# EXECUTIVE FUNCTION SKILLS IN DEAF CHILDREN: AN INTERVENTION STUDY

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I, Kathryn Christine Mason confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

# ABSTRACT

Executive Functions (EFs) include cognitive processes such as attention, problem solving, inhibition, cognitive flexibility and working memory. EFs develop throughout childhood and into early adulthood, and are essential for school readiness and success. The significant role of EFs in academic achievement and beyond brings to light the distinct disadvantage of children who experience EF deficits. Deaf children, like some other groups with atypical development, have been found to have delays in EF development, particularly in planning, problem solving, and inhibition.

This thesis reports the findings from two studies investigating EF in two groups of deaf participants. The first study explores the EF skills of a unique group – deaf musicians. This study compares the EF skills of deaf and hearing adult musicians with deaf and hearing non-musicians. The results reveal similarities in the EF profiles of deaf and hearing musicians, adding to the current debate in the literature about the impact of musicianship on EF skills and the underlying mechanisms that drive gains in EF through music.

The second study, which is the main focus of the thesis, describes a music-based EF intervention carried out with deaf children in three London mainstream primary schools. It covers the design and implementation of the intervention, what effect the intervention had on children's EF (in particular, the significant impact found on children's working memory and inhibition skills), the implications of the findings for existing models of EF, and the potential for using musical training to improve deaf children's EF skills.

Results from both studies indicate that music-based EF training may be a valuable tool for improving EF skills in deaf individuals and highlights the need for further investigation into the relationship between music and EF within the deaf population.

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# Table of Contents

## List of Figures

## List of Graphs

## List of Tables

# Chapter 1 INTRODUCTION

This chapter addresses the topics of the thesis, its research focus and an overview of the main studies it contains. This is followed by the definition of relevant terms which are used frequently throughout the work and a brief overview of how deaf children in the UK are currently educated, providing a context for the practical application of the study.

## 1.1 Statement of research focus

The main topic of this thesis is the development, implementation and evaluation of an intervention programme designed to improve the executive function (EF) skills of deaf children. As a background to the study, **Chapter 2** of this thesis explores the developmental trajectory of EFs, their relationship with language and the impact of deafness. There is a discussion of currently available training programmes designed to improve children's EF skills, and a review of the literature looking at the cognitive benefits of a range of activities, including exercise, mindfulness and computerised training games. Emphasis is placed on the influence of musicianship on executive function skills, with a review of findings from previous studies of the way in which music appears to positively affect specific EFs such as working memory and inhibition. Following this, **Chapter 3** details the first study of this thesis, comparing the executive function skills of deaf and hearing adult musicians and non-musicians, and includes a discussion of the potential for music to positively influence the cognition of deaf individuals. **Chapter 4** introduces the main study of the thesis – the creation and implementation of a music-based EF training programme for deaf children. This chapter will provide a rationale for the study, and contains a report on the results of a questionnaire sent to teachers of the deaf and other practitioners who work with deaf children on their familiarity with existing EF training programmes. It also provides details of their feedback and opinions of EF programmes, including activities that they have found beneficial (or not) in their teaching experience. Results of the questionnaire influenced the design of the intervention programme in the main study, which will be outlined in detail in **Chapter 5**. Chapter 5 will also describe the methodology used, the recruitment of participants and their school and language backgrounds. **Chapter 6** provides a detailed analysis of the data from the music-based EF intervention study, including data from individual participants and group data.

Finally, **Chapter 7** provides an overview and discussion of the results of both studies, including their limitations, theoretical implications, and the future direction of research into music, EF and the deaf population.

## 1.2 Definition of terms used throughout this thesis

Before embarking on a discussion of EF, language and deaf children, I will first provide a short description of the terminology frequently used in the field of deafness and educational research. Many of these terms will be used in their abbreviated form throughout this thesis, so this section will serve as a definition and reference for terms relating to severity and level of deafness, communication modes and hearing technologies, as well as providing a brief introduction to the different educational environments available to deaf children in the UK.

### 1.2.1 Definitions relating to age of onset and severity of deafness

There is no single definition of what it is to be deaf. Distinctions can be made between individuals according to the age they became deaf, the severity of their deafness, and important family and cultural considerations.

Regarding the onset of deafness, **pre-lingual deafness** relates to people who were born deaf, or became deaf prior to acquiring spoken language, often through illnesses such as meningitis. **Post-lingual deafness** relates to people who became deaf after having acquired spoken language. Common causes of post-lingual deafness are certain illnesses or loud environmental conditions which can damage hearing. This category is relevant for musicians who become deaf due, in part, to prolonged exposure to loud music.

The severity of types of deafness are referred to on a continuum as either mild, moderate, severe or profound, according to the decibel level of sound a person is able to hear. The quietest threshold of sound heard by those with **mild deafness** is between 25-39 decibels. These people will have typically have trouble following conversations in noisy environments. Those who are able to hear sounds at 40-69 decibels are described as **moderately deaf,** and it is this level of deafness at which a person may require hearing aids. A lower hearing threshold of 70-94 decibels applies to people who are **severely deaf**, who will most likely rely on lipreading in addition to the use of additional aids (such as hearing aids or cochlear implants) and many people with severe deafness have sign language as their preferred communication mode. People who are **profoundly deaf** have a hearing threshold of 95 decibels and are likely to have sign language as their first or preferred language. However, this is not always the case, and some severe or profoundly deaf people who use hearing aids and/or cochlear implants have spoken English as their preferred language (Action on Hearing Loss, 2015).

People who are ‘**deaf’** (with a lower case ‘d’) is the most common general way of referring to a wide range of people who were either born deaf or became deaf. They may communicate using either sign language or spoken language, however they do not identify themselves as culturally deaf or members of the “big D” Deaf community.

**‘Deaf’** (with an upper case ‘D’) refers to members of the Deaf community who often come from Deaf families and whose preferred mode of communication is sign language. They use an upper case ‘D’ in order to emphasise their strong deaf identity.

**‘Hard of hearing’** is a term used to describe people with a mild to severe hearing loss and often refers to those who have experienced a gradually worsening hearing loss.

People who are **‘deafened’** were born hearing and have subsequently become severely or profoundly deaf. The onset of deafness in these cases may be either sudden or gradual.

### 1.2.2 Communication modes

Just as there is a spectrum of deafness, there are a variety of methods of communication that people with different levels of deafness prefer to use. There is a common prevailing myth that sign language is a universal manual language shared by deaf people all over the world. However, the reverse is true. There are numerous individual and distinct sign languages throughout the world, each of which developed independently wherever deaf people came together to form a community. Another misconception is that each of these sign languages is based on the dominant spoken language of their country, and follows the same grammatical and syntactic structure as that spoken language. The reality is the contrary, with sign languages differing in their lexicon, syntax and grammatical rules. There are also notable regional variations or ‘dialects’ in sign languages, just as are found in spoken languages. Whilst an estimated 70,000 people in the UK use British Sign Language (Signature, 2016), a large proportion of deaf people prefer to use other modes of communication. Deaf adults and children who have taken part in the two studies described in this thesis use one of the following as their primary (or preferred) mode of communication.

a) **British Sign Language (BSL).** Recognised as an official language of Great Britain in 2003, British Sign Language is a rich language with its own grammar, syntax and phonology. It is often the first language of members of the Deaf community and the focal point of Deaf identity and Deaf culture in the UK.
b) **Sign Supported English (SSE).** Sign Supported English is a signing system which uses signs from BSL, but follows the word order of spoken English.
c) **Total Communication (TC).** Total communication is an all-encompassing system adopted by many schools with children who have special educational needs. Communication methods include signs and gestures, speech, electronic aids and pictorial devices such as photos/pictures and cue cards.
d) **Spoken English.** Many deaf children and adults choose to communicate in spoken English instead of BSL/SSE or in addition to BSL/SSE. They are described as “oral deaf” and may have English as their first language or, depending on their familial mother tongue, as an additional language.

### 1.2.3 Hearing Technologies

a) **Hearing aids** are commonly used devices designed to improve hearing and amplify sound. However, they do not “correct” hearing loss or deafness, and the benefit to the wearer depends on how well they are configured to match the hearing level of the wearer. They make many sounds accessible to D/deaf and hard of hearing people and often aid speech recognition and lipreading skills.
b) **Cochlear implants** are medical devices designed to replicate the function of the cochlea (the inner ear). As well as amplifying sound as hearing aids do, cochlear implants are surgically implanted and provide sound signals to the brain. They are often chosen to be used by people who receive little to no

benefit from hearing aids, and their use is becoming more prolific as there are currently around 11,000 cochlear implant users in the UK, and the majority of profoundly deaf children have received an implant (The Ear Foundation, 2016). People may receive cochlear implants to one ear (unilateral implant) or both ears (bilateral implants).

c) **Bone Anchored Hearing Aids (BAHA)** are devices which use bone conduction in order to aid hearing. They are generally used by individuals who have conductive hearing loss or unilateral deafness. BAHAs are surgically implanted sound processors which turn sound into vibrations which are subsequently transmitted through bone, directly into the inner ear (Cochlear, 2016)

### 1.2.4 Methods of educational instruction

In 2015 the Consortium for Research in Deaf Education published their latest annual survey on educational provision for deaf children in the UK (CRIDE, 2015). According to the report there are at least 48,932 deaf children in the UK, the majority of whom are born to hearing parents. 78% of deaf children attend mainstream schools with no specialist provision or support; 7% attend mainstream schools with resource provisions; 3% attend specialist schools for the deaf; and 12% attend special schools that are not specifically for deaf children. The report notes that improvements in cochlear implant and hearing aid technology, and the impact of mainstreaming education policies, means that the profile of deaf children in the UK has changed dramatically over recent years with many more deaf children attending mainstream schools. Whilst historically specialist schools for the deaf adopted either a strict oral or signing approach (and many still do), it is now more common for the language in which deaf children are educated to be dictated by the specific needs of individuals, as far as possible. The report found that 87% of deaf children communicate primarily in spoken English or Welsh, and around 10% use sign language (BSL or SSE) either exclusively or alongside another language.

## Specialist Deaf Schools

There are currently 23 specialist schools for d/Deaf children in the UK, some of which deliver education through English (oral) methods, whist others use BSL as the primary educational medium. These schools may be day or residential and often admit deaf children who have additional special educational needs. These types of schools are often preferred by Deaf parents of Deaf children as they want to provide a Deaf cultural and linguistic environment for their child (DEXperience, 2016), however deaf children with a wide range of language and cultural backgrounds attend specialist d/Deaf schools.

