperformed their non-acting counterparts in tests of empathy using the 'Index for Empathy for Adolescents' and the 'empathic concern' sub-scale on the 'Interpersonal Reactivity Index' (IRI) respectively. The authors suggest a number of explanations for these results. For example, they suggest that acting training may confer advantages in analysing other people's mental states but not in empathy so that there is not confusion between their own feelings and the feelings of the person that they are attempting to portray. A further explanation is that empathy is only felt during performance but not beyond the performance, therefore empathy is a state rather than a trait. Goldstein and Winner (2012) conducted two studies in which children and adolescents received ten months of acting or other arts training (music or visual arts). Using a self-report measure of empathy (the 'Index of Empathy for Children'), children (n = 35, age range 7-10 years) who received acting training showed increases in empathy but did not show increases in theory of mind tests (the 'Faux Pas Test'; the 'Strange Stories Test'; the 'Reading the Mind in the Eyes Test for Children') compared to those who engaged in visual arts classes (n = 40, age range 8-10 years). The children enrolled in acting demonstrated a higher score than the visual arts group in another empathy test (a 'Fiction Emotion-Matching' measure), though this difference was already apparent at pre-testing stage which presents an obvious confound to the post-test results.

In study number two with adolescents aged between 13 and 16, 28 students majoring in acting were compared to 25 students majoring in either visual arts or music. The two groups were measured pre- and post- ten months of intensive training on two theory of mind tasks: 'Reading the Mind in the Eyes Test for Adults', and the 'Empathic Accuracy Paradigm', and two empathy tests: the 'Basic Empathy Scale for Adolescents' and the 'Fiction Emotion Matching' task. Actors scored more highly in the 'Reading the

Mind in the Eyes Test' than the visual arts or music group at pre-testing which, as in the first study presented a confounding factor. After ten months of training, actors gained significantly more in 'Empathic Paradigm' scores and marginally more in dispositional empathy scores than the non-acting group. Taken together, these two studies suggest that acting training can increase scores on empathy measures in both children and adolescents and can also increase theory of mind abilities in adolescents when compared to a non-acting group, though these results must be taken with caution due to the actors scoring higher in some of the empathy measures at the pre-testing stage. Furthermore, in study number two, music and visual art groups were pooled for analyses and it would have been interesting for the present study in this thesis, to see the differences between these groups.

Using a cross-sectional design, Nettle (2006) aimed to investigate the psychological profiles of professional actors. He found actors to score significantly higher on the EQ than data derived from general population samples taken from Baron-Cohen, Richler, Bisarya, Gurunathan and Wheelwright (2003). However, these two groups were compared using Cohen's d which assumes that both groups have comparable sample sizes, and Nettle compared his 191 actors to 278 participants in the comparison data. Furthermore, the EQ was administered differently (combined with the Systemising Quotient) in Nettle's study and as part of a larger study, with participants in Nettle's study completing a number of questionnaires compared to participants in the comparison data which makes comparing these two groups difficult. However, generally, the research investigating empathic tendencies in actors suggests that acting appears to enhance our perspective taking and empathic abilities.

Visual Art: Visual artistry shares similar processes to music such as engagement with emotional material.

Despite the fact that art therapy is believed to encourage empathy (see Peloquin, 1996), there do not appear to be any empirical studies which investigate links between visual artistry and empathising abilities. However, studies have measured processes which are believed to be related to empathy and their relationship with visual artistry.

Taylor, Witt, and Grimaldi (2012) conducted five experiments to investigate whether abstract art can simulate movement in the observer. Participants executed arm movements which resembled painting horizontal brushstrokes while observing paintings in which clear brushstroke marks were visible. Participants were faster to respond when the arm movement was congruent with the observed direction of the brushstrokes than when they were incongruent (i.e. participants executed an arm movement left to right faster than an arm movement right to left when viewing a brushstroke clearly made by the artist painting left to right), even though this was irrelevant to the task. The authors suggest that this provides evidence of a connection between the artist and the audience; observers do appear to process the actions of the painter when viewing artwork although the observer may be unaware of this. Furthermore, 14 participants in an EEG experiment showed greater mu suppression (a marker for mirror neuron activation) when participants viewed original pieces of abstract artwork compared to computer generated control stimuli (graphically modified versions); motor networks were only activated when viewing abstract images produced by a person (Umilta, Berchio, Sestito, Freedberg, & Gallese, 2012). This lends support to the role of embodied stimulation via mirror neurons when viewing artwork, therefore if an artist has experience in this, they may be better able to simulate the movements and therefore might better understand and empathise with the artist behind the work which may or may not transcend the artistic domain. However, as already mentioned, empirical research has not looked specifically at the relationship between engaging in visual artistry and empathy.

Dancing: Similar to musical activity, dancing involves motor control, understanding movement, imitation and synchronization, engagement with emotional material, and understanding the perspective of others to convey the emotionality of a piece.

A number of articles discuss how dance may enhance empathy. For example, Behrends, Mueller and Dziobek, (2012) suggest that imitation, synchronizing body movement and motoric cooperation may be the mechanisms responsible for links between dance and empathy. Despite a plethora of research which discusses how dance may do this theoretically, empirical studies investigating links between dance and empathy remain few. However, in a qualitative study, participants were interviewed following observation of a dance performance and responses suggest that pleasure in viewing dance is related to kinaesthetic empathy including descriptions of inner mimicry and emotions (Reason & Reynolds, 2010). Investigating differences between dancers and non-dancers, Kalliopuska (1989) found that 62 junior ballet dancers had more empathy than age matched control groups as measured by a modified version of the 'Mehrabian and Epstein Empathy Scale', and years of dancing positively correlated with empathy scores. Using a cross-sectional design with online participation from 5431 individuals, Bojner Horwitz et al., (2015) found that greater dance experience was associated with less prevalence of alexithymia which is an inability to identify and describe emotions, and which can lead to dysfunctions in emotional awareness and interpersonal relations. Based on these findings, the authors suggest that dance activity is involved in the emotion regulation system and that this in turn can relate to empathy.

Furthermore, in a randomised control trial investigating the benefits of dance/movement therapy on socio-cognitive skills in adults with autism, Koehne, Behrends, Fairhurst and Dziobek (2016) had participants complete ten sessions of synchronization based dance/movement therapy over a three month time period. Results showed significant improvements in emotion inference, synchronization and imitation, while a control movement intervention did not. No improvements however were seen in self-reported emotional empathy or perspective taking using the IRI. Christensen et al., (2016) asked 19 professional ballet dancers and 24 controls to watch video clips of emotionally expressive body movements and complete an affect rating task while recording their galvanic skin response. Results showed that the ballet dancers were more sensitive to others' body movements in both self-ratings and physiological measures of affect, suggesting that motor expertise increases sensitivity to body movement. Again, these are not direct measures of empathy but one may assume that these measures could be related to empathy. Kirsch, Snagg, Heerey and Cross (2016) aimed to investigate the relationship between experience and affective evaluation of whole body movements. Kirsch et al., (2016) recorded facial EMG and asked 26 non-dancers and 25 dancers to rate how much they liked clips showing movements performed by professional ballet dancers. A relationship between liking rating and EMG data was only observed in the dancers but not the non-dancers. Based on these findings, the authors suggest that experience with movements can engage the facial muscles which have been linked to affective processing. Interestingly however, the authors also measured empathy using the IRI and found no differences between the dancers and non-dancers.

Taken together these studies suggest that dancing may be linked to processes typically involved in an empathic response, though this may not transcend to advantages in empathetic abilities.

Gaming: Computer gaming shares similar characteristics with musical activity such as fine motor control, and engaging with emotional content.

A number of studies have examined the effects of violent video gaming on empathising and pro-social behaviour. Anderson et al., (2010) conducted a large meta-analysis which revealed that violent video gaming was negatively related to empathy and prosocial behaviour regardless of study design, culture or sex. In comparison to research on violent video gaming, little research has focused on prosocial gaming. Greitemeyer and Osswald (2009) suggest that game content can lead to differing effects on behaviour, with violent content encouraging aggressive tendencies and prosocial games decreasing aggressive tendencies. Indeed, they did find that playing prosocial games reduced anti-social tendencies such as hostile expectation bias and antisocial thoughts. In addition, Greitemeyer and Osswald (2010) conducted four experiments and reported that exposure to prosocial video games increased helping behaviour such as helping after a mishap, willing to help with future experiments and intervening in a harassment situation. Furthermore, Gentile et al., (2009) conducted three large studies using different study designs (correlational, longitudinal, and experimental) and found that exposure to prosocial gaming did appear to positively correlate with, or predict prosocial behaviour. Similarly, Greitemeyer, Osswald and Brauer (2010) found that playing a prosocial game reduced schadenfreude (measured by participants rating how much relief, happiness, and schadenfreude they felt after reading a vignette about a celebrity) and increased interpersonal empathy (measured by how much compassion, sympathy and soft-heartedness they felt towards the authors of two essays). Together these studies suggest that due to the mediating effect that empathy can have on prosocial behaviour, the associations between gaming and empathy do depend on game content. However, as most gaming is violent, with five out of the six top selling games between January and June, 2017 containing violent content ("The best-selling game of 2017 so far is… GTA V | Metro News," 2017), this does suggest that the majority of gaming may be negatively associated with empathy.

Sports-related research: Similar to musical activity, sports participation involves excellent motor control, understanding movements, and if participating in team sports, teamwork, and understanding other people's perspectives.

A number of studies have investigated the links between participation in sports, moral reasoning and aggressive tendencies while most have not looked specifically at the associations between sports participation and empathy. However, some evidence suggests that higher empathy is related to higher moral reasoning (e.g. Berenguer, 2010; Eisenberg-Berg & Mussen, 1978), and more prosocial (Kavussanu & Boardley, 2009), and less antisocial behaviour in sports (Kavussanu, Stamp, Slade, & Ring, 2009). Interestingly, research has shown that participation in contact sports has been linked to aggressive tendencies, low levels of moral reasoning and legitimising injurious acts within sporting contexts. Bredemeier and Shields (1986) tested 100 high school and college students, 60 of which were basketball players. The students were presented with four moral dilemmas. It was found that the basketballers used much greater egocentric reasoning when reasoning within a sport context when compared to their reasoning in everyday life, and more so for male players. Conroy, Silva, Newcomer, Walker, and Johnson, (2001) asked 1018 children and adolescents, 618 of which currently participated in sports, about perceptions of legitimacy of aggressive behaviour in sport. A multiple regression revealed that age, being male, and contact sport participation was positively related with legitimacy of aggression in sports. Kavussanu and Ntoumanis (2003) asked 221 college athletes to complete questionnaires regarding sport participation, goal orientations, moral functioning, and social desirability. Using structural equation analysis they found that contact sport participation predicted ego orientation, which predicted low levels of moral functioning. Similarly, Kavussanu et al., (2009) suggest that the sex differences in antisocial behaviour (measured by three judges scoring antisocial behaviour in videotaped football matches) may be mediated by greater participation in football playing as males had more experience than females.

As mentioned in the general introduction, Sevdalis and Raab (2016) investigated transfer effects of sporting training on understanding movement in another domain, namely dancing. They tested 46 university students with a wide range of sporting experience on perceptual accuracy in discriminating between expressive and inexpressive dance movements. It was found that identification accuracy was higher in individuals with more years of sports training and with an earlier age of onset in sports engagement. This suggests that training gleaned within a sporting context did transfer beyond the sporting domain to other non-sporting, dancing contexts. The authors also tested empathy levels using the IRI but there was only one effect, with more years of training being negatively related to scores on the personal distress subscale which was also negatively correlated with judgement accuracy. As moral reasoning and antisocial and prosocial behaviours seem to be related to empathy, this would suggest that sport participation may be negatively associated with empathy.

6.1.1. Rationale of Current Study

The aim of study six was to further explore the relationship between music and empathising using the self-report measure as used in the studies reported in chapters four and five, but with a larger, and more diverse online sample. A further aim was to investigate whether other activities which share similar processes to musical activity and which are typically conducted as hobbies, confer the same advantages in empathy skills. This will provide more insight into which processes may or may not enhance empathy such as imitating and synchronizing movement, engaging in emotional material, and/or understanding the perspectives of others.

6.1.2. Hypotheses

1. **1.** Based on findings in this thesis and previous literature, it is predicted that musical activity will be positively related to empathising.
2. **2.** It is also predicted that acting training may be positively associated with empathy based on the findings of a number of previous studies.
3. **3.** Due to the processes used to convey emotions in visual artistry and dance, it is predicted that these activities may be associated with enhanced empathy though the empirical research in this area is limited and/or conflicting and this is unclear.
4. **4.** Based on findings which suggest negative relationships between sporting activities and pro-social behaviour it is predicted that empathy will be negatively related with sporting activities.
5. **5.** The associations between gaming and empathy depend on the game content, though as most game content is violent, a negative association between empathy and general gaming is predicted.

6.2. Methodology

6.2.1. Participants

Participants were recruited via poster advertising, the University of St Andrew's participant pool, and social media. Any incomplete responses were deleted which resulted in 444 participants having fully completed the study, with an age range of 17-72 years, *M* = 25.49 (*SD* = 10.26). Of these, 315 were female, 123 male and 29 people chose not to state their gender. A monetary incentive was provided; participants could win one of 10 £5 Amazon vouchers.

6.2.2. Apparatus

The study was designed and distributed using 'Qualtrics' software. Participants could complete the study on any device with access to the internet.

6.2.3. Materials

The Empathy Quotient: The EQ (Baron-Cohen & Wheelwright, 2004) was used as in the studies in chapters four and five. See section **4.2.2.**

Demographical and Activities Questionnaire: A questionnaire regarding demographical information and leisure activities was designed to ask participants to state which leisure activities they currently take part in or have taken part in previously, asking for information about weekly hours of activity and type of activity (e.g. what type of sport did you/do you participate in?). See **<u>Appendix 7</u>**.

6.2.4. Procedure

Participants completed the EQ and were provided with their score. It was stated that participants would learn more about the meaning of this score at the completion of the study. This was included as an incentive for the participants to continue. A progress bar was included at the bottom of each page. After completion of the questionnaire, participants completed the demographical and leisure activity information. Participants could take as long as they wished to complete the study but were asked to complete the study on their own.

6.3. Results

6.3.1. Participant Characteristics

As in the previous two studies, participants were divided into groups depending on amount of hours spent in each activity. See **Table 17** for a breakdown of participants split by group for each activity.

Table 17: No. of participants split by group for each activity

	Low (<500hrs)	**Medium (501-3000)**	**High (>3000hrs)**
Acting	349	72	26
Art	288	96	63
Dance	309	86	52
Gaming	248	94	105
Music	181	159	107
Sport	163	161	123

6.3.2. Linear Trend Analyses

Linear trend analyses were conducted on these six variables split by hours: low (<500hrs), intermediate (501-3000hrs) and high (>3000hrs), see **Table 18** for these results.

Table 18: Empathy Quotient Score: Means, SD's, and F(linear) for different groups

	Group			
	Low *M (SD)*	**Medium** *M (SD)*	**High** *M (SD)*	*F*(linear)
Acting	44.47 (13.15)	48.00 (11.78)	50.12 (12.57)	**4.728***
Art	44.68 (13.12)	44.72 (11.22)	49.16 (14.44)	**6.195***
Dance	43.66 (12.84)	49.64 (12.13)	48.04 (13.48)	**5.223***
Gaming	47.79 (13.12)	42.28 (13.10)	42.22 (11.43)	**14.102*****
Music	44.73 (13.25)	45.66 (12.57)	45.80 (13.29)	0.453
Sport	59.03 (18.86)	62.18 (19.77)	66.17 (20.39)	**9.285****

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

As many people tend to do more than one of these activities, the correlations between hours of experience and empathising were analysed and a multiple regression between the measure and the activities conducted to investigate which activity may be the best predictor variable of our outcome variable empathising.

6.3.3. Multiple Regression

As there are several predictor variables (acting, art, dance, gaming, music and sport) a multiple regression analysis on the outcome variable empathising was conducted.

Tests for normality: An analysis of standard residuals was carried out on the data to identify any outliers; no outliers were found in the empathy quotient scores. Tests to see if the data met the assumption of collinearity indicated that multicollinearity was not a concern. The data met the assumption of independent errors (Durbin-Watson value = 1.97). The histogram of standardised residuals indicated that the data contained approximately normally distributed errors, as did the normal P-P plot of standardised residuals. The scatterplot of standardised values (standardised residuals) showed that the data met the assumptions of homogeneity of variance and linearity. The data also met the assumption of non-zero variances.

Result: Using the enter method, the model including the six activities was found to be significant $F(6, 400) = 5.442$, $p < .001$, $R^2 = .069$, $R^2 adjusted = .056$, though hours of acting, art, and music were not significant predictors. Gaming hours were found to be a significant negative predictor of scores on the EQ ($\beta = -.179$, $t(441) = -3.889$, $p < .001$). Dance ($\beta = .110$. $t(441) = 2.243$, $p = .025$) and sport ($\beta = .111$, $t (441) = 2.387$, $p = .017$) were both shown to be significantly positive predictors of higher scores on the empathy quotient.

6.5. Discussion

The current study aimed to investigate whether the links between musical activity and scores on the EQ could be replicated in a larger and more diverse online sample. Furthermore, this study aimed to investigate whether other activities which engage similar processes to musical activity also show associations with empathy. If other activities did, this would suggest that it is not something intrinsically musical which is responsible for the relationship between music and empathy, rather it may be due to other processes that are present in other activities such an engagement with emotional material, understanding the perspectives of others, imitating, understanding, and synchronizing movements.

Based on previous findings reported in this thesis and other empirical literature (Hietolhti-Ansten & Kalliopuska, 1990; Kalliopuska & Ruokonen, 1986; Kirschner & Tomasello, 2010; Kreutz et al., 2004) a positive relationship between musical activity and empathising was expected. EQ scores were found to increase with increasing hours of participation in acting, art, dance and sport but not musical activity, while more gaming hours were associated with a decrease in EQ scores. A multiple regression revealed that dance and sport hours were significant predictors of increases in EQ scores, and gaming was a significant predictor of decreases in EQ scores.