## Mainstream Schools

Mainstream school educational provision for D/deaf children can be in either 'Resourced' or 'Local' mainstream schools. 'Resourced' mainstream schools are equipped with specialist staff (qualified Teachers of the Deaf and teaching assistants with sign language skills, specially trained to support deaf children), and may provide access to the curriculum through BSL, SSE, TC or spoken English depending on the individual needs of each child. The D/deaf children receive tuition in maths, English and science alongside other D/deaf children in a specialist resource unit for part of the school day, and spend the other lessons integrated in mainstream classes with their hearing peers. During mainstream classes they are supported in their learning and communication by a specialist teaching assistant. 'Local' mainstream schools may also provide these services, but the level of support d/Deaf children receive at these schools differs greatly between Local Education Authorities. Children in these schools may have one to one support in class or may only have contact with a peripatetic Teacher of the Deaf once a week. Others may spend most of the week in mainstream classes, but spend a set number of hours a week having specialist tuition at a school for the Deaf. The variation in the type of educational environment d/Deaf children receive is illustrative of the wide variety of language, social and learning experiences of d/Deaf children as a group.

Considering the variation in educational environment, language exposure and use, and individual family and cultural backgrounds of deaf people, it is clear that the terms "deaf child" and "deaf people" refer to members of a very heterogeneous group.

# Chapter 2 LITERATURE REVIEW

This chapter will provide a review of the current literature regarding executive functioning; the definition of executive function and models of organisation, its development throughout childhood and adolescence into adulthood, the relationship between executive functioning and language, disorders of executive functioning, and the impact of deafness on executive function skills.

## 2.1 Executive Functions

"A band is only as good as its drummer". So says Bobby Gillespie of the Scottish rock band *Primal Scream* (Wilde, 2007), and it is a widely held sentiment. Providing a strong steady beat, drummers keep the band 'together', determining the pace of songs, whether to speed up or slow down, and often deciding when to start or end songs. Similarly, the conductor of an orchestra ensures the co-ordination of many musicians, all playing different instruments and different parts, to create one unified, emotive and seamless sound. Although the conductor does not contribute directly to the sound produced, the orchestra would struggle without him, potentially lose their tempo, miss their entries and the overall performance would suffer. Just as a conductor monitors and directs an orchestra, air traffic controllers have the heavy responsibility of co-ordinating the safe journey of thousands of passengers at an airport. They are responsible for the movement of vehicles on the runways and multiple aircraft arriving and leaving in quick succession, having to make many important logistical decisions during rapidly changing situations. Whilst they may not be as well-known or celebrated as the frontman, the soloist, or the pilot, each of these aforementioned roles are vital to the running of their respective groups and, without them, disorder would likely take over. Another thing each of these roles has in common is that they have all been used in the past as a metaphor for executive functioning e.g. (Goldberg, 2001).

'Executive functions' (EFs) is a term used to cover a broad range of metacognitive processes that control, monitor, regulate and organise other cognitive processes. Although it is universally agreed that EFs refer to metacognitive processes that are conscious and require some degree of effort, researchers and other academics with a variety of backgrounds and perspectives all tend to define EFs slightly differently (Banich, 2009). Consequently, there is, at present, no conclusive list of specific EFs due to ongoing debate about their roles and structure. Nevertheless, they are generally agreed to include attention, inhibition, planning, problem solving, working memory, mental flexibility and task switching. They have been described as requiring effortful, conscious, executive control or supervisory attention (Shallice, From Neuropsychology to Mental Structure, 1988) and are described by Diamond (2006) as *"required whenever going 'on automatic' would be insufficient and especially when it would lead one astray"* (Diamond, 2006, pp.70). EFs are therefore involved in most processes we all rely on everyday – from tying our shoelaces or making a shopping list, to working out a new route to work during a tube strike and ignoring distractions and focusing our attention for long enough to write a research report.

Whilst a definitive and concise definition of EFs is yet to be agreed, a distinction between EFs influenced by emotional and motivational factors, and those which are driven more heavily by cognition alone, has emerged in the literature. These are known as 'hot' and 'cold' EFs respectively. The dichotomy between these two types of EF is highlighted further by their association with different regions of the brain, with the orbitofrontal cortex associated with 'hot' EFs and the dorsolateral prefrontal cortex with 'cold' EFs (Zelazo & Muller, 2002). 'Cold' EFs are referred to as such because they generally have minimal emotional or social influence on the cognitive process. Examples of 'cold' EFs include attentional control (selectively paying attention to something and ignoring competing or intrusive information; sustaining attention and focusing on a particular task; and inhibiting impulsive responses to irrelevant or distracting information), goal setting (planning, initiating and problem-solving) and cognitive flexibility (the ability to shift attention and stop one task and begin another). Examples of standard tasks used to measure these types of 'cold' EFs are, in adults, the Wisconsin Card Sort Task (Grant & Berg, 1948), and for a wide age range of participants including children, the Dimensional Change Card Sort (Zelazo, 2006). Both of these assessments are 'set-shifting' tasks which require participants to sort cards according to a particular rule e.g. by colour or shape. The ability to prevent perseveration once the sorting rule changes provides a measure of the subject's cognitive flexibility. In the case of the Wisconsin Card Sort, the initial sorting rule and subsequent rules also need to be ascertained by the participant using trial and error, and therefore include an additional problem solving element. There are no overt risks, rewards or social components involved in these kinds of abstract tasks, resulting in the cognitive processes involved being labelled as ‘cold’ EFs.

‘Hot’ EFs are those which involve social-affective elements such as emotion, self-awareness, perspective taking (i.e. Theory of Mind) or moral judgements, and they typically have emotionally significant outcomes. An example of typical tasks requiring ‘hot’ EFs are those which involve delaying or inhibiting behaviours, such as the well-known ‘Stanford Marshmallow Test’ (Mischel & Ebbesen, 1970). In this study, children aged between four and six years old were presented with a treat of their choice (either a marshmallow, a cookie or a pretzel) and were told that they could either eat the treat immediately, or, if they didn’t eat it and waited for 15 minutes, they would be rewarded with a second treat. Whilst a few of the younger participants immediately gave in to temptation and ate their treats, the majority of the children attempted to delay eating the treat. However, of those who attempted to delay, only one third were successful in doing so, with the others succumbing to the impulse to eat the treat before the 15 minutes was through. The authors reported that age was a significant determinant in the children’s ability to delay gratification, inhibiting their compulsion to eat the treat and successfully achieving their goal of being rewarded with a second treat.

## 2.2 Theoretical Models of Executive Function

It is clear that even everyday tasks require the seamless co-ordination of several EFs, and rarely require only one to be implemented at a time. It can be assumed that holding a telephone number in your head as you write it down is primarily utilizing working memory. However other tasks, such as cycling to work via a new route, require the integration of working memory (to recall the new route you mapped out before you left home), attentional and inhibitory skills (to prevent you from automatically pursing your usual route) and monitoring and updating skills (if your new route is blocked, you may need to come up with a different plan). The roles and organisation of EFs, including the extent to which they are separable from one another, is under debate, and opinions and models vary between different fields of study (e.g. between cognitive psychology and educational psychology). Miyake, Emerson and Friedman (2000) point out three important issues that are relevant to understanding the context of various models of EF. The first is that, due to differing terminology used to describe EFs, different concepts used in models may overlap. Leading on from this, the second point made by the authors is that researchers from different disciplines often use different terminology to refer to the same cognitive function (e.g. the terms "cognitive flexibility" and "switching" are often used to describe the same cognitive construct), or conversely, the same term may be used to refer to conceptually different functions. Thirdly, an important issue in the consideration of theoretical models of EF is the current lack of consensus between researchers as to whether EF is itself a single construct which consists of many interconnected cognitive processes, or whether it is a collection of independent and dissociable processes. In other words, whether EF can be considered unitary or non-unitary (Miyake, Emmerson, & Friedman, 2000). While some studies have advocated for a unitary view of EF (Duncan, Emslie, Williams, Johnson, & Freer, 1996) a considerable number of researchers have adopted a non-unitary view of EF in the development of theoretical models.

One of the most prominent **non-unitary models of EF** was developed by Miyake et al. (2000), who examined the performance of adults on 9 EF tasks considered to measure three main EF processes; set shifting/switching; updating/working memory; and inhibition. Using confirmatory factor analysis, Miyake et al. established working memory, set shifting and inhibition to be independent and separable EFs which were moderately related to each other. They also used structural equation modelling to determine that these were specific to individual EF tasks, therefore indicating that particular EFs can indeed be differentiated from each other. Miyake & Freidman (2009) re-emphasised that EFs show both unity and diversity (as individual EFs are correlated with each other) and additionally highlighted the developmental stability of the model, established through longitudinal studies of twins (Miyake & Friedman, 2009). In recent years, Miyake & Friedman (2012) have adapted their model, continuing to consider the mechanisms which underpin aspects of unity and diversity of EFs. They have put forward a new unity/diversity framework whereby EFs are 'decomposed' into elements which are common across all of the three key EFs (referred to as Common EF), and elements which are *"unique to a particular ability, or diversity"*(Miyake & Friedman, 2012, p.3).

A very important set of studies on what later became known as EF, originated from **Badeley's model of working memory** (Badeley & Hitch, 1974). In this unitary model, the authors describe the 'central executive' as being a flexible management system that oversees and regulates other subsystems: the 'phonological loop' and the 'visuospatial sketchpad'. The phonological loop is conceptualised as a component which temporarily holds and manipulates verbal and auditory information, while the visuospatial sketchpad is responsible for the storage and manipulation of visuospatial information. A fourth component, the 'episodic buffer', was added to the model later (Baddeley, 2000, 2002). This component was conceptualised as providing temporary storage of integrated information from the phonological loop, the visuospatial sketchpad, and long term memory. The episodic buffer is under the control of the central executive and is described by Baddeley as a component which enables representation of the current environment and additionally, the utilization of past experience to inform decisions and actions. Therefore, in this model the episodic buffer plays a vital role in learning; retrieving information about previous experiences from long term memory, consolidating them with information from the present which aids in decision making and learning.

However, while Baddeley's working memory model effectively describes the supervisory role of the central executive, it does not account for how EFs develop in children. One theory which is specifically concerned with the development of EFs is the **Cognitive Complexity and Control (CCC) Theory** (Zelazo & Frye, 1998). This non-unitary theory examines the way in which different EF processes integrate in order for a person to achieve a goal or solve problems. Language plays a key role in this model, as Zelazo and Frye predict that it is through the development of an increasingly sophisticated and complex language-based rule system that children are equipped with the ability to formulate more complex plans and use more advanced reasoning skills. Therefore, according to this model any disruption to a child's language development will impair their ability to successfully tackle more complex challenges. In other words, language development drives EF development.