Musical activity was not found to be correlated with EQ scores which contradicts the results reported in chapter four. The effect was indeed small in chapter four, and in this case, there is a larger and more diverse sample. Furthermore, the population tested in the previous study diverges from the population in this study. The population tested in chapters four and five was a highly homogenous sample of young adults studying at the University of St Andrews. In other studies which have found relationships between music participation and empathy scores, the participants were young children (Kirschner & Tomasello, 2010; Rabinowitch et al., 2012). Perhaps the differences are only seen in younger populations but with age, empathic abilities reach a plateau, or there is a critical stage at which empathic abilities can be enhanced by musical activity. However, in the current data, when participants over the age of 30 were excluded, this did not affect the overall results. For further studies, it may be interesting to look specifically at differences in young, middle aged and older adult populations and/or ask at what age musical training was started.

With the EQ, the most physical activities (dance and sport) were significant predictors of EQ scores. Surprisingly sport was positively associated with empathy which is not what was predicted based on the literature which reports associations between contact sports participation and egocentric reasoning, low moral functioning, and antisocial behaviour (Bredemeier & Shields, 1986; Conroy et al., 2001; Kavussanu & Ntoumanis, 2003; Kavussanu et al., 2009). The literature pertaining to links between dance training and empathy was mixed with one study finding correlations between number of years dance training and empathy scores (Kalliopuska, 1989) and others finding no such association (Kirsch et al., 2016; Koehne et al., 2016). This could suggest that the use of gross motor skills, understanding movement, and awareness of own body movement (all which relate to kinaesthesia) are the best predictors of self-reported empathic abilities. In this study only the activities which use overt movements and gross motor skills were related to self-reported empathising which supports the embodied simulation theories that suggest that emotional responses are activated due to sensorimotor simulation as discussed in sections **1.2.2.3** and **1.2.3**. Training in activities which use less overt body movements, such as music or acting, does not appear to lead to enhanced embodied simulation in empathy, as may be the case for the results observed in dance and sport. It could be that kinaesthesia relates to empathy and emotion understanding and this could potentially be controlled for in future studies.

6.5.1. Limitations

Considering that the current study was administered online it cannot be determined if the questionnaire was completed individually or in a quiet space which may have impacted the results. The study had quite a larger dropout rate of 29% which may have resulted in a non-representative sample.

Due to the study being cross-sectional, cause and effect claims cannot be substantiated. It could be that dancers and people who persist with sport are more empathetic to begin with; a longitudinal study would be useful to determine this. Discussion regarding the limitations of cross-sectional designs will be considered in the general discussion chapter.

People have a tendency to respond to self-report measures in a socially desirable manner when in direct contact with the experimenter. Without having met the experimenter, it could be that people online are more truthful with how they answer. If this was the case, one would expect the means of the EQ scores to be significantly higher than the means of EQ scores on the online study, however when comparing the face-to-face with the online mean scores there were no differences. Furthermore, items on the EQ have not been found to strongly correlate with answers to items on the 'Social Desirability Scale' (Lawrence, Shaw, Baker, Baron-Cohn, & David, 2004). It would however be of interest to investigate if the same results are found not only in how much participants agree or disagree with statements designed to measure potential levels of empathy, but also in empathising performance.

6.5.2. Conclusions

The aim of the current study was to investigate whether the relationship between musical training and EQ scores could be replicated as observed in chapter four, as well as to explore whether other activities which engage similar processes to music could confer similar advantages in empathic abilities. This study could not replicate the relationship between musical training and EQ scores. This suggests that any links between music and empathy are fragile and perhaps other non-musical underlying mechanisms were responsible for the effects found in chapter four. Dance and sport were associated with EQ which supports perception-action coupling and emotional embodiment theories; engaging in and perceiving overt body movements on a regular basis may lead to a better understanding of overt body movements in others which may in turn be linked to the ability to empathise. The use of overt body movements in musical activity can vary greatly depending on the musical style, genre, and/or the instrument played during active musical activity. It could be that the variance in associations between musical engagement and empathising abilities observed across the three studies in this thesis are due to variations in the style of the musical engagement which are details which could be explored in future research studies.

7. Chapter 7: General Discussion: Musical Training, Cognitive Control, and Emotional Processing

7. Chapter 7: General Discussion: Musical Training, Cognitive Control, and Emotional Processing

Past research strongly suggests that musical training is associated with enhanced cognitive control (e.g. Bialystok & DePape, 2009; Jentzsch et al., 2014; Moreno et al., 2011, 2014; Palmer & Drake, 1997; Seinfeld et al., 2013; Travis et al., 2011), though it is not clear why this may be. Considering that emotions can influence cognitive control performance (see Mueller, 2011), these benefits could potentially be explained by an emotional response mediating the effect, such as increased affective responses to the occurrence of errors and conflicts. Expert musicians must repeatedly engage with emotional material during training and express emotions during a musical performance. It could be that musical training is associated with enhanced emotional processing abilities which could increase the emotional processing of events. This might explain why musical training may be associated with increased affective responses to errors during cognitive control tasks, which consequently leads to improved performance on measures of cognitive control.

The aim of this thesis was to firstly investigate why musicians may demonstrate enhanced cognitive control by considering whether musical training affects emotional responses to errors using electrophysiological, behavioural, and self-report measures. The second aim was to explore whether musical training is associated with emotional processing abilities using a variety of self-report and behavioural measures, which could potentially explain why musicians may react more emotionally to errors, subsequently increasing cognitive control.

7.1. General Discussion and Implications

The first empirical study reported in this thesis (chapter two) found that musical training was associated with heightened affective responses to errors, supporting the idea that emotional responses might affect cognitive control processes. However, unfortunately, the results in chapter two could not confirm that musical training was associated with enhanced cognitive control.

However, one confound that could explain this null result was a speed/accuracy trade off; participants in the highly musical group appeared to trade speed for accuracy which could potentially explain the lack of group differences. Therefore, chapter three explicitly manipulated speed/accuracy trade off to investigate why no differences between the musical groups were found. Unfortunately however, the study in chapter three was also unable to replicate past findings; although some electrophysiological components showed some predicted effects, musical training was not shown to be associated with increased cognitive control behaviourally. One problem with this study however, was that the musical group was found to be significantly younger than the non-musical group which makes analysis between groups problematic due to age-related differences in performance on interference tasks (Bugg et gal., 2007; Verhaeghen & De Meersman, 1998), and electrophysiological activity (Band & Kok, 2000; Dywan et al., 2008; Hoffmann & Falkenstein, 2011; Koelsch et al., 2009; Kolev et al., 2005; Mathewson et al., 2005; Nieuwenhuis et al., 2002; Schreiber et al., 2011). Interestingly, these age differences did not differentially affect the ERN which contrasts a number of research studies which typically find smaller ERN amplitudes in older participants when compared to younger participants (Band & Kok, 2000; Dywan et al., 2008; Hoffmann & Falkenstein, 2011; Koelsch et al., 2009; Kolev et al., 2005; Mathewson et al., 2005; Nieuwenhuis et al., 2002; Schreiber et al., 2011).

Neither chapter two nor chapter three could replicate previous findings reporting that musical training enhances performance on cognitive control tasks. Results reported in chapter two however do suggest that musical training may heighten affective responses to errors. Chapter four therefore explored whether musical training can affect a range of emotional processing abilities using a battery of tests revealing two interesting findings: musical training was found to be associated with increased levels of empathy, and the ability to recognise emotions in vocal sounds.

Music uses a number of higher order social processes such as understanding other people's perspectives, and imitating and synchronising movements of others which could potentially explain the relationship between musical training and empathy. There are a number of possible explanations, and/or a combination of these explanations, which could clarify what may be driving this effect.

Firstly, a musician may attempt to understand the perspective of the composer and contemplate on what the composer is endeavouring to convey with their musical score. As discussed in chapter five, evidence suggests that listeners participate in mental state attribution when they believe they are listening to a composer written piece (Steinbeis & Koelsch, 2008). It could be that because musicians actively, repeatedly, and frequently engage with the emotional content during musical performance, and must convey the emotional content and the meaning of this piece successfully, they may engage in more perspective taking behaviours than passive listeners, or those uninterested in music.

Secondly, theories discussed in the introduction: the SAME model, the emotional contagion mechanism in the BRECVEM model, and the embodied simulation account of aesthetic experiences all converge on the notion that musical emotions may be simulated by the listener thus allowing them to experience the same emotion felt or at least conveyed by the performer. As explained in the general introduction, the putative MNS is believed to be involved in our ability to understand the movements of others via neural circuits that mimic these movements. While it is believed that the MNS allows us to simulate actions in ourselves during action observations of others, so to it is believed that the MNS is activated when observing the emotions of others (see Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003). It could be that musical training requires observation of actions and emotions that subsequently trains these neural circuits. Christensen et al., (2016) suggest that expertise in the bodily expression of emotion may heighten the sensitivity of emotion conveyed in the movements of others, and research shows that this effect can be found both within (e.g. Calvo-Merino et al., 2005; Calvo-Merino et al., 2006; Christensen et al., 2016; Kirsch et al., 2016), and between domains (Sevdalis & Raab, 2016).

The MNS is thought to be involved in a number of higher order processes including empathy and intention understanding (Overy & Molnar-Szakacs, 2009); (see Gazzola et al., 2006; McGarry & Russo, 2011), potentially therefore training of the MNS while actively engaging with music and musical emotions might have far-transfer effects to recognising and understanding emotions in others leading to enhanced intention understanding and empathy.