Linked to this, a second key element of the CCC theory is a child's ability to independently reflect on their experiences (Zelazo, Frye, & Rapus, 1996). According to Zelazo and colleagues, increasingly sophisticated language enables children to reflect on their experiences, which in turn drives developmental changes in EF. They observe that very young children will fail some EF tasks due to an inability to reflect on known rules, rather than a lack of awareness of the rules altogether. An example of this dissociation in young children's knowledge of rules and their use of them can be seen in the performance of three year olds on the Dimensional Change Card Sorting Task (DCCS: Frye, Zelazo, & Palfai, 1995). In this task, children are required to sort cards with different coloured shapes on them into piles (e.g. "if it is a circle, put it is this pile; if it is a triangle, put it in this pile"). Studies have shown that three year olds are able to complete this task when there is only one rule that they need to attend to in order to succesfully sort the cards, e.g. shape. However, when a second rule is introduced (e.g. colour) three year old children will perseverate to the old rule and continue to sort the cards according to shape, despite being explicitly aware of the new rule (e.g. "now we are sorting by a different rule, if it is blue, put it in this pile; if it is red, put it in this pile"). Conversley, four and five year olds make very few errors with this task and are able to reflect on the task, mentally switching to the new sorting rule (Zelazo et al., 1996). Advancing language skills enable children to 'step out' of their immediate situation and to reflect, facilitating conscious control of their behaviour (Muller, Jacques, Brocki, & Zelazo, 2009), and the use of private speech (eiher vocal or sub-vocal) helps the child to reinforce rules and to *"bring the right knowledge to bear on their behaviour…at the right time, in specific situations"* (Mueller et al., 2009, p57.). For tasks such as the DCCS, four and five year olds are therefore able to both demonstrate their knowledge of the new rules, reflect on and monitor their behaviour (showing awareness if they make errors), and successfully implement their knowledge of the rules. Generally, three year olds have not yet developed this level of self-regulation and, while able to demonstrate that they are aware of the new rules, make frequent errors in practice which are not often consciously observed by the child.

An alternative model of EF often reported in the literature is **Barkley's neuropsychological behavioural model of EF** (Barkley, 1997). Barkley puts self-regulation and control at the heart of his model of EF, and claims that response inhibition is the key prerequisite of self-regulation. In this respect, he views attention deficit hyperactivity disorder (ADHD) to primarily be a disorder of EF (this will be addressed further in section 2.5). Barkley emphasises the importance of behavioural inhibition, without which, it is argued, other EFs are unable to properly develop. The model proposes an overarching behavioural inhibition system which consists of four main components of EF: verbal working memory, non-verbal working memory, motivation/regulation and analysis/reflectiveness. In this model, behavioural inhibition is believed to be fundamental to effective EF, as all other functions depend upon it either by way of inhibiting a prepotent response, preventing an ongoing response or behaviour that is ineffective, or by maintaining focus by inhibiting distractors. As Vygotsky (1978) theorized that children internalise behaviour as they mature (for example, externally vocalised self-talk eventually becomes internalised 'inner speech') Barkley (2001) also proposes that EFs are initially externalised and observable, often scaffolded by adults. As children develop, their EFs become internalised and they begin to monitor and control their own behaviour more independently, using self-directed speech to support self-regulation. Therefore, in this model language again plays an important mediating role in the development of self-regulation and, subsequently, EF skills – *"Private speech…provides a means for self-questioning through language, creating an important source of problem-solving ability as well as a means of generating rules and plans"*(Barkley, 1997, p.175).

## 2.3 The Development of Executive Functions.

The results of the Stanford Marshmallow Experiment (described in section 2.1) illustrate how EFs developmentally refine over time. In the case of this experiment, between the ages of four and six the children ranged from having seemingly no self-regulatory control, to demonstrating some control, then finally mastering and inhibiting their impulses in order to benefit at a later point. Many studies have sought to address questions relating to the developmental trajectory of EFs such as: At what age do different EFs begin to emerge? Do all EFs develop in tandem and at the same rate? Do all children develop EF skills in the same order and go through the same 'stages'? and at what point is EF development considered to be complete? In order to address these questions, recent studies have sought to chart the development of EFs beyond a child's early years, throughout adolescence and beyond (e.g. Best , Miller, & Jones, 2009; Mischel, et al., 2011).

Best and Miller (2010) note that many of the early studies investigating the development of EFs tended to focus only on young children up to the age of five. Whilst it is noted that this age group experiences a period of rapid development in EFs

(Zelazo, 2006), there continues to be substantial EF development throughout childhood, adolescence and into early adulthood (Best , Miller, & Jones, 2009). This is consistent with the association between EFs and the prefrontal cortex, the region of the brain primarily responsible for the orchestration of EFs. The frontal lobe is often likened to the ‘conductor of an orchestra’ or the brain’s ‘Chief Executive’ and is the final area of the brain to reach developmental maturation (Goldberg, 2001). It is also one of the most heavily connected areas of the brain, having direct connections with every other distinct functional area (Nauta, 1972).

Before they are even a year old, children display evidence of early EF development. Between six and ten months of age, infants’ inhibitory skills begin to develop as they are capable of refraining from touching or grabbing objects when instructed not to by an adult, and maintaining their focus on a task despite the potential for becoming distracted. The next section will briefly chart the development of the three key elements of EF: working memory, inhibition and cognitive flexibility.

### 2.3.1 Working Memory

‘Working memory’ refers to our capacity to hold information in mind for a short period of time, before retrieving it again for use. We use working memory in order to hold a phone number in mind whist searching for a pen with which to write it down, or to recall the order of ingredients to be added to a dish whilst cooking, after briefly reading the recipe. It enables us to follow instructions that have several steps, holding in mind which actions need to be completed next in order to reach a particular goal or complete a task. During the first year of life, children pass several developmental milestones for working memory skills. The first of these occurs between 7 and 9 months of age when children learn ‘object permanence’ (Piaget, 1977, Baillargeon & DeVos, 1991) which is the ability to remember that an object is still present even when it is obscured by another object or hidden (for example, a toy being hidden under a blanket). At around 10 months of age children utilise working memory to plan and execute simple two-step plans, such as moving one object in order to reach another. By the age of 3, young children are able to complete simple sorting tasks which involve holding two rules in mind (for example, “blue bricks go in this pile, red bricks go in another”). By 5 years old children are aware that objects may not be as they appear, for example, when they are given a sponge with the appearance of a rock

(Best , Miller, & Jones, 2009). They are also able to hold in mind the perspective of others, known as ‘theory of mind’ (Perner & Lang, 1999). Throughout their remaining childhood, children’s working memory skills become increasing sophisticated, enabling them to explore new locations and remember complicated routes, and play popular games designed to test memory skills, such as ‘Concentration’ or ‘Pairs’ where a pack of picture cards (usually with a theme such as animals or shapes) are spread out face down on a table. During a turn, two cards are flipped over and children need to memorise the location of different cards in order to locate two matching pairs. The player with the most number of pairs wins. Throughout school years and into adolescence, demands on working memory increase greatly as teenagers are encouraged to become more independent and take responsibility for their own work. Young adults become skilled at remembering and planning multiple tasks that need to be completed by different times, managing workloads and prioritising tasks – all tasks which require good working memory skills (Cronklin, Luciana, Hooper, & Yarger, 2007)

### 2.3.2 Inhibitory Skills

Ignoring distractions, keeping on task, resisting temptation and delaying gratification are all important inhibitory skills. Inhibitory control is, however, a particularly difficult skill for young children to master. By 6 months of age children display early rudimentary inhibitory skills, such as not touching something when warned by a parent that the object is hot or dangerous. This develops further over the next 6 months and by 11 months old they are able to delay reaching for objects or toys when there is a barrier or obstacle in the way and an alternative plan is needed in order to reach their goal. It is also at this age that children’s attention skills show development as they begin to maintain their focus on a task, inhibiting other distractions around them. Large developmental strides are made in children’s inhibitory skills around 4-5 years of age. (Livesey & Morgan, 1991). At this age children can demonstrate delayed gratification (e.g. by inhibiting the urge to eat a treat immediately, as in the Stanford Marshmallow experiment). They also make fewer perseveration errors, (i.e. persisting with a previous rule when a new one is needed to successfully complete a task), by inhibiting an old rule and attending to the new one. Inhibitory skills continue to mature, and by the age of 7 children perform similarly to adults on tasks and experiments that require focused attention and the ability to ignore unimportant peripheral stimuli (Molfese, et al., 2010). During the teenage years, self-control continues to develop and young adults become adept at inhibiting distractions and prioritising attention when needed. Multi-tasking and complex activities such as driving require focus and inhibition of distractions, whist being able to remain alert and shift attention quickly when necessary. However, as adolescence is a period of development typically characterised by seemingly impulsive or "risky" behaviour, it also exemplifies the fact that full maturity of the prefrontal cortex, and sophisticated inhibitory skills are yet to emerge (Blakemore & Choudhury, 2006). As adults, people are able to demonstrate consistent self-control and advanced inhibitory responses in different social situations where immediately responding in a certain way may be socially inappropriate.

### 2.3.3 Cognitive flexibility

Cognitive flexibility refers to our ability to change and adapt our thinking as required by different situations. Babies start developing this skill when learning how to problem solve. For example, from around 9 months old onwards young children develop the ability to try alternative methods in order to successfully obtain a toy, when the method they usually use no longer works (Anderson, 2002). This cognitive flexibility continues to develop through the early years, where children learn that there are different rules for different situations, something particularly important for when they start school (e.g. you take your shoes off when you get home, but leave them on when you arrive at school; wellington boots are for rainy days and not for trips to the beach etc.). This behaviour develops further throughout childhood as children learn to adapt their behaviour according to different social situations (Amso & Davidow, 2012). They become increasingly accomplished at switching their focus and adapting to changing rules. By the time adulthood is reached, people are able to adapt quickly to last minute deviations and changing situations, for example, having to arrange an alternative route home if their usual train is cancelled.

While it is possible to chart the development of individual EFs, it is important to note that they are strongly interrelated and develop in tandem with each other. For example, during an activity that involves two rules, you need to utilize working memory in order to hold both rules in mind, inhibitory skills to attend to one rule whilst inhibiting the other, and cognitive flexibility to switch between the two rules when necessary (Banich, 2009).

## 2.4 The Impact of EF Development on School Readiness and Achievement

When they first enter primary school at the age of four years, the main behaviours that children are required to possess are the ability to sit still, pay attention and to follow basic rules. These are the key foundational skills which indicate ‘school readiness’. Blair (2002) emphasises the importance of EF skills for children’s school readiness, concluding that skills such as problem solving, reasoning and planning play a vital role in this respect, more so than other factors such as IQ or socioeconomic status (Blair, 2002). Fitzpatrick et al. (2014) examined the extent to which EFs accounted for socioeconomically based disparities in school readiness amongst 3-6 year olds. They found that children’s scores on a series of EF tasks predicted their academic ability (as measured by maths, reading and vocabulary assessments), after controlling for fluid intelligence and speed of cognitive processing. Children who grow up in impoverished families tend to live in environments that offer less support and stability (Evans, 2004) and fewer opportunities to develop attentional skills and self-control (Dilworth-Bart et al., 2010) than children from higher socioeconomic backgrounds. Studies such as these highlight the important issue that it cannot be assumed that all children start school having developed their EF skills (which are a prerequisite for academic achievement) to equivalent levels. Greater awareness of the importance of EF skills for school readiness has led to an increase in preschool EF screening and provision of early intervention programs (such as the “Head Start” programme) for children considered to be “at risk” of having poorer EF skills than their peers (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008). It is not only children from low socioeconomic backgrounds whose delayed EF development may put them at a disadvantage when starting school. Many children with different developmental impairments and disabilities also display impaired EF skills, which have the potential to impact their ability to learn and achieve in school (these children will be discussed in section 2.5).

There has been a wealth of research investigating the relationship between EFs, school readiness and academic achievement. A study of the role of self-regulation in the emerging academic ability of 3 to 5 year olds indicated that self-regulation accounted for unique variance in the children's academic outcomes (irrespective of IQ), with inhibitory control as a prominent correlate of early reading and maths ability (Blair & Razza, 2007). It has been long established that working memory is of particular importance to academic achievement, as children with poor working memory skills typically have poor performance on a host of academic measures, such as school assessments of English, mathematics and science (Jarvis & Gathercole, 2003; Gathercole, Pickering, Knight & Stegmann, 2004). Specifically, associations have been found between verbal working memory and English attainment, and between visuospatial working memory and achievements in science and mathematics (Jarvis & Gathercole, 2003). Cognitive flexibility is important for successful writing skills in school aged children (Hooper, Swarts, Wakley, de Kruif & Montgomery, 2002) as well as for mathematical skills (e.g. Bull & Scerif, 2001). Inhibition has also been identified as being associated with mathematical skills (e.g. Espy et al., 2004) and with literacy skills including reading, vocabulary development and comprehension (Dempster & Corkhill, 1999; De Beni, Palladino, Pazzaglia & Cornoldi, 1998; Dempster & Cooney, 1982). As children get older and attend school regularly, they are immersed in an environment which challenges and develops their EF skills; academically, socially and emotionally. Several authors have highlighted the bidirectional relationship between schooling and EF development (Visu-Petra et al., 2011, Blair, Gamson, Thorne & Baker, 2005).

Not only are EFs vital for early academic success, but there is some evidence to suggest that early EF skills can be an indicator for success later in life. For example, a large longitudinal study found that children with lower self-control levels (relating to attention and inhibition skills) at ages 3 to 11 tended to have poorer health, earn less and have a higher tendency to commit crimes 30 years later, compared to those with higher levels of self-control, even when the researchers controlled for IQ, gender and social class (Moffitt, et al., 2011).

With such an influence on academic and social functions, any disruption to EF development can have lasting consequences for an individual. The remainder of this literature review will examine the impact of various developmental disorders EF skills. There will also be a review of studies investigating the links between language and EF, and the performance of D/deaf children and adults on various EF-focused tasks.

Finally, there will be an overview of EF intervention work, outlining the key characteristics of successful EF interventions with specific focus on the EF benefits of musicianship.

## 2.5 Developmental Disorders and Executive Function Difficulties

The significant role of EFs in academic achievement and beyond brings to light the distinct disadvantage of those who experience EF deficits or developmental delays. Some children experience deficits in one or more elements of EF, which may manifest in a variety of ways such as; having reduced working memory ability, poor planning skills, the inability to suppress impulsive behaviour or being mentally inflexible when it comes to problem solving (Anderson, 2002). Studies have shown that different developmental disorders have distinctive EF profiles, with children presenting patterns of EF impairment according to their particular disorders (Ozonoff & Jensen, 1999). For example, one of the characteristics of children with autism is a lack of cognitive flexibility, which manifests in an insistence on adhering to routines, and a strong dislike of disruption to daily timetables. It is thought that this cognitive rigidity also has a negative effect on their planning and problem solving skills (Hill, 2004; Ozonoff & Jensen, 1999). Corbett et al. (2009) reported on the EF profiles of 7-12 year old children who were diagnosed with either autism or attention deficit hyperactivity disorder (ADHD), comparing them with a group of typically developing children. The three groups of children completed a battery of EF tests which measured working memory, cogntive flexibility, planning, inhibition, fluency and attention (which was referred to as “vigilance” in the study). Corbett and colleagues found the children with autism to have wide raning EF deficits, with inpaired attention skills (in comparison to the typically developing group), and poorer cognitive flexibility, working memory and response inhibition in comparison to the other two groups. Their findings indicate that children with autism demonstate a generalised impairment in EF, showing deficits in several different EFs. By contrast, children with ADHD appreared to have a particular deficit in their attentional skills. These findings support those of an earlier study by Geurts, Verte, Oosterlaan, Roeyers & Sergent (2004), where the EF performance of children with ADHD and high functioning autism were compared. This study also found the autistic group to have EF deficits across all domains, except for working memory and interference control. Children with autism also displayed a larger deficit in cogntivie flexibility and planning skills in comparison to the ADHD group. The ADHD group again showed particular deficits in inhibitory response and, additionally, in verbal fluency (Geurts et al., 2009).

The three core symptoms of ADHD are hyperactivity, impulsivity and inattention. Barkley (1997), places response inhibition at the heart of his model of ADHD and EF (see section 2.2) and asserts that poor response inhibition subsequently affects four other EFs which depend upon it; working memory, self regulation, internalisation of speech and reconsititution. The fact that there is a comorbid profile of ADHD in autism (i.e. with observed deficits in attention and inhibition, a significant number of children with autism have cognitive profiles which are consistent with ADHD), raises questions about the relationship between the two disorders. Studies profiling EF skills of children with autism and ADHD help to highlight the areas of overlap and distinction in EF skill between the two disorders (Geurts et al., 2004), emphasising the challenges and care needed to be taken in their diagnosis (Barkley, 2003).

Two other groups of children who display particular EF profiles are those with Down syndrome and Williams syndrome. Children with these disorders are of particular interest to researchers studying EF, as individuals with each syndrome generally exhibit contrasting abilities from one another. Children with Down syndrome have linguistic impairments, particularly for expressive language (Chapman, 2003; Vicari, Caselli, & Tonucci, 2000), and display working memory deficits for the recall of verbal material, but not for visuospatial material (Brock & Jarrold, 2005). Conversely, children with Williams syndrome have particularly strong linguistic abilities, but display severe deficits in visuospatial skills (Bellugi, Korenberg, & Klima, 2001), translating to poor performance on visuospatial working memory tasks while perfromance on verbal working memory tasks is in line with their mental age (Jarrold, Baddeley, & Hewes, 1999). Carney, Brown, and Henry (2013) administered executive loaded working memory (ELWM), inhibition, fluency and set-shifiting tasks to children with Williams syndrome, Down syndrome and to typically developing children. Both of the groups with developmental disorders displayed their expected pattern of EF deficit, however they each additionally showed pervasive deficits in both visuospatial and verbal tasks in one domain; inhibitory skills in children with Williams syndrome and ELWM in those with Down syndrome. This suggests that whilst patterns of EF strengths and weaknesses can be associated with particular disorders, these strengths do not always manifest consistently across EF domains (Carney, Brown, & Henry, 2013).

Specific language impairment (SLI) is a diagnosis traditionally given to children who have a disorder specific to language which exists despite the child having normal non-verbal IQ, hearing, motor development and social interaction (Leonard, 1998). However, children with SLI have varied, heterogeneous language and cognitive profiles, and some studies have provided evidence that their impairments are not entirely limited to the linguistic domain. For example, children with SLI have been found to have poorer perfomance on a variety of EF tasks in comparison to typically developing children (Conti-Ramsden, Ullman, & Lum, 2015). Henry, Messer, and Nash (2012) carried out a comprehensive battery of ten EF tests with children diagnosed with SLI. They found that children with SLI showed EF deficits on 6 out of the 10 assessments, and that these deficits persisted once adjustments were made of the children's language abilities. Areas of EF that were problematic for the SLI group were verbal and non-verbal ELWM; verbal and non-verbal fluency; non-verbal inhibition and non-verbal planning. Findings from this study have important implications for SLI interventions, which the authors conclude should tackle broader cognitive difficulties with EF skills (Henry, Messer, & Nash, 2012).

Specific profiles of EF dysfunction outlined in studies of children with different developmental disorders provide evidence of the dissociability of individual EFs. Studies such as these therefore provide support to Miyake et al.'s theoretical model of EF (outlined earlier in section 2.2) of unity and diversity of EFs. There is research which strongly suggests that deaf children, like other groups with patterns of atypical development, have different EF profiles, compared to typically developing hearing peers. The following section will outline recent studies that have investigated the EF profiles of deaf children and the current debates around the impact of deafness and/or language delay on EF skills.

## 2.6 Deafness and Executive Function

Deaf children, like other groups with atypical development, have been found to experience EF developmental delays, particularly in working memory and inhibition (Beer, Kronenberger, & Pisoni, 2011; Figueras, Edwards, & Langdon, 2008; Hintermair, 2013). There is still some debate as to whether this delay is a direct result of deafness (Pisoni & Cleary, 2003), or due to a language delay (Hall, Inge-Marie, Bortfeld, & Lillo-Martin, 2016). It has been suggested that early auditory processing "primes" the brain for processing sequential information (Conway, Pisoni, & Kronenberger, 2009). Conway et al. argue that sound, being a temporal and sequential signal to the brain, provides a "scaffold" for the development of cognitive abilities that are associated with temporal or sequential patterns, such as sequential memory. This "auditory scaffold hypothesis" is supported by studies which demonstrate adults' superior performance on tasks requiring sequential processing (when order and timing are important factors), when they have auditory patterns available to them. For example, it has been established that adults with normal hearing are able to recall sequences of auditory tones more accurately than sequences of flashing lights (Collier & Logan, 2000). Likewise, in tests of working memory ability, people tend to have better recall for words that are presented aurally than visually, i.e. spoken vs. written words (Penney, 1989). Findings such as these have led to the suggestion that time is coded more accurately for auditory events than for visual events (Glenberg & Jona, 1991).

Conway et al. (2011) argue that due to the role auditory processing plays in the development of general sequentially-related cognitive abilities, deafness is therefore likely to impact on the development of cognitive abilities relating to learning, recalling or producing sequential information. Findings from some studies support this hypothesis, where deaf participants have shown poorer performance on non-auditory tasks which require serial order recall (Marschark, 2006). There has also been some support for this theory from studies involving deaf children. For example, Conway et al. (2011) found that deaf children with cochlear implants performed poorly in relation to an age-matched hearing control group on a motor sequencing task. This finger tapping task required children to repetitively tap their fingers and/or thumbs in a sequence as fast as possible. Additionally, children were given a visual sequential learning task which required them to remember and reproduce the order in which coloured squares appeared on a computer screen. This task incorporated the potential for sequence learning, as the presentation of coloured squares was generated from a novel grammar system. Results from this study found deaf children adopted implicit sequence learning at a lower rate in comparison to their hearing peers (34% to 53%), and they also had significantly lower scores for the tasks. The authors state that these findings are an indication that early childhood deafness may impact children's non-auditory sequencing skills (Conway, et al., 2011).