Another possible explanation for this association between musical training and empathy may be because a large majority of music playing and performance is carried out in groups. This gives more opportunities for socialising with others which could potentially benefit social and empathic understanding. Moreover, musicians must be aware of other player's musical parts and movements in an ensemble or in a duet. For some instruments, musicians attempt to play notes as well as movements in synchrony. For example, during musical performances, violinists attempt to synchronize upwards and downwards movements of their bows; upwards and downwards bow movements firstly can create different sounds, and secondly, uniformity between players appears professional and is visually pleasing for the observer. This cooperation and synchronization with other players requires social awareness, and studies have shown that synchronization with another can lead to greater affiliation with them (e.g. Hove & Risen, 2009). High levels of affiliative behaviour is reported as being linked to appropriate responses during social interactions (e.g. Seyfarth & Cheney, 2013). Therefore perhaps this training in synchronization may partially explain why musical training appears might be associated with heightened empathy.

The study in chapter four also found that musical training was associated with enhanced abilities in recognising emotions in vocal sounds. This could suggest that the training of musical emotions during active engagement with music may have near-transfer effects to the recognition of emotions beyond the musical domain as mentioned above. However, surprisingly, although musicians use facial, and bodily movements (in addition to the sounds of the music) to express musical emotions (see Davidson, 2012), musical training was *not* associated with emotion recognition benefits in any of the visual domains tested (bodily gestures, facial expressions or emotional expressions in the eyes). It could therefore be that training in musical emotions has transfer effects to emotion recognition within the auditory domain, though these transfer effects are insufficiently far reaching to stretch beyond the auditory domain.

On the other hand, it could be that musical training is not related to heightened auditory emotion recognition per se, rather this effect is observed because of enhanced auditory abilities. Indeed, a number of studies have reported that musical training is related to improvements in auditory perceptual abilities (see Kraus & Chandrasekaran, 2010).

Surprisingly no association between musical training and long-term benefits to emotional well-being were observed. This is unexpected considering that music does appear to have positive effects on short-term emotions as a number of studies discussed in the introduction have shown (e.g. Koelsch et al., 2010; Kreutz et al., 2004; Panksepp & Bernatzky, 2002). Moreover, these results contrast the findings reported in a number of studies demonstrating that both passive (Chan et al., 2010), and active (Choi et al., 2008; Costa-Giomi, 2004; Seinfeld et al., 2013) musical engagement can have long term positive benefits on emotional well-being including reducing depressive symptoms (Chan et al., 2010; Choi et al., 2008; Seinfeld et al., 2013), improving sleep quality (Chan et al., 2010), reducing symptoms of anxiety, improving relationships with others (Choi et al., 2008), and improving self-esteem (Costa-Giomi, 2004). However, these studies were conducted with children, older adults, and psychiatric patients. These groups may include individuals who have reduced levels of well-being (such as older people or psychiatric patients), and may be motivated to increase it, or individuals who could improve their well-being (such as increasing self-esteem in children). It could be that participants in the sample used in chapter three had already reached a ceiling effect in levels of well-being; levels of well-being were already at ‘normal’ levels and therefore could not be improved.

Considering that no other empirical study has thus far reported associations between musical training and empathy in adults, chapter five aimed to investigate if this finding could be replicated, additionally investigating whether the empathy finding could be verified using a second measure of empathy. Though similar numerical trends were observed between the three musical groups, with empathy levels measured by the empathy quotient (EQ) increasing with increasing musical practice, this effect was not significant. Moreover, no association between musical training and scores on the second empathy measure (the interpersonal reactivity index (IRI)) was observed. Furthermore, the association between musical training and emotional sound recognition was not replicated. This suggests that these two effects are fragile and could be due to individual differences rather than musical training. A combined analyses using the two samples therefore was conducted and did show that musical training was positively correlated with both empathy levels (using only the EQ measure), and emotional sound recognition.

Chapter six aimed to explore whether the association between music and empathy could be observed in a larger and more diverse online sample, and whether the results are specific to music training. Musical activity exercises a number of higher order processes that could potentially foster empathic tendencies such as engagement with emotional material, understanding other people's perspectives, and imitating and synchronising movements of others, though many of these processes are not specific to music and are also employed in other activities. Chapter six therefore further aimed to investigate whether other activities engaging similar higher order processes to music, could also confer the same potential advantages. The results in chapter six showed no association between musical activity and empathy, though accumulated hours of sport and dance were significant predictors of higher empathy levels. The embodiment account of aesthetic experiences suggests that emotions are experienced via embodied simulation, and evidence suggests that experience with the movements being observed can heighten the emotional response to them. Both dance and sport train coordination of body movements. Music uses more implicit movements and more fine motor skills than dance and sport which typically use gross motor skills. Therefore perhaps less training is necessary for sports persons and dancers, while musicians require more training to observe similar benefits.

It could also be that the differences between results reported in chapters four and five in regards to empathy could be due to individuals in the highly musical group in chapter four participating in more dance or sport than individuals in the highly musical group in chapter five. However, data was collected which asked participants to indicate how much time was spent on hobbies including sport in both chapters four and five. No significant differences between the three musical groups were observed. However, such data was not collected for experience in dance. Empirical research investigating the association between empathy and dance, and empathy and sport based on the results of the study in chapter six, may be a very interesting future research direction. However, considering that this was only one study and the effects of music on empathy appear to be fragile as shown by the differing results between the three studies reported in this thesis, it could also be that the effects observed in study six are likewise fragile and might be subject to individual differences.

In sum, the effects of musical training on cognitive control appear to be fragile but may be associated with increased emotional responsiveness to errors. The results in chapter four provide some support that musical training might be associated with enhanced emotional sound recognition abilities and increasing levels of empathy. However, the effect of musical training on empathic abilities appears to be fragile as shown by the null results reported in chapters five and six, and could be due to differences in participant samples between studies.

7.2. Limitations and Future Research Directions

The finding that empathy may be related to musical training is fragile in that one study found an association, while another found only a numerical trend, while the online study found no evidence of such an association. No other past studies have reported a relationship between musical activity and empathy in adults, though a number of studies have shown that musical programmes may heighten empathy in children (Hietolhti-Ansten & Kalliopuska, 1990; Kalliopuska & Ruokonen, 1986, 1993; Kirschener & Tomasello, 2010; Rabinowitch et al., 2012). It could therefore be that musical activity during childhood may aid in the development of empathic abilities, though eventually this empathy reaches its natural plateau at a later age. The adults who had not received musical training during childhood eventually 'catch up' with their musical counterparts cancelling out any superior empathic abilities improved with musical training. Future research could compare differences in empathy across, and between, age groups to explore this proposal.

The current thesis used only self-report measures to measure empathy including the EQ and the IRI. While self-report measures can provide useful insight into individual differences, on such measures investigating internal thoughts towards others, individuals may be inclined to provide, what they believe to be, socially desirable answers. However, as briefly mentioned in chapter six, answers to items on the EQ have not been found to be correlated to answers to items on the 'Social Desirability Scale' (Lawrence et al., 2004). However, it would be of interest to use other measures which may be able to test empathy and empathic performance using more implicit measures (e.g. the Social Stories Questionnaire (Lawson, Baron-Cohen, & Wheelwright, 2004), the Fiction Emotion Mapping Test (Goldstein, 2011), or the Movie for Assessment of Social Cognition (Dziobek et al., 2006)).

Other activities which use more overt and gross motor movements appeared to be associated with empathy, which supports the notion that in order to feel empathy for another we simulate the emotions we observe in them in ourselves. If empathy is related to movements, it may be of interest for future research to investigate whether dyspraxia is associated with lower empathy levels; it has thus far been related to autism and a number of deficits including social, motor and communicative deficits (e.g. Dowell, Mahone, & Mostofsky, 2009; Dziuk et al., 2007) and lower EQ scores (Cassidy et al., 2016). This is an area which requires more research and may be thought-provoking to clinical areas interested in enhancing the ability to understand emotions in others and empathy.

As discussed previously, the association between empathy and musical training could be due to the socialisation required when playing and training within a musical group. The type of instrument played therefore may affect the association between music and empathy. A pianist, for example will likely take part in less social musical activities than vocalists or other instrumentalists who typically play in an orchestra or band (such as, for example, a drummer, flautist, or violinist). Differences between instruments were considered though no significant differences in empathy or emotion recognition were observed between instruments. However, the sample sizes for these analyses were extremely small therefore conclusions regarding these non-significant results must be regarded with caution. Future research could consider the differences between instruments and the type of musical engagement participated in; either mainly solo training and performance, or group training.

Additionally, the type of music played could potentially differentially affect the association between musical training and empathy. Greenberg et al., (2015) propose that empathy levels may be related to listening preferences for certain musical genres. For example, they suggest that individuals who prefer emotionally deep, reflective music will be more empathetic than people who prefer energetic and forceful music. It could be that differences between musical genres actively played are even more pronounced than differences between musical genre listening preferences. For example, while classical musicians are very restricted to the musical score and have very little chance for improvisation with others, jazz musicians frequently improvise and their decisions are heavily reliant on the decisions of others. It could therefore be that jazz musicians are more social and/or jazz music trains social awareness and the ability to improvise with others, subsequently increasing empathic abilities. Future research could investigate whether differences in the types of music engaged with are related to empathy, something that was not considered in the studies reported in this thesis.

Chapter two used just one self-report measure to evaluate performance on the interference tasks and affective responses to the number of predicted errors and speed which the experimenter asked the participant verbally (to avoid the participant needing to move when attached to the EEG equipment). It could be that answers to a visual rating scale may have differed to answers on the verbally administered scale used in chapter two, though meta-analyses have demonstrated that both verbal and visual scales work similarly well in affective response ratings (Hjermstad et al., 2011). However, future research could develop more in-depth methods for measuring affective responses to errors and investigate if the effects of musical training on evaluations of performance can be replicated.

Slevc et al., (2016) suggest that musical ability is not a dichotomous variable, therefore the way in which groups are defined in this thesis and in past research may have a significant impact on the results of any studies investigating musical training. Studies use a wide variety of criteria to distinguish musicians from non-musicians, therefore this could explain why chapters two and three were unable to replicate the finding that musical training is associated with increased cognitive control reported in the literature. In the current thesis, for all five studies, groups were defined by self-reported hours of musical training which is the same method used by Jentzsch et al., (2014), though the groups were defined differently with three musical groupings used throughout this thesis (<500, 501-3000, >3000 hours) compared to the four musical groups in Jentzsch et al's design (<200, 200-2000, 2000-5000, and >5000 hours). While hours of musical training are believed to be a valid measure of musical ability (Ericsson et al., 1993; Sloboda et al., 1996), other studies have included a measure testing musical ability (e.g. Slevc et al., 2016) which may have been useful here. However, measures were taken during each study conducted in this thesis to ensure that the groups differed, not only in self-reported hours of musical practice, but also in years of practice, and self-reported musical knowledge (measured using four dimensions along a five point scale including reading ability, knowledge of music history, knowledge of music theory, and overall ability). However, these again, were self-report measures, thus it cannot be determined whether the groups differed substantially in musical ability. Furthermore, as allocation to the high musical group was defined in this thesis as an individual having had at least 3000 hours of musical training, it could be that differences in the quantity of musical training were simply not great enough to demonstrate differences that may otherwise be observed between musicians and non-musicians. In the first four studies of this thesis, participants were University students, and individuals allocated to the highly musical group were not professional musicians. In fact, some individuals allocated to the highly musical groups may not be considered even amateur musicians considering that some were no longer actively engaged in musical activity. While data was collected regarding the musical grade level that the musical participants had completed, many individuals who play a musical instrument to a high level do not necessarily complete formal musical examinations. In most studies investigating differences in adults using cross-sectional designs, professional musicians (individuals who have typically accumulated more than 10,000 hours of musical practice time) are compared to non-musicians (e.g. Moussard et al., 2016), or professional musicians are compared to other skilled groups such as bilinguals (e.g. Bialystok & DePape, 2009; Moreno et al., 2014), or professional musicians are compared to amateur musicians (e.g. Travis et al., 2011). There may be differences between professional musicians and non-musicians that the studies in this thesis were unable to capture using the relatively small differences of musical training to define the musical groups that were used here. This may partially explain why no differences in cognitive control nor emotional processing abilities were found in the current thesis, contradicting the results in the previous literature. Future research could therefore investigate differences in affective responses to errors during cognitive control tasks and emotional processing abilities between professional musicians and non-musicians.

Both musicians and non-musicians were recruited using different advertising (i.e. advertisements online or posters either sought ‘Musicians’ or ‘Non-musicians’), and groups were aware pre-testing that the studies concerned the effects of musical training. The groups may have therefore experienced a Hawthorne effect; behaving differently depending on what they thought their role was in the study; a problem discussed by Slevc et al., (2016). Advertisement and information provided to participants in chapter six merely mentioned that the study investigated associations between empathy and leisure activities, therefore participants were unaware that the specific focus in the latter study was music. No association between musical training and empathy was observed in this final study, therefore perhaps differences between groups with varying levels of musical training observed in chapter three were due to a

Hawthorne effect. This could be easily explored by recruiting participants without informing them of the specific aims of the research study.

Finally, the present studies were cross-sectional and therefore cannot control for confounding variables such as innate differences between groups (differences in personality, heritability, motivation etc.), levels of education (though the tested group is highly homogenous in this respect) or socio-economic background. Evidence does indeed suggest that involvement with music lessons is related to socio-economic status (Corrigall, Schellenberg, & Misura, 2013). It could well be that people who take up or continue on with musical activity are intrinsically more empathetic. Indeed, evidence suggests that individuals who are more empathetic appear to have more intense emotional responses when listening to music (Vuoskoski & Eerola, 2012; Vuoskoski et al., 2012), therefore engaging with musical material may be more rewarding for them than an individual who does not experience such strong reactions. Moreover, people who have superior auditory awareness may be more likely to begin, and continue with, musical practice. To make a stronger causal claim, a longitudinal design would be beneficial, where participants are randomly assigned to either a control group or a musical training group. Though such a design would be highly valuable, it would take a number of years, a great expense and a great commitment on the part of the participants and the researchers. In order to reach the same levels of musical training of the minimum of our amateur highly musical group (3000 hours), this would take approximately 12 years with 5 hours per week of musical activity. In addition, longitudinal studies are subject to selective drop out effects that can result in a final unrepresentative sample.

7.3. Conclusions

The results of this thesis suggest that musical training may lead to stronger affective responses to errors although no link between musical training and cognitive control abilities was found here, contradicting past research. It was suggested that differences in how musicians emotionally respond to errors could be due to differences in emotional processing abilities owing to repeated and frequent active engagement with emotional material. Musical activity does appear to affect specific emotional processing abilities including emotional sound recognition and empathy. However, these associations also appear to be fragile, considering that, while one study found this association, two subsequent studies were unable to replicate this effect. The final study did however uncover associations between empathy levels and active engagement with dance and sport. Considering that all studies reported in this thesis are cross-sectional, these differences in results could be due to individual differences within groups. This could suggest that associations between musical training and empathy may be due to individual differences, such as concurrent involvement, for example, with dance lessons. In sum, musical activity may affect emotional responses to errors and specific emotional processing abilities which could enhance cognitive control, and improve social emotional interactions with others.

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Appendices

1. Musical Experience Questionnaire (Jentzsch et al., 2014)

Age: ………….
Sex: ……………
Handedness (left or right): …………
Years of Education + Current Occupation: …………………………………
Native English Speaker YES/NO:………….

Do you **currently** play or are you learning to play a musical instrument? YES/NO
If yes,

Instrument	Number of years played	Accumulated Practice time	Start age

Have you ever, **in the past** played or learned to play an instrument **but have stopped** playing it? YES/N0
If yes,

Instrument	Number of years played	Accumulated Practice time	Start age	End age

Did you complete formal exams in the above instruments/ voice: YES/No
If yes,

Instrument	Grade level	Age at which that grade was achieved

On a scale of 1 to 5, rate the following
(1=None or Not Able; 2=Limited; 3=Average; 4=Above Average; 5=Extensive or Very Able).

Knowledge of music history:	1	2	3	4	5
Knowledge of music theory:	1	2	3	4	5
Ability to read music:	1	2	3	4	5
Overall music ability:	1	2	3	4	5

Any other comments to music-related activities:
……………………………… ………………………………………………………………………………………
……..
……………………………… ………………………………………………………………………………………

How many hours per week on average do you listen to music: ………………………………

List any other non-music-related hobbies you have, e.g. artistic hobbies, sport, computer gaming and indicate how many hours per week do you roughly spend on each of these (please list each hobby and number of hours for each):

<u>Sports:</u>

_________________ ___________(hrs a week)

_________________ ___________(hrs a week)

_________________ ___________(hrs a week)

<u>Computer gaming/Internet gaming activity</u>

_________________ ___________(hrs a week)

_________________ ___________(hrs a week)

_________________ ___________(hrs a week)

<u>Other artistic Activities or any other hobbies</u>

_________________ ___________(hrs a week)

_________________ ___________(hrs a week)

_________________ ___________(hrs a week)

_________________ ___________(hrs a week)

2. **Difficulties in Emotion Regulation Scale (DERS)** (Gratz & Roemer, 2004)

1	**2**	**3**	**4**	**5**
Almost Never	Sometimes	About Half the Time	Most of the Time	Almost Always
(0-10%)	(11-35%)	(35-65%)	(66-90%)	(91-100%)

Please indicate how often the following 36 statements apply to you by writing the appropriate number from the scale above (1 – 5) in the box alongside each item.