However, other studies investigating the wider range of EF skills in deaf adults and children have reported mixed results. Several early studies relating to deaf children's EF concluded that deaf children were generally more impulsive than their hearing counterparts (e.g. Chess & Fernandez, 1980; Ouellette, 1988), a behavioural difference thought to be maintained into adulthood (Campbell & Douglas, 1972). However, with the advancement of research in deafness and EF over time, improvements have been made in the design of studies to include better controlled measures of inhibition (as opposed to reliance on personality testing and behaviour rating scales of the past), and, importantly, involving participant samples which are more representative of the deaf population, consisting of participants from both d/Deaf communities. Subsequently, a more recent study by Marschark and Everhart (1999) of hearing and deaf children across four age groups (from age 7 through to college age) found no significant differences in levels of impulsivity between groups, as measured by two behavioural tests; the Wisconsin Cart Sorting Test (WCST, Berg, 1948 – see chapter 3 for a full description of this task), and the Porteus Mazes task (Porteus, 1965). It should also be noted that an early study of impulsivity in the deaf population (Harris, 1978) made an important distinction between participants born to hearing parents (deaf-of-hearing) and those born to deaf parents (deaf-of-deaf). This study found lower rates of impulsivity amongst deaf-of-deaf participants in comparison to deaf-of-hearing participants, indicating that early environmental and linguistic experiences have a role to play in the development of inhibition (this will be explored further in section 2.7). In a later study, young deaf adults of hearing parents demonstrated a greater level of impulsivity during a continuous performance task (administered to assess an individual's ability to sustain attention) compared to a hearing control group. However, deaf-of-deaf participants did not display elevated impulsivity levels (Parasnis, Samar, & Berent, 2003).

In addition to studies of deaf individual's inhibitory skills, several studies have suggested that deaf individuals perform more poorly on working memory tasks in comparison to hearing individuals (e.g. Burkholder & Pisoni, 2003; Beer, Kronenberger, & Pisoni, 2011; Hintermair, 2013). However, in their study of D/deaf children's non-verbal working memory skills, Marshall, et al. (2015) point out that previous studies of working memory in deaf individuals were often conducted using tasks which were verbal as opposed to non-verbal, or with deaf children who use spoken language (and who therefore may have experienced impoverished language during early development, or a delay to their language development). Marshall et al. argue that by using non-verbal measures of working memory and including native BSL users in their study (who had been exposed to fluent language models from birth) the question of whether it is deafness or languge exposure behind the difference in hearing and deaf children's performance on working memory tasks can be tackled. They carried out a battery of language and non-verbal working memory tests with three groups of children (hearing children, deaf native BSL users and deaf non-native sign language users) aged between 6-11 years old. Their results found the non-native signers to have poorer performance on the working memory measures than the native BSL users and hearing group, whose performance was not significantly different from one another. The authors concluded that early exposure to fluent language models (regardless of modality) and subsequent good language skills play a critcal role in the development of non-verbal working memory, and may account for the findings of previous studies where deaf children's working memory skills have been found to be poorer than their hearing peers.

Studies of deaf children's academic achievement have reported that deaf students lag far behind the academic standard that is expected of hearing children (Allen, 1986; Anita, Jones, Reed, & Kreimeyer, 2009) and one American nationwide study found that half of all deaf children were performing at a below-basic proficiency level in mathematical problem solving and reading (Traxler, 2000). Whilst much of the discrepancy between deaf and hearing children's academic achievement is due to issues with language delay, communication and access to education, additional delays to deaf children's EF development may also play a role. Studies which have found Deaf children from Deaf families to have comparable EF skills to typically developing hearing children illustrate the apparent role that exposure to fluent language models plays in the development of EF. The following section addresses this issue further, and focuses on the relationship between language and EF.

## 2.7 Language and Executive Function

The relationship between language and cognition has long been of interest to psychologists and linguists (e.g. Vygotsky, 1978; Pinker, 1994). Introduced in section 2.4, Vygotsky distinguished between more basic and reflexive cognitive processes (such as attention and memory) and higher cognitive processes which include abstract thought and conscious, willful behaviour. Vygotsky argues that our uniqe linguistic system is a ‘tool’ which enables us to percieve and maipulate actions, objects and sitations mentally, thus enabling the formation of conceptual categories which form the basis of rational thought (Vygotsky, 1986). Vygotsky and his protégé, Luria, asserted that children engage in “private speech”, essentailly, speaking to themselves, which serves as a tool used for planning and organising oneself (Vygotsky & Luria, 1994). As children mature, “private speech” becomes internalised and children are able to utilise “inner speech” for self-regualtion and problem solving.

The role that language and inner speech play in EF skills was reviewed by Cragg and Nation (2010), in their overview of studies investigating cognitive flexibility through task switching. They found a strong developmental association between inner speech and cogntive flexibility in children, with children’s inner speech initally acting as a ‘commentary’ on tasks they are currently undertaking, but gradually evolving to include the formulation of plans and devising strategies before engaging in a task. Cragg and Nation (2010) also highlight the role that inner speech plays throughout childhood, adolescence and into adulthood, citing studies which utilse articulatory suppression (e.g. Miyake, Emerson, Padilla, & Ahn, 2004) as examples of how inability to use inner speech interferes with particpants’ performance on tasks involving swithching and planning. This is in line with previous articulatory suppression studies which have found adolecents’ and adults’ performance on memory tasks to be reliant on verbal strategies and inner speech (e.g. Hitch, et al., 1983).

However, fewer studies have investigated a link between inner speech, language, and inhibitory skill. Kray, Kipp and Karbach, (2009) used a Go/No-Go task (a task commonly used to measure sustained attention and inhibitory responses, whereby particpants have to physically respond to a stimulus -"Go", or inhibit their active response – "No-go"); in order to investigate the impact of language on performance. They found that when participants verbally labeled the stimuli they were presented with (but *not* the required action, i.e. stop or go), their performance improved. Younger particpants aged between seven and nine showed a stronger effect of this strategy than adult participants, which the authors conclude suggests language has an indirect effect on the ability to effectively inhibit responses, primarily by way of strengthening the mental representation of task stimuli. Fatzer and Roebers, (2013) also investigated the impact of using verbal strategies on three EF tasks - a complex span task, cognitive flexibility task, and an inhibition task – with three groups of children aged four, six and nine. They found a significant improvement on children's performance on the complex span and cognitive flexibility tasks, but no significant improvement was found for the inhibition task. The authors noted that these findings demonstrate the different ways in which language is related to specific EFs. As with Kray, Kipp and Karbach's study, Fatzer and Roebers also noted a decline in the effect of verbal strategies with the increasing age of the children, which is indicative of their increasing ability to self-initiate spontaneous verbal strategies as they develop.

Whilst it is evident that language and EF develop in tandem, the directional influence of language on EF or EF on language is still strongly debated. Some longitudinal studies have charted the relationship between language proficiency and EF in preschool aged children in an attempt to unpack this complex relationship. Weiland, Barata and Yoshikawa, (2014) found that the EF ability of 4 year olds (as determined by their performance on tasks involving inhibition, working memory and switching) predicted their receptive vocabulary scores at the age of 5. However, there was no correlation between their receptive vocabulary scores at the age of 4 and their EF skills at the age of 5. Their findings suggest that children's EF skills support the growth of their receptive vocabulary and, at least in the preschool years, it is EF that primarily supports language development and not vice versa. However findings from other studies suggest that the relationship between language and EF is not so clear-cut. Fuhs and Day, (2011) conducted a battery of EF and verbal language tests with 4 year old pre-schoolers at the start and end of a eight month "head-start" programme. They found the children's verbal ability at the start of the program to be a significant predictor of their EF skills at the end, however they did not find that EF predicted language ability. The opposing findings between these two studies suggests that the relationship between EF and receptive language is likely to be different to that of EF and expressive language, as Weiland, Barata and Yokinawa (2014) focused on receptive language skills, while Fuhs and Day (2011) assessed children's productive language. Another longitudinal study conducted by Gooch, Thompson, Nash, Snowling, and Hulme, (2016), discovered a strong concurrent relationship between language and EF. They followed the EF and language development by carrying out assessments with a group of 243 children every year between the ages of 4 and 7. Despite identifying a strong relationship between language and executive skills and considerable longitudinal stability in their development, the authors found little evidence for either skill predicting future ability in the other. However, they also found children's executive function skills (but not their language skills) to be longitudinal predictors of attention and behaviour.

Other studies have looked at the impact of EF skill on literacy, specifically in reading comprehension. Some studies have found executive-loaded working memory ability in particular to impact on reading comprehension (e.g. Cain, Oakhill, & Bryant, 2004), and others, such as Jerman, Reynolds, & Swanson (2012), who studied the relationship between EF, reading and maths skills in a groups of children with reading disabilities; concluded that development of EFs underlies performance in reading and maths.

The association between language skill and EFs is well documented and associations between bilingualism and enhanced executive control have been extensively researched. Being able to communicate fluently in more than one language from a young age has been found to enhance executive control in many studies covering different age groups. From children (Carlson & Meltzoff, 2008), to adults (Bialystok, 2006; Colzato, et al., 2008) and older adults (Bialystok, Craik, & Ryan, 2006), studies have found that bilinguals who utilise both languages on a regular basis demonstrate enhanced executive control, particularly in terms of cognitive flexibility and inhibitory skill compared to monolinguals. While the precise cause of this bilingual EF advantage is unclear, it has been suggested that it is due to bilinguals having to manage and switch attentional control between two simultaneously active language systems and inhibit one language whilst utilising the other (Bialystok & DePape, 2009; Abutalebi & Green, 2007).

## 2.8 Training Executive Function Skills

With such a broad spectrum of cognitive processes being reliant on EF it is unsurprising that research attention has turned, in recent years, to the investigation of various activities with potential to enhance EF skills in different populations. Advances in neuroscience over the past two decades have altered perceptions about the brain's capacity to adapt and change. While it was previously thought that cognitive capabilities and organisation changed very little after early childhood, many studies have now shown that not only can the brain change in terms of neuronal activity, connection and cognitive capability, but these changes are possible throughout an individual's lifespan (Rabipour & Raz, 2012). This ability for adaptation due to environmental influences and experiences is known as 'plasticity'. Neuroscientific research into brain plasticity has had strong implications for EF research, with many studies focusing on activities with the potential to improve EF skills from childhood through to old age (e.g. Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Smith, et al., 2009) From computerised training (Klingberg T. , et al., 2005) to aerobic exercise (Hillman, Erickson, & Kramer, 2008), martial arts and mindfulness (Flook, et al., 2010) to classroom curricula such as Montessori (Montessori, 1949) and Tools of the Mind (Bodrova & Leong, 2007), many activities and programmes have been studied with a view to them being potential keys to EF enhancement. The following sub-sections will review the literature on EF interventions, including; the key elements necessary for successful EF training; interventions using computer training programmes; curriculum based intervention programmes; and finally an overview of general activities found to be beneficial to the development of EF skills.

### 2.8.1 Successful training of EF skills

Various diverse activities have been found to have a positive impact on children and adult's EF skills. The variety of intervention types encompass not only different activities (such as sport, mindfulness, meditation or music), but also class-based school interventions, strategies tailored to individuals, and both computerised and non-computerised EF loaded training games. Whilst the types of interventions available for training EF are wide and varied, all successful interventions have four key characteristics in common with each other.

The first characteristic relates to a concept considered to be central to the notion of training or improving EF in children, that of the 'zone of proximal development' (ZPD). This comes from Vygotsky's studies of cognitive development, and his investigation of the relationship between teaching/learning and development (Vygotsky, 1978). Vygotsky was concerned with the transition from 'maturing' to 'matured' cognitive processes. The ZPD relates to tasks that a child cannot yet master independently, but can accomplish with the help of others. It is therefore considered to have two levels – the *actual* developmental level of the child (that which they can achieve independently), and the level of *potential* development (where tasks can be achieved with the help of others). Another concept closely linked to the ZPD is 'scaffolding'. Scaffolding refers to the support mechanism employed to help a child successfully complete a task or challenge (Wood, Bruner, & Ross, 1978). An adult or more advanced peer may model a behaviour or action, or work through a problem so that the child can observe and follow them. Alternatively, they may provide a 'scaffold' for the child by offering suggestions and/or guidance as the child carries out the task. These two concepts must be considered during the design and implementation of EF interventions, as previous research has shown that challenges to EF which fall within the level of potential development within a child's ZPD are the most effective at improving EF skill. Tasks that the child can complete with ease do not train or develop EFs (Diamond, 2012), and so the hallmark of a successful EF intervention is one that continuously challenges the child within the boundaries of their ZPD.

The second characteristic of successful interventions is that they contain an element of repetition and practice. Tasks which are repetitious, and contain a challenging element, enable children to strengthen and develop their skills. Associated with this is the amount of time children dedicate themselves to the task (Klingberg et al., 2005). Mastering any complex skill requires dedication to repeated practice (Ericsson, Nandagopal, & Roring, 2009) and frequent exposure to a task helps to improve EF skills as a function of experience.

A third important characteristic of a successful intervention is that the participants are engaged and motivated to take part in the activity (Diamond, 2006). This point is again linked to Vygotsky's ZPD, as it is important to ensure that an activity has the potential to become more challenging as children improve, otherwise few gains in EF will be seen (Bergman-Nutley et al., 2011) and children will begin to find the task boring and lose their motivation to continue. By their nature, EFs require effortful, goal-oriented motivation, and without this no improvements to EF skills can be expected. Children need to be motivated and encouraged in order to push themselves to do better. Diamond (2012) suggests that *"The most important element of a program might be that it involves an activity children love, so they will devote intensive time and effort to it…an enthusiastic, charismatic adult can often engender passionate interest in children…one can be joyful even when working hard"* (p.338). Therefore, it may not only be the type of activity that plays a role in training EFs, but additionally the way in which it is delivered may also impact its success. Intervention activities that are engaging, fun and children do not regard to be 'work' are more likely to be successful.

The fourth characteristic of successful EF interventions is that they require the child to reflect on their actions and suppress any automatic impulse to respond immediately. Encouraging discipline and self-control will enable children to develop the ability to pause and consider the best way to address a problem or, depending on the activity, resist reacting immediately without taking time to processes the task (Diamond & Lee, 2011). These four general principles for successful EF training are relevant to all types of intervention. It is important to note that, as yet, very little research has looked a 'how much' training is required to impact on a child's EF skills. While it is generally accepted and logical that the longer a child is engaged in an intervention programme, the more likely it is that EF improvements will be seen, there is no consensus on the optimal duration or frequency of EF interventions, or how these factors vary according to the child's age or the type of intervention/activity. The following sections will consider the various different types of EF interventions and their respective success and limitations.

### 2.8.2 Computerised Executive Function Interventions

An EF intervention which has been extensively studied is the Cogmed computerised working memory training program (Klingberg et al., 2005). Originally developed by Klingberg and colleagues in 2005 to help improve attention and working memory skills in children with ADHD, the programme consists of a series of computer games that successively increase demands on the player's working memory. As children complete each 'level', the tasks become increasingly challenging. It is also suitable for use with adults (Pearson Assessments, 2016). Evaluation of Cogmed's impact on working memory skills has been carried out in studies involving children with ADHD (Klingberg et al., 2005), poor working memory (Holmes, Gathercole, & Dunning, 2009) and with typically developing children (Thorell, Lindqvist, Bergman-Nutley, Bohlin, & Kingberg, 2009) where it has been found to have a positive effect on children's working memory skills, for tasks closely related to the training.

Thorell et al. (2009) investigated the training and transfer effects of EF in preschool children who received 5 weeks of Cogmed training in either visuospatial working memory or inhibition. The inclusion of both an active control group (who played commercial video games for the same duration), and a passive control group (who only took part in the pre and post testing stages of the study), provided strength to the study design, the omission of which is often a limitation of other intervention studies. The authors found that children who completed 5 weeks of working memory training showed a statistically significant improvement on tasks they had been trained in, and also on untrained spatial and verbal working memory tasks. Children who were included in the control groups did not show such gains. The children who received training on inhibitory skills showed improvement on two out of three of the trained tasks. However, this group showed no significant improvement on working memory or attention tasks in relation to the two control groups. Thorell et al. posit that the difference in effect of the two types of intervention may indicate that individual EFs differ in how easily they can be trained, suggesting fundamental differences in their underlying psychological and neural processes. This important point is discussed further in chapter 8 of this thesis.

Bergman-Nutley, et al. (2011) carried out a randomised control trial involving multiple computerised training tasks with groups of 4 year old children. One group of children received Cogmed training, another group were trained in non-verbal reasoning, and a third group receieved a combination of both training programmes. A fouth group were included as an active control, who were also given a combination of both training programmes, but the difficulty of the tasks did not increase with time and remained on the easiest level. Results of the study found improvement in the experimental groups on practised skills in comparison to the control group. The two groups that received training in solely working memory or non-verbal reasoning improved more on their respective tasks than the group who received a combination of training. While the group who received the combination training also made gains in working memory and non-verbal reasoning, these were considerably smaller than the other two experimental groups, as they had received less practice on each. However, EF gains in this study were 'narrow' and did not transfer to skills other than those specifically trained. For example, non-verbal working memory training improved children's performance on other untrained non-verbal working memory tasks, but not to measures of verbal working memory.

While there have been a considerable number of studies conducted to evaluate Cogmed's potential for use as a viable intervention to be marketed at schools and individuals, some controversy surrounding its potential usefulness and efficacy remains (Morrison & Chein, 2012). Although many studies that have been carried out, similar to those detailed here, have highlighted Cogmed's potential benefits, other studies have failed to reproduce previous findings, such as the evidence that Cogmed training can result in positive enhancement to other cogntive abilities like fluid reasoning (Holmes, Gathercole, & Dunning, 2009). Shipstead, Hicks, and Engle (2012) presented a detailed evaluation of a large number of studies that tested Cogmed, and reported on its successes and limitations. They point out that, while there has been some very promising research done using this intervention tool, caution must be taken when considering its real-life application. Participants spend many hours in training, which is perhaps a cost not worth the rather limited benefit, as Shipstead et al. (2012) remark that *"the only unequivocal statement that can be made is that Cogmed will improve performance in tasks that resemble Cogmed training"* (p.19).

This has also been a criticism of other commercially available computerised EF training programmes. In recent years, the popularity of "brain training" games and mobile apps claiming to improve memory and concentration has risen dramatically. Online and computerised “brain training” has evloved from laboratory based research into a billion dollar industry with projected revenues of over $6 billion by 2020 (SharpBrains, 2013). Boot and Kramer (2014) also note that, apart from increasing popularity within the general population, some health-insurance companies in the United States have made brain training products available to their clients; an endorsement which encourages belief in their effectiveness (Boot & Kramer, 2014). There is substantial evidence to support the claim that brain training games have the ability to improve EFs, particularly in the elderly. For example, Nouchi, et al., (2012) found the the game ‘Brain Age’ (Nintendo, 2005) improved EF and processing speed in elderly participants after 4 weeks of spending 15 minutes per day playing the games. Likewise, studies with younger participants have also found benefits to computerised EF training, particularly for working memory skills (e.g. Au, et al., 2015). However, a question that still remains unanswered is the extent to which these improvements transfer to meaningful everyday activities. Boot and Kramer (2014) call attention to some critical issues related to computerised EF training that need to be addressed before any clear claims can be made about their effectiveness. One key issue is that of methodological rigour and replication. More research is needed with appropriate active control groups and larger groups of participants in order to establish the strength of any training effect transfering to EF skills. Another issue relates to the comparative effectivness of computerised EF interventions; how outcomes of different EF programmes compare to each other, and with other cognitively beneficial activties, such as exercise.

### 2.8.3 Curriculum-based Executive Function Intervention Programmes

Recently, many studies have debated the potential for neuroscientific findings to inform education and teaching practice. Some believe that scientific practices and lab-based findings have such low ecological validity that they cannot yet effectively inform practice in a classroom context (Hirsh-Pasek & Bruer, 2007). However, research into the underlying physiological processes driving conditions such as ADHD or dyslexia has aided in the accuracy of their diagnosis and, subsequently, successful early intervention (e.g. Goswami, 2009). Psychologists collaborate with neuroscientists in order to validate behavioural interventions and help ‘complete the puzzle’ of cognitive development (Diamond & Amso, 2008). In this context, it is clear that teachers and other educational professionals have a vital role in the implementation of interventions and observation of children's development, so there are now calls for closer collaboration and knowledge exchange between neuroscientists, psychologists and educators (Dubinsky, 2010).

There are a number of EF intervention programmes that have been specifically developed for use with preschool and primary school aged children. Given the importance of EF skills for school readiness and learning (outlined earlier in section 2.4), this section will briefly describe some established EF interventions designed to be supplementary to school curriculums and their various strengths and limitations.

**Providing Alternative Thinking Strategies (PATHS) (Kusche & Greenberg, 1994)**

One of the most well-known EF intervention programmes for the past 30 years, the PATHS programme is designed as a whole-school emotional literacy programme to be used with primary school aged children. It aims to develop children's skills in five key areas: self-awareness, managing feelings, motivation, empathy and social skills. It has been used with typically developing children, children with special educational needs, and also with deaf children (Greenberg & Kusche, 1993). The programme focuses on improving different elements of self -control, by helping children to recognise, understand and process their emotions. The PATHS programme is based on the ABCD (Affective-Behaviour-Cognitive-Dynamic) model by Greenberg and Kusche (1993), which postulates that children's development and ability to cope with new demands and challenges is a function of their emotional awareness, affective cognitive control and social-cognitive understanding. The programme consists of four goals for children to achieve in order to improve their problem-solving skills. The first goal is to "stop and think", as a response to any situation which may require novel problem solving skills. This encourages children to take time to reflect on the situation and their response to it, and to use 'self-talk' or verbal talk to help enable self-regulation. The second goal of the programme is to equip children with the appropriate linguistic skills and labels for emotional states to enable them to express themselves and mediate their understanding of themselves and others. Often, children who struggle with self-regulation and present difficulties with cognitive control lack the necessary linguistic and communicative skills for interpersonal problem-solving (Greenberg & Kusche, 1998). The PATHS programme aims to explicitly teach children these skills. Closely linked to this is the third goal of the programme, which is to help children to understand the connection between their emotions and cognitive states. Children are given a variety of experiences in which they are guided in integrating emotional understanding with their cognitive and linguistic skills in order to problem-solve. In short, children are taught that their emotions and feelings are signals which contain useful information for helping them to decide what to do next. The fourth goal is to encourage children to apply these skills (self-control, emotional understanding and problem-solving) independently to other contexts outside of the classroom such as in the playground, lunchroom and at home.