1. I am clear about my feelings	
2. I pay attention to how I feel	
3. I experience my emotions as overwhelming and out of control	
4. I have no idea how I am feeling	
5. I have difficulty making sense out of my feelings	
6. I am attentive to my feelings	
7. I know exactly how I am feeling	
8. I care about what I am feeling	
9. I am confused about how I feel	
10. When I'm upset, I acknowledge my emotions	
11. When I'm upset, I become angry with myself for feeling that way	

12. When I'm upset, I become embarrassed for feeling that way	
13. When I'm upset, I have difficulty getting work done	
14. When I'm upset, I become out of control	
15. When I'm upset, I believe that I will remain that way for a long time	
16. When I'm upset, I believe that I'll end up feeling very depressed	
17. When I'm upset, I believe that my feelings are valid and important	
18. When I'm upset, I have difficulty focusing on other things	
19. When I'm upset, I feel out of control	
20. When I'm upset, I can still get things done	
21. When I'm upset, I feel ashamed with myself for feeling that way	
22. When I'm upset, I know that I can find a way to eventually feel better	
23. When I'm upset, I feel like I am weak	
24. When I'm upset, I feel like I can remain in control of my behaviours	
25. When I'm upset, I feel guilty for feeling that way	
26. When I'm upset, I have difficulty concentrating	
27. When I'm upset, I have difficulty controlling my behaviours	

28. When I’m upset, I believe that there is nothing I can do to make myself feel better	
29. When I’m upset, I become irritated with myself for feeling that way	
30. When I’m upset, I start to feel very bad about myself	
31. When I’m upset, I believe that wallowing in it is all I can do	
32. When I’m upset, I lose control over my behaviours	
33. When I’m upset, I have difficulty thinking about anything else	
34. When I’m upset, I take time to figure out what I’m really feeling	
35. When I’m upset, it takes me a long time to feel better	
36. When I’m upset, my emotions feel overwhelming	

3. The Empathy Quotient (Baron-Cohen & Wheelwright, 2004)

Below are a list of statements. Please read each statement very carefully and rate how strongly you agree or disagree with it by circling your answer. There are no right or wrong answers, or trick questions.

IN ORDER FOR THE SCALE TO BE VALID, YOU MUST ANSWER EVERY QUESTION.

Examples

E1. I would be very upset if I couldn't listen to music every day.	strongly agree	slightly agree	slightly disagree	strongly disagree
E2. I prefer to speak to my friends on the phone rather than write letters to them.	strongly agree	slightly agree	slightly disagree	strongly disagree
E3. I have no desire to travel to different parts of the world.	strongly agree	slightly agree	slightly disagree	strongly disagree
E4. I prefer to read than to dance.	strongly agree	slightly agree	slightly disagree	strongly disagree

1. I can easily tell if someone else wants to enter a conversation.	strongly agree	slightly agree	slightly disagree	strongly disagree
2. I find it difficult to explain to others things that I understand easily, when they don't understand it first time.	strongly agree	slightly agree	slightly disagree	strongly disagree
3. I really enjoy caring for other people.	strongly agree	slightly agree	slightly disagree	strongly disagree
4. I find it hard to know what to do in a social situation.	strongly agree	slightly agree	slightly disagree	strongly disagree
5. People often tell me that I went too far in driving my point home in a discussion.	strongly agree	slightly agree	slightly disagree	strongly disagree

6. It doesn't bother me too much if I am late meeting a friend.	strongly agree	slightly agree	slightly disagree	strongly disagree
7. Friendships and relationships are just too difficult, so I tend not to bother with them.	strongly agree	slightly agree	slightly disagree	strongly disagree
8. I often find it difficult to judge if something is rude or polite.	strongly agree	slightly agree	slightly disagree	strongly disagree
9. In a conversation, I tend to focus on my own thoughts rather than on what my listener might be thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
10. When I was a child, I enjoyed cutting up worms to see what would happen.	strongly agree	slightly agree	slightly disagree	strongly disagree
11. I can pick up quickly if someone says one thing but means another.	strongly agree	slightly agree	slightly disagree	strongly disagree
12. It is hard for me to see why some things upset people so much.	strongly agree	slightly agree	slightly disagree	strongly disagree
13. I find it easy to put myself in somebody else's shoes.	strongly agree	slightly agree	slightly disagree	strongly disagree
14. I am good at predicting how someone will feel.	strongly agree	slightly agree	slightly disagree	strongly disagree
15. I am quick to spot when someone in a group is feeling awkward or uncomfortable.	strongly agree	slightly agree	slightly disagree	strongly disagree
16. If I say something that someone else is offended by, I think that that's their problem, not mine.	strongly agree	slightly agree	slightly disagree	strongly disagree
17. If anyone asked me if I liked their haircut, I would reply truthfully, even if I didn't like it.	strongly agree	slightly agree	slightly disagree	strongly disagree
18. I can't always see why someone should have felt offended by a remark.	strongly agree	slightly agree	slightly disagree	strongly disagree
19. Seeing people cry doesn't really upset me.	strongly agree	slightly agree	slightly disagree	strongly disagree

20. I am very blunt, which some people take to be rudeness, even though this is unintentional.	strongly agree	slightly agree	slightly disagree	strongly disagree
21. I don’t tend to find social situations confusing.	strongly agree	slightly agree	slightly disagree	strongly disagree
22. Other people tell me I am good at understanding how they are feeling and what they are thinking.	strongly agree	slightly agree	slightly disagree	strongly disagree
23. When I talk to people, I tend to talk about their experiences rather than my own.	strongly agree	slightly agree	slightly disagree	strongly disagree
24. It upsets me to see an animal in pain.	strongly agree	slightly agree	slightly disagree	strongly disagree
25. I am able to make decisions without being influenced by people's feelings.	strongly agree	slightly agree	slightly disagree	strongly disagree
26. I can easily tell if someone else is interested or bored with what I am saying.	strongly agree	slightly agree	slightly disagree	strongly disagree
27. I get upset if I see people suffering on news programmes.	strongly agree	slightly agree	slightly disagree	strongly disagree
28. Friends usually talk to me about their problems as they say that I am very understanding.	strongly agree	slightly agree	slightly disagree	strongly disagree
29. I can sense if I am intruding, even if the other person doesn't tell me.	strongly agree	slightly agree	slightly disagree	strongly disagree
30. People sometimes tell me that I have gone too far with teasing.	strongly agree	slightly agree	slightly disagree	strongly disagree
31. Other people often say that I am insensitive, though I don’t always see why.	strongly agree	slightly agree	slightly disagree	strongly disagree
32. If I see a stranger in a group, I think that it is up to them to make an effort to join in.	strongly agree	slightly agree	slightly disagree	strongly disagree
33. I usually stay emotionally detached when watching a film.	strongly agree	slightly agree	slightly disagree	strongly disagree

34. I can tune into how someone else feels rapidly and intuitively.	strongly agree	slightly agree	slightly disagree	strongly disagree
35. I can easily work out what another person might want to talk about.	strongly agree	slightly agree	slightly disagree	strongly disagree
36. I can tell if someone is masking their true emotion.	strongly agree	slightly agree	slightly disagree	strongly disagree
37. I don't consciously work out the rules of social situations.	strongly agree	slightly agree	slightly disagree	strongly disagree
38. I am good at predicting what someone will do.	strongly agree	slightly agree	slightly disagree	strongly disagree
39. I tend to get emotionally involved with a friend's problems.	strongly agree	slightly agree	slightly disagree	strongly disagree
40. I can usually appreciate the other person's viewpoint, even if I don't agree with it.	strongly agree	slightly agree	slightly disagree	strongly disagree

4. Self-Positivity Bias (Watson et al., 2008)

Please rate the self-referential content of each word. Indicate your choice of how much each word describes you by crossing the appropriate box (1: not like me; 5: like me)

Not like me Like me
1…………………………………………5

	1	2	3	4	5
tender					
worthless					
unpopular					
talented					
bright					
anxious					
foolish					
trustworthy					
helpless					
creative					
generous					
rejected					
stupid					
disliked					
capable					
unwanted					
defeated					
hopeful					
lonely					
peaceful					
pleasant					
rough					
inadequate					
caring					
lively					
devoted					
awful					
enthusiastic					
terrified					
excited					
friendly					
boring					
upset					
pathetic					
kind					
loveable					

ugly					
abrupt					
skillful					
funny					

5. Hospital and Anxiety Depression Scale (HADS) (Zigmond & Snaith, 1983)

Please read each item below and mark the response which comes closest to how you have been feeling in the past week.

Don't take too long over your replies, your immediate reaction to each item will probably be more accurate than a long, thought-out response.

	Most of the time	A lot of the time	From time to time, occasionally	Not at all
1. I feel tense or wound up:	☐	☐	☐	☐

	Definitely as much	Not quite so much	Only a little	Hardly at all
2. I still enjoy the things I used to enjoy:	☐	☐	☐	☐

	Very definitely and quite badly	Yes, but not too badly	A little, but it doesn't worry me	Not at all
3. I get a sort of frightened feeling as if something awful is about to happen:	☐	☐	☐	☐

	As much as I always could	Not quite so much now	Definitely not so much	Not at all
4. I can laugh and see the funny side of things:	☐	☐	☐	☐

	A great deal of the time	A lot of the time	From time to time, but not too often	Only occasionall y
5. Worrying things go through my mind:	☐	☐	☐	☐

	Not at all	Not often	Sometimes	Most of the time
6. I feel cheerful:	☐	☐	☐	☐

	Definitely	Usually	Not often	Not at all
7. I can sit at ease and feel relaxed:	☐	☐	☐	☐

	Nearly all the time	Very often	Sometimes	Not at all
8. I feel as if I am slowed down:	☐	☐	☐	☐

	Not at all	Occasionally	Quite often	Very often
9. I get a sort of frightened feeling like 'butterflies' in the stomach	☐	☐	☐	☐

	Definitely	I don't take as much care as I should	I may not take quite as much care	I take just as much care as ever
10. I have lost interest in my appearance:	☐	☐	☐	☐

	Very much indeed	Quite a lot	Not very much	Not at all
11. I feel restless as if I have to be on the move	☐	☐	☐	☐

	As much as I ever did	Rather less than I used to	Definitely less than I used to	Hardly at all
12. I look forward with enjoyment to things:	☐	☐	☐	☐

	Very often indeed	Quite often	Not very often	Not at all
13. I get sudden feelings of panic:	☐	☐	☐	☐

	Often	Sometimes	Not often	Very seldom
14. I can enjoy a good book or a TV program:	☐	☐	☐	☐

6. Interpersonal Reactivity Index (IRI) (Davis, 1980; Davis, 1983)

The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate letter on the scale at the top of the page: A, B, C, D, or E. When you have decided on your answer, please mark your answer in the corresponding column. READ EACH ITEM CAREFULLY BEFORE RESPONDING. Answer as honestly as you can. Thank you.