The PATHS curriculum includes six volumes of lessons, divided into three units: 1) the ‘Readiness and Self-control unit’, 2) the ‘Feelings and Relationships’ unit, and 3) the ‘Problem-solving’ unit. Each unit contains developmentally sequenced lessons, which build on previous learning, a key element being the reinforcement of how lessons and skills can be generalised to everyday life. Additionally, each day a different child is chosen to be the ‘PATHS child for the day’ which means they will have extra responsibilities, helping the teacher during PATHS lessons and receiving feedback and compliments from the teacher and classmates.

Several studies have looked at the effectiveness of the PATHS programme (e.g. Riggs, Greenberg, Kusche, & Pentz, 2006). One of the earliest studies found a significant improvement in children’s emotional vocabulary, tolerance, social skills and peer relationships, in comparison to a control group (Greenberg M. , Kusche, Cooke, & Quamma, 1995). A large-scale study evaluating the PATHS programme (Curtis & Norgate, 2007) found a significant improvement on all five skills sets (self-awareness, managing feelings, motivation, empathy and social skills) for children in schools who took part in the intervention, but not in children from control schools who did not take part. They used the Strengths and Difficulties Questionnaire (SDQ, Goodman, 1997), completed by class teachers, in order to evalute the impact of the intervention, and conducted additional teacher interviews to review perceived effectiveness and gain practioner feedback. Teachers felt that the programme helped children to improve their understanding of emotions, supported the self-control skills and made them more empathetic towards others. Whilst interpretation of the findings of this study are limited (as it only relied on one self-report questionnaire measure, which may be open to observer bias), the results indicate that, overall, PATHS may be a very useful tool in developing children's interpersonal problem-solving skills.

**Tools of the Mind (Bodrova & Leong, 2007)**

The 'Tools of the Mind' (Tools) curriculum was developed by Bodrova and Leong and is based on theories of children's cognitive development put forward by Luria (1966) and his predecessor Vygotsky (1978), as described earlier in section 2.4. It is an early intervention programme, aimed at children in preschool and kindergarten years and focuses on promoting self-regulatory skills in children through a variety of different activities. The programme utilises Vygotskian theory about how children think and learn and is designed to *"help teachers be more effective in identifying teachable moments, assessing children's development and differentiating instruction"… "the concept of tools of the mind came from Vygotsky who believed that just as physical tools extend out physical abilities, mental tools extend out mental abilities, enabling us to solve problems and create solutions"* (Bodrova & Leong, 2007, Tools of the Mind webpage).

There are two main emphases in the 'Tools' curriculum. The first is the view that EF skills are fundamentally foundational skills that can be developed through improving children's ability to regulate their own emotional, social and cognitive behaviour, and to hone their attentional skills while learning to 'remember on purpose' (Leong & Hensen, 2003). Secondly, emphasis is put on the key prerequisites to literacy skills (such as phonemic awareness, knowledge of letters, familiarity with print etc.), and also mathematical skills (such as recognising patterns and counting meaningfully). The activities that are designed to improve prerequisite skills of literacy and maths also require self-regulatory skills (Bodrova & Leong, 2007). The programme consists of forty activities which are used by teachers to encourage self-regulatory speech, improve attention and memory and encourage 'mature dramatic play' (Vygotsky, 1978). Play is extremely important in the programme and is seen as a key source of self-regulation, promoting further EF development. Teachers encourage 'mature play' (which is a more planned process than simply 'letting children play') that involves specific interactions and pretend scenarios which are complex, sustained and involve multiple roles (Barnett, et al., 2008).

‘Tools’ shares similarities with the PATHS programme in that it promotes self-regulation and social problem solving skills. However, it is differentiated from PATHS and other curriculum add-ons by the way in which it specifically addresses the theory that academic achievement and learning is hindered if children lack the necessary level of cognitive control required for many academic activities. An example of one of the ‘Tools’ curriculum activities is the “Buddy Reading” system, where children read books to each other in pairs. Each child is given a picture of either a mouth or an ear. Those with the mouth picture choose a book and read it to their partner, turning the pages and pointing to pictures as they read. The children who have a picture of an ear listen to the story and wait until it is finished for their turn to become the reader, when the children switch pictures and roles with each other. The pictures serve as a ‘tool’ to remind the preschool children of their role and help them to regulate their behaviour. After a while, the children are able to self-regulate and maintain their respective roles without the need for external reminders, so the cards are phased out by the teacher (Bodrova & Leong, 2007).

Quasi-experimental pilot studies found evidence of the ‘Tools’ curriculum’s effectiveness, and the programme was named as an “exemplary educational intervention” by the International Bureau of Education, a UNESCO program, in 2001 (Bodrova & Leong, 2001). However, further evaluations of the curriculum’s effectiveness have been carried out by researchers unrelated to its development, and these have yielded varying results. A notable study that supported the programme’s effectiveness was carried out by Barnett et al. (2008). The group carried out a study using a randomized trial whereby preschool children were assigned to either the ‘Tools’ programme, or an active control condition. 88 children were assigned to receive the ‘Tools’ curriculum, while 122 children took part in an active control condition which consisted of a preschool curriculum purposefully created by the local school district that the study took place in, described as a “balanced literacy curriculum with themes”. Barnett et al. found that the ‘Tools’ curriculum improved classroom quality and children’s EF, above improvements seen in the control group. The ‘tools’ programme also improved children’s classroom experience and social development (as determined by a rating scale), and additionally and importantly demonstrated that it is possible to explicitly teach self-regulation skills to preschool children.

Wilson & Farran (2012) are currently carrying out a longitudinal evaluation of the ‘Tools’ curriculum. The careful and strong design of this randomised control trial will add weight to the evaluation as it aims to answer three key questions: 1) Do children in ‘Tools’ classrooms show greater improvement in language, literacy, maths and social skills during the preschool years in comparison to children in regualr classrooms?; 2) Do children in ‘Tools’ classrooms show greater gains in self-regulatory skills than children in regular classrooms?, and; 3) Are there differential effects for ‘Tools’ associated with characteristics of the children? The study is taking place in Tennessee and North Carolina in the USA and invovles 455 preschool aged children in ‘Tools’ classrooms and 359 children in regaular comparison classrooms. Their assessments include Woodcock-Johnson tests of achievement to measure literacy, language and mathematics, and a range of EF tasks such a visuospatial span task for working memory (described in section 7.2.1), peg tapping and the ‘Head-toes-knees-shoulders’ game for assessing inhibitory control. Attentional skills are being assessed using a design copy task and the Dimensional Change Card Sort task. Additionally, classroom observations are being made using a ‘fidelity of curriculum implementation’ measure which was created in conjunction with the ‘Tools’ curriculum developers. This provides the researchers with more data regarding the number and timing of ‘Tools’ activities carried out throughout the day. They are also collecting ratings of each teacher’s curriculum delivery, made by curriculum trainers, coaches and classroom observers in order to control for individual differences in the administration of he curriculum. The study is ongoing, however after the first year of implementation no signifciant effects of ‘Tools’ were found for literacy, language or mathematics gains in comparison to children in a regular classroom setting. There were also no significant effects found between the two groups of children on improvements in self-regulatory control (EF). Wilson & Farran (2012) note that this finding is particularly surprising given the extensive scaffolding and training of self-regulatory behaviours in the ‘Tools’ programme, and futher add that while their study had thus far found no evidence that ‘Tools’ was preferential to a typical preschool classroom, it was in no way detrimental to preschool children’s performance. However, findings from this study have described the EF benefits of ‘Tools’ to be “lacklustre” (Wilson &

Farran, 2012), and the overall benefit of adopting this particular preschool training programme is currently under debate.

The PATHS programme and Tools of the Mind are two of the more common curriculum-based EF interventions, but there are many others available which share similarities and differences. A technique that was favoured in some schools in the early 1990s was “Brain Gym” (Dennison & Dennison, 1994). This is a focused intervention which aims to improve a person’s concentration, memory, co-ordination, organisational skills, attitude and relationships. The organisation that runs the courses and promotes the programme was founded in 1987 under the name ‘Educational Kinesiology Foundation’. The programme is aimed at both children and adults and centres around activities based on 26 core movements, claimed to be those that are *“naturally done during the first years of life when learning to co-ordinate the eyes, ears, hands and whole body”*. Brain Gym is extremely controversial as there is a lack of significant evidence that it is effective (this will be discussed in further detail in Chapter 4, section 4.4.4 of this thesis).

A final and important point to note regarding curriculum interventions is that the majority of them have been designed for use with young children and are usually presented as preschool programmes. In her review of programmes and activities found to improve children’s EF, Diamond (2012) notes that none of the main EF curriculum interventions (such as the two outlined here) have been shown to improve EFs in children beyond the age of 9 years old. There are some recently available EF interventions which also cater for older children (such as the ‘Mind Up’ programme (The Hawn Foundation, 2011), described in section 5.3). However substantial evidence of their effectiveness is yet to be shown.

### 2.8.4 Common activities shown to be beneficial to EF development

Purposefully created EF interventions are by no means the only activities that are found to improve children’s EF skill. There are many studies which have indicated that physical exercise can robustly improve EFs (e.g. Hillman, Erickson, & Kramer, 2008; Hillman et al., 2004; Chaddock, Pontifex, Hillman, & Kramer, 2011). However, the majority of these studies have been carried out with adults. Nevertheless, a few EF studies in which children exercised over an extended period of time discovered improvments to their EF; although the effects were not very strong (e.g. Tuckman & Hinkle, 1986; Kamijo, et al., 2011). More substantial effects on children's EFs have been found in physical activities which involve both exercise and an element of character development or mindfulness, such as activities which emphasise discipline and self control, like martial arts or yoga (Diamond, 2012).

A study which provides strong evidence for the impact of martial arts on EF was carried out by Lakes and Hoyt (2004), where children aged between 5 and 11 years old were randomly assigned to do tae kwon do or regular physical education classes. They found that children who had taken part in the tae kwon do classes had greater gains in working memory and inhibitory control than the children who had taken part in the regular physical education classes. Similarly, Manjunath and Telles (2001), investigated the impact of yoga on the EF skills of teenaged girls. Yoga involves both physical training and flexibility with relaxation, mindfulness and focus. The children in the study were randomly assigned to either regular physical exericise training or to a yoga class for an intensive course of 75 minutes everyday for one month. The study found that those who had taken part in the yoga sessions showed superior performance on the Tower of London Task (described here in section 6.2.4) to those who had been assigned the control physical education condition. This effect was particularly seen in the more complex task conditions. One key importance to these findings is the generalisability of the effects, as the impact of the activities appears to transfer to previously untrained tasks.

It is clear from studies looking at computerised training, curriculum interventions and studies involving physical exercise that focusing narrowly on training individual EFs themselves tends to have small and only near transfer effects on EF skills. Activities, games and curricula which are more broad-based in design and also include opportunities for emotional and social development, and reflection appear to be more likely to yield greater EF gains. Diamond (2012) has hypothesised that programmes which will prove to be the most successful in improving EF skills in children are those which will continually challenge them, but additionally bring them joy and pride in their progress, along with a sense of social inclusion and belonging.

This review has focused on key interventions available for children. However, there are a wide variety of programmes and training studies which have demonstrated considerable cognitive plasticity in different populations (See Diamond, 2012; Titz & Karbach, 2014; and Verhaeghen, 2014 for recent reviews). Despite encouraging findings from a range of cognitive training interventions which cover the lifespan from infancy to old age, transfer effects are not consistent across studies. This has caused many to debate the efficacy of (sometimes lengthy) interventions (e.g. Melby-Lervag & Hulme, 2013; Redick, et al., 2013). However, a lack of consistent findings across studies may be explained by the corresponding variation in methodologies, duration and type of interventions used, and how intensively they are administered. It should also be noted that, to date, the majority of systematic reviews of EF training studies have focused on children of preschool age (e.g. Zelazo & Lyons, 2012), with little consistent research interest in EF training in middle childhood through to adolescence. In their review of EF training concerning these age groups, Karbach and Unger (2014) highlight the contribution that such studies would make in terms of determining the underlying cognitive mechanisms involved in brain plasticity and EF development.

In their review of interventions shown to aid executive function development in young children, Diamond and Lee (2011) emphasise that many different activities have the potential to enhance executive functions, providing the activity is practiced regularly, is sufficiently challenging, and one is willing and motivated to devote time to it (Diamond & Lee, 2011). As research in this area progresses, further studies are likely to investigate many other activities which have the potential to improve EFs, such as playing chess, acting or rock climbing. However, one such activity that has been investigated for its apparently beneficial effect on EFs is musical training. The following section will review the literature on the relationship between music and EF and studies which have investigated musical training as a resource for EF training.

## 2.9 Music and Executive Function

The production of music is highly intricate and complex, requiring the integration and rapid processing of auditory, visual, motor and memory processes (Moreno & Bidelman, 2014). Zatorre (2005) illustrates this complexity with the example of humming a familiar tune, a seemingly simple activity, which requires complex auditory pattern-processing mechanisms, attention, memory storage and retrieval, motor programming, and sensory motor integration amongst others: *"Playing, listening to and creating music… involves a tantalizing mix of practically every human cognitive function." (Zatorre, 2005, p312)*

From a neuroscientific perspective, musicianship provides a powerful tool for studying experience-dependent neuroplasticity as music training encompasses many of the requirements for inducing plasticity, such as repetition and intensity of practice alongside strong motivational and emotional reward (Wilson, 2013).

The way in which music is processed in the brain has also been of interest to researchers (Peretz, 2006). Whilst some studies provide evidence for a degree of brain specialisation for music even in the absence of any kind of musical training (Bigand & Poulin-Charronnat, 2006), others have searched for links between music cognition and other cognitive processes. One of the major findings from this avenue of research is the discovery of strong links between music and language processing in the brain (Patel, 2008). An increasing number of studies are finding that music training has positive outcomes for language skills. As Patel, (2009) notes, musical abilities have been found to predict: one's ability to accurately perceive and produce subtle phonetic contrasts in a second language (Slevc & Miyake, 2006), the reading abilities of young children (Anvari, Trainor, Woodside, & Levy, 2002), and the ability to interpret affective prosody (Thompson, Schellenberg, & Husain, 2004).

### 2.9.1 Studies with long-term musicians

Findings such as this led researchers to consider other experiences that may yield similar enhancement to EF skills. Bialystok and Depape (2009) compared the performance of bilinguals and monolinguals to those of musicians on EF tasks involving inhibition and attentional control. The authors considered musical expertise as a potential experience that would impact cognition as it involves extensive repeated practice and *"demands high levels of control through the need for selective attention and inhibition, switching, and updating and monitoring"* (Bialystok & Depape, 2009 p566).

Bialystok and Depape (2009) compared the performance of monolingual English speakers, bilinguals and monolingual musicians (who played a variety of different instruments) on two different executive function tasks involving conflict (i.e. a task where participants are required to respond to one element of a stimulus, while inhibiting their response to another). One of the notable findings regarding the effects of bilingualism on cognition is that it enhances skills that are far removed from language. In order to investigate potential near and far transfer benefits of musical expertise, Bialystok and Depape (2009) designed two computerised executive function tasks intending to measure domain general skills (with a classic Simon arrows task) and domain specific skills (with an auditory stroop task). The Simon task used in the study was a purely spatial task, with no connection to either linguistic or musical experience. Participants had to judge the direction of an arrow displayed on a computer screen irrespective of its location on the screen. In another condition, participants needed to respond to the location of the arrow on the screen, irrespective of the direction in which the arrow was pointing. The auditory stroop task had two conditions: a pitch control condition whereby participants simply had to indicate whether the pitch of a sung note was either high or low, and a word-conflict condition where the words “High” or “Low” were sung at a pitch that either matched the word, or was incongruent with the word.

Bialystok and Depape (2009) found that both bilinguals and musicians outperformed the monolinguals on the Simon task, however musicians demonstrated better performance on the auditory stroop task than both the bilingual and monolingual groups. The findings provide evidence of the impact of extensive musical experience on the enhancement of executive control, in both domain- specific tasks (as in the auditory stroop), and also domain-general effects in tasks that bear no obvious relationship with music.

Building on this research into musicianship and EF skills, a study of older professional musicians (Amer, Kalender, Hasher, Trehub, & Wong, 2013) sought to investigate whether long-term musical training was associated with enhancement of cognitive abilities including some EF skills. They tested 18 professional musicians and 24 non-musicians (with mean ages of 59 and 60 years respectively) on near and far transfer tasks. The near transfer tasks assessed speed of auditory processing and auditory conflict resolution in an auditory stroop task, similar to the one used by Bialystok and Depape (2009). The far transfer tasks assessed cognitive control (with a

Simon task), response inhibition (Go/No Go task) and control over distraction (Reading with Distraction task). Musicians in the study outperformed the non-musicians on the auditory conflict task and, on the far transfer tasks, they performed significantly better than non-musicians on a visuospatial span test, the Simon task and control over irrelevant information when reading aloud. The only task in which there was no difference between groups was in the Go/No go task. The authors acknowledge this as a surprising result given the musicians' enhanced performance on the other tasks, and suggest that it may be attributable to the close to ceiling performance by both groups on the Go/No Go task.

### 2.9.2 Studies with experimental groups

Whilst Amer et al.'s (2013) study provides evidence of a strong correlation between musical expertise and enhanced EF skills in older musicians, it cannot claim a causal link between music training and EF. Potential pre-existing differences in executive control between the two groups, prior to the commencement of the musicians' training is one of many factors that prohibits claims of any causal link. However, other studies implementing short-term music interventions have addressed this issue and have provided some evidence of a causal link. For example, Bugos and colleagues (Bugos, Peristein, McCrae, Brophy, & Bedenbaugh, 2007) randomly assigned 31 "musically naïve" older adults (aged between 60-85 years old) to either an experimental group or control group. The experimental group received six months of individual piano instruction consisting of three hours of lessons every week. They assessed all of the participants pre-training, after the six-month intervention period and again after three months using neuropsychological tests from the Weschler Adult Intelligence Scale (Wechsler D. , 1997) including tests of overall cognitive and musical ability, working memory and executive functions.

Their results showed a steady improvement on the "Trail Making Task" – a test of cognitive flexibility – for the experimental group. The experimental group also outperformed the control group on the digit span task, indicating a possible enhancement of perceptual speed, visual scanning and memory. However this effect was not sustained when the lessons were discontinued. Overall, significant improvements in planning, working memory and processing speed were found in the experimental group. This study provides some evidence of musical instruction having a demonstrable effect on cognitive flexibility in particular. However, one of the limitations of the design is the lack of an active control group. Without the control group engaging in an activity of comparable novelty and duration a general effect of individual attention given to each member of the experimental group cannot be ruled out.

The lack of adequate active controls in intervention studies has been an ongoing limitation of this type of study design (discussed in (Schellenberg, 2006). Over the past forty years, there have been many studies investigating the non-musical benefits of music instruction but these studies have been limited by a lack of active control group. For example, Hurwitz et al.'s (1975) study examined the impact of music instruction (using the Kodály method) on young children's cognitive abilities, specifically their sequencing, spatial skills and reading ability (Hurwitz, Wolff, Bortnick, & Kokas, 1975). The Kodály method focuses on the development of rhythm and sequencing, with concepts being constantly reinforced through different games, songs, hand movements and exercises. Hurwitz and colleagues assigned six and seven year olds to one of two groups - the experimental group, who received Kodály music lessons for five days each week for seven months, or the control group, who received no extra instruction. Children were tested using a variety of sequencing and spatial tasks, as well as two tasks measuring general verbal intelligence. The experimental group scored significantly higher than the control group on three of the five sequencing tasks and four of the five spatial tasks. No significant differences between groups were found for either of the verbal measures. While the results of the study imply a promising effect of the Kodály method on EF skills, the lack of an active control group prevents any suggestion of causation.

The issue of experimental design using an appropriate active control group was addressed by Moreno and colleagues (Moreno, et al., 2011), who studied of the effect of short-term music training on children' EF and IQ. They assigned a group of 48 preschool hearing children aged between 4 and 6 years to either music or art computerized training programmes. Both the art and music programmes were balanced in every aspect; duration, graphics and design used, number of breaks, number of teaching staff present during the training etc. The only factor that differed was the content of the training. A crucial difference in this study compared to others that look at the effects of musical instruction is that this one focused on music listening and auditory discrimination rather than instrumental learning. However, after only 20 days of training, consisting of 90 minutes a day, the music group showed improved performance on the go/no-go inhibition task and on a measure of verbal intelligence. The computerised go/no go task required participants to press a key when they saw a white stimulus appear on the screen (a ‘go’ trial) and refrain from pressing a key if they were presented with a purple stimulus (a ‘no-go’ trial). The stimuli presented were either triangles or squares, but this was irrelevant to the target responses. Accuracy and response rates were recorded. Additionally, the authors collected ERP data whilst the participants performed the go/no-go task, which revealed a positive correlation between increased verbal intelligence and changes in functional brain plasticity (measured by change in peak P2 amplitude); an effect found only in the group who received music training. The authors highlight that *“The link between executive function and music is understandable if one considers that music training requires high levels of control, attention, and memorization. Therefore, the