<u>ANSWER SCALE</u>:

A	B	C	D	E
DOES NOT DESCRIBES ME WELL				DESCRIBES ME VERY WELL

	A	B	C	D	E
1. I daydream and fantasize, with some regularity, about things that might happen to me.					
2. I often have tender, concerned feelings for people less fortunate than me.					
3. I sometimes find it difficult to see things from the "other guy's" point of view.					
4. Sometimes I don't feel very sorry for other people when they are having problems.					
5. I really get involved with the feelings of the characters in a novel.					
6. In emergency situations, I feel apprehensive and ill-at-ease.					
7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it.					
8. I try to look at everybody's side of a disagreement before I make a decision.					
9. When I see someone being taken advantage of, I feel kind of protective towards them.					
10. I sometimes feel helpless when I am in the middle of a very emotional situation.					
11. I sometimes try to understand my friends better by imagining how things look from their perspective.					
12. Becoming extremely involved in a good book or movie is somewhat rare for me.					

ANSWER SCALE:

A	B	C	D	E
	DOES NOT DESCRIBES ME WELL			DESCRIBES ME VERY WELL

	A	B	C	D	E
13. When I see someone get hurt, I tend to remain calm.					
14. Other people's misfortunes do not usually disturb me a great deal.					
15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments.					
16. After seeing a play or movie, I have felt as though I were one of the characters.					
17. Being in a tense emotional situation scares me.					
18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them.					
19. I am usually pretty effective in dealing with emergencies.					
20. I am often quite touched by things that I see happen.					
21. I believe that there are two sides to every question and try to look at them both.					
22. I would describe myself as a pretty soft-hearted person.					
23. When I watch a good movie, I can very easily put myself in the place of a leading character.					
24. I tend to lose control during emergencies.					
25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while.					
26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me.					
27. When I see someone who badly needs help in an emergency, I go to pieces.					
28. Before criticizing somebody, I try to imagine how I would feel if I were in their place.					

7. Demographics and Leisure Activities Questionnaire (Online Study)

Please state your age:

Gender:

◯ Male

◯ Female

◯ Prefer not to say

Handedness:

◯ Left

◯ Right

Years of Education (from primary school and upwards):

Current Occupation:

Do you currently take part in and perform any forms of acting?

◯ Yes

◯ No

Did you previously undertake and perform acting and have now stopped?

◯ Yes

◯ No

Answer If Do you currently take part in and perform any forms of acting? Yes Is Selected Or Did you previously undertake and perform acting and have now stopped? Yes Is Selected

In what capacity did you undertake acting? E.g. theater, film etc. Please list.

Answer If Do you currently take part in and perform any forms of acting? Yes Is Selected Or Did you previously undertake and perform acting and have now stopped? Yes Is Selected

How many years have you acted for and, on average, how many hours a week do/ did you act? Please list in order noted in previous question.

	Length of time	
	Number of years	Average hours per week (average over all years)?
Acting Activity 1		
Acting Activity 2		
Acting Activity 3		
Acting Activity 4		
Acting Activity 5		
Acting Activity 6		

Do you currently draw/ paint or undertake other forms of visual art?

- ◯ Yes
- ◯ No

Did you previously undertake a form of visual artistry? E.g. sculpture, painting, drawing

- ◯ Yes
- ◯ No

Answer If Do you currently draw/ paint or undertake other forms of visual art? Yes Is Selected Or Did you previously undertake a form of visual artistry? E.g. sculpture, painting, drawing Yes Is Selected

What type of visual artistry do/did you undertake? Please list.

Answer If Do you currently draw/ paint or undertake other forms of visual art? Yes Is Selected Or Did you previously undertake a form of visual artistry? E.g. sculpture, painting, drawing Yes Is Selected

How many years and how many hours, on average per week, did you draw/ paint/ sculpt etc.? Please list in order written above.

	Length of time	
	How many years?	Average hours per week (average over all years)?
Artistic Activity 1		
Artistic Activity 2		
Artistic Activity 3		
Artistic Activity 4		
Artistic Activity 5		
Artistic Activity 6		

Do you currently play computer games (including online gaming)?

◯ Yes

◯ No

Did you engage in computer gaming (including online gaming) previously but not have stopped?

◯ Yes

◯ No

What kind of gaming do/ did you do? Please list.

Answer If Do you currently play computer games (including online gaming)? Yes Is Selected Or Did you engage in computer gaming (including online gaming) previously but not have stopped? Yes Is Selected

Please state how many years you have engaged in gaming, how many hours a week you do/ did game and for each type of game. Please list in the same order as answered above.

	Length of time	
	How many years?	Average hours per week (average over all years)?
Game 1		
Game 2		
Game 3		
Game 4		
Game 5		
Game 6		

Do you currently undertake any form of dancing?

- Yes
- No

Did you undertake any form of dancing but now have stopped?

- Yes
- No

Answer If Do you undertake any form of dancing? Yes Is Selected Or Did you undertake any form of dancing but now have stopped? Yes Is Selected

What kind of dancing do/ did you do? Please list.

Answer If Do you undertake any form of dancing? Yes Is Selected Or Did you undertake any form of dancing but now have stopped? Yes Is Selected

Please state how many years you have danced and on average, how many hours a week you do/ did dance, for each type of dancing. Please list in the same order as answered above.

	Length of time	
	How many years?	Average hours per week (average over all years)?
Dancing Activity 1		
Dancing Activity 2		
Dancing Activity 3		
Dancing Activity 4		
Dancing Activity 5		
Dancing Activity 6		

Do you currently play or are you learning to play a musical instrument (including singing)?

- ◯ Yes
- ◯ No

Did you play any musical instruments (including singing) in the past, but now have stopped?

- ◯ Yes
- ◯ No

Answer If Do you currently play or are you learning to play a musical instrument (including singing)? Yes Is Selected Or Did you play any musical instruments (including singing) in the past, but not have stopped? Yes Is Selected

Which instrument(s) do/ did you play? Please list.

Answer If Do you currently play or are you learning to play a musical instrument (including singing)? Yes Is Selected Or Did you play any musical instruments (including singing) in the past, but not have stopped? Yes Is Selected

Which instrument(s) do/ did you play? Please list and indicate how many years and, on average, how many hours played per week. Please list in order as you stated above.

	Length of time	
	How many years?	Average hours per week (average over all years)?
Instrument 1		
Instrument 2		
Instrument 3		
Instrument 4		
Instrument 5		
Instrument 6		

Do you currently take part in any sporting activities?

◯ Yes

◯ No

Have you taken part in any sporting activities in the past but have now stopped?

◯ Yes

◯ No

Answer If Do you take part in any sporting activities? Yes Is Selected Or Have you taken part in any sporting activities in the past but have now stopped? Yes Is Selected

Please list which sporting activities you do/ did participate in.

Answer If Do you take part in any sporting activities? Yes Is Selected Or Have you taken part in any sporting activities in the past but have now stopped? Yes Is Selected

Please indicate how many years and on average, how many hours per week you do/ did take part in sporting activities. Please list in same order as you completed in the previous question.

	Length of time	
	How many years?	Average hours per week (average over all years)?
Sporting Activity 1		
Sporting Activity 2		
Sporting Activity 3		
Sporting Activity 4		
Sporting Activity 5		
Sporting Activity 6		

8. Ethics

8.1. Approval of Ethical Application Chapter 1

University of St Andrews | FOUNDED 1413

University Teaching and Research Ethics Committee

08 October 2015

Dear Nina

Thank you for submitting your ethical application which was considered at the School of Psychology & Neuroscience Ethics Committee meeting on 6th October 2015; the following documents have been reviewed:

1. Ethical Application Form
2. Advertisements
3. Participant Information Sheet
4. Consent Form
5. Debriefing Form
6. Questionnaires
7. Data Management Plan

The School of Psychology & Neuroscience Ethics Committee has been delegated to act on behalf of the University Teaching and Research Ethics Committee (UTREC) and has granted this application ethical approval. The particulars relating to the approved project are as follows -

Approval Code:	PS11776	**Approved on:**	07/10/2015	**Approval Expiry:**	07/10/2018
Project Title:	Executive Functioning and Error Processing in Musicians (EEG Study)				
Researcher:	Nina Fisher				
Supervisor:	Dr Ines Jentzsch				

Approval is awarded for three years. Projects which have not commenced within two years of approval must be re-submitted for review by your School Ethics Committee. If you are unable to complete your research within the 3 three year approval period, you are required to write to your School Ethics Committee Convener to request a discretionary extension of no greater than 6 months or to re-apply if directed to do so, and you should inform your School Ethics Committee when your project reaches completion.

If you make any changes to the project outlined in your approved ethical application form, you should inform your supervisor and seek advice on the ethical implications of those changes from the School Ethics Convener who may advise you to complete and submit an ethical amendment form for review.

Any adverse incident which occurs during the course of conducting your research must be reported immediately to the School Ethics Committee who will advise you on the appropriate action to be taken.

Approval is given on the understanding that you conduct your research as outlined in your application and in compliance with UTREC Guidelines and Policies (http://www.st-andrews.ac.uk/utrec/guidelinespolicies/). You are also advised to ensure that you procure and handle your research data within the provisions of the Data Provision Act 1998 and in accordance with any conditions of funding incumbent upon you.

Yours sincerely

Convener of the School Ethics Committee

cc Dr Ines Jentzsch (Supervisor)

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071

8.2. Approval of Ethical Application Chapter 3

University of St Andrews | FOUNDED 1413

University Teaching and Research Ethics Committee

08 November 2016

Dear Nina

Thank you for submitting your ethical application which was considered at the School of Psychology & Neuroscience Ethics Committee meeting on 3rd November 2016; the following documents have been reviewed:

1. Ethical Application Form
2. Advertisements
3. Participant Information Sheet
4. Consent Form
5. Debriefing Form
6. Questionnaire
7. Data Management Plan

The School of Psychology & Neuroscience Ethics Committee has been delegated to act on behalf of the University Teaching and Research Ethics Committee (UTREC) and has granted this application ethical approval. The particulars relating to the approved project are as follows -

Approval Code:	PS12424	**Approved on:**	03/11/2016	**Approval Expiry:**	503/11/2021
Project Title:	Conflict Processing in Musicians and Non-Musicians using EEG				
Researcher:	Nina Fisher				
Supervisor:	Dr Ines Jentzsch				

Approval is awarded for five years. Projects which have not commenced within two years of approval must be re-submitted for review by your School Ethics Committee. If you are unable to complete your research within the five year approval period, you are required to write to your School Ethics Committee Convener to request a discretionary extension of no greater than 6 months or to re-apply if directed to do so, and you should inform your School Ethics Committee when your project reaches completion.

If you make any changes to the project outlined in your approved ethical application form, you should inform your supervisor and seek advice on the ethical implications of those changes from the School Ethics Convener who may advise you to complete and submit an ethical amendment form for review.

Any adverse incident which occurs during the course of conducting your research must be reported immediately to the School Ethics Committee who will advise you on the appropriate action to be taken.

Approval is given on the understanding that you conduct your research as outlined in your application and in compliance with UTREC Guidelines and Policies (http://www.st-andrews.ac.uk/utrec/guidelinespolicies/). You are also advised to ensure that you procure and handle your research data within the provisions of the Data Provision Act 1998 and in accordance with any conditions of funding incumbent upon you.

Yours sincerely

Convener of the School Ethics Committee

cc Dr Ines Jentzsch (Supervisor)

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071

8.3. Approval of Ethical Application Chapter 4

University of St Andrews

University Teaching and Research Ethics Committee
Sub-committee

13 November 2014

Ethics Reference No: *Please quote this ref on all correspondence*	PS11227
Project Title:	The Effects of Musical Training on Emotional Well-Being
Researchers' Names:	Nina Fisher, Dr Ines Jentzsch and Dr Reiner Sprengelmeyer
Supervisor:	Dr Ines Jentzsch

Thank you for submitting your application which was considered at the Psychology & Neuroscience School Ethics Committee meeting on the 4th November 2014. The following documents were reviewed:

1.	Ethical Application Form	11/11/2014
2.	Advertisements	11/11/2014
3.	Participant Information Sheet	11/11/2014
4.	Consent Form	11/11/2014
5.	Debriefing Form	11/11/2014
6.	Questionnaires	11/11/2014
7.	Data Management Plan	11/11/2014

The University Teaching and Research Ethics Committee (UTREC) approves this study from an ethical point of view. Please note that where approval is given by a School Ethics Committee that committee is part of UTREC and is delegated to act for UTREC.

Approval is given for three years. Projects, which have not commenced within two years of original approval, must be re-submitted to your School Ethics Committee.

You must inform your School Ethics Committee when the research has been completed. If you are unable to complete your research within the 3 three year validation period, you will be required to write to your School Ethics Committee and to UTREC (where approval was given by UTREC) to request an extension or you will need to re-apply.

Any serious adverse events or significant change which occurs in connection with this study and/or which may alter its ethical consideration, must be reported immediately to the School Ethics Committee, and an Ethical Amendment Form submitted where appropriate.

Approval is given on the understanding that the 'Guidelines for Ethical Research Practice' https://www.st-andrews.ac.uk/utrec/guidelines/ are adhered to.

Yours sincerely

Convenor of the School Ethics Committee

Ccs Dr I. Jentzsch (Supervisor)
School Ethics Committee

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071

8.4. Approval of Ethical Application Chapter 5

University of St Andrews

University Teaching and Research Ethics Committee
Sub-committee

30 April 2015

Ethics Reference No: *Please quote this ref on all correspondence*	PS11469
Project Title:	The Effects of Musical Training on the Processing of Emotion
Researchers' Names:	Nina Fisher, Dr Ines Jentzsch and Dr Reiner Sprenglemeyer
Supervisor:	Dr Ines Jentzsch

Thank you for submitting your application which was considered at the Psychology & Neuroscience School Ethics Committee meeting on the 21st April 2015. The following documents were reviewed:

1.	Ethical Application Form	24/04/2015
2.	Advertisements	24/04/2015
3.	Participant Information Sheet	24/04/2015
4.	Consent Form	24/04/2015
5.	Debriefing Form	24/04/2015
6.	Questionnaires	24/04/2015
7.	Data Management Plan	24/04/2015

The University Teaching and Research Ethics Committee (UTREC) approves this study from an ethical point of view. Please note that where approval is given by a School Ethics Committee that committee is part of UTREC and is delegated to act for UTREC.

Approval is given for three years. Projects, which have not commenced within two years of original approval, must be re-submitted to your School Ethics Committee.

You must inform your School Ethics Committee when the research has been completed. If you are unable to complete your research within the 3 three year validation period, you will be required to write to your School Ethics Committee and to UTREC (where approval was given by UTREC) to request an extension or you will need to re-apply.

Any serious adverse events or significant change which occurs in connection with this study and/or which may alter its ethical consideration, must be reported immediately to the School Ethics Committee, and an Ethical Amendment Form submitted where appropriate.

Approval is given on the understanding that the 'Guidelines for Ethical Research Practice' https://www.st-andrews.ac.uk/utrec/guidelines/ are adhered to.

Yours sincerely

Convenor of the School Ethics Committee

Cc School Ethics Committee

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071

8.5. Approval of Ethical Application Chapter 6

University of St Andrews | FOUNDED 1413

University Teaching and Research Ethics Committee

28 June 2016

Dear Nina

Thank you for submitting your ethical application which was considered at the School of Psychology & Neuroscience Ethics Committee meeting on 23rd June 2016; the following documents have been reviewed:

1. Ethical Application Form
2. Advertisement
3. Participant Information Sheet
4. Consent Form
5. Debriefing Form
6. Questionnaires
7. Data Management Plan

The School of Psychology & Neuroscience Ethics Committee has been delegated to act on behalf of the University Teaching and Research Ethics Committee (UTREC) and has granted this application ethical approval. The particulars relating to the approved project are as follows -

Approval Code:	PS12214	**Approved on:**	27/06/2016	**Approval Expiry:**	27/06/2021
Project Title:	Personality Traits and Leisure Activities				
Researcher:	Nina Fisher				
Supervisor:	Dr Ines Jentzsch				

Approval is awarded for five years. Projects which have not commenced within two years of approval must be re-submitted for review by your School Ethics Committee. If you are unable to complete your research within the five year approval period, you are required to write to your School Ethics Committee Convener to request a discretionary extension of no greater than 6 months or to re-apply if directed to do so, and you should inform your School Ethics Committee when your project reaches completion.

If you make any changes to the project outlined in your approved ethical application form, you should inform your supervisor and seek advice on the ethical implications of those changes from the School Ethics Convener who may advise you to complete and submit an ethical amendment form for review.

Any adverse incident which occurs during the course of conducting your research must be reported immediately to the School Ethics Committee who will advise you on the appropriate action to be taken.

Approval is given on the understanding that you conduct your research as outlined in your application and in compliance with UTREC Guidelines and Policies (http://www.st-andrews.ac.uk/utrec/guidelinespolicies/). You are also advised to ensure that you procure and handle your research data within the provisions of the Data Provision Act 1998 and in accordance with any conditions of funding incumbent upon you.

Yours sincerely

Convener of the School Ethics Committee

cc Dr Ines Jentzsch (Supervisor)

School of Psychology & Neuroscience, St Mary's Quad, South Street, St Andrews, Fife KY16 9JP
Email: psyethics@st-andrews.ac.uk Tel: 01334 462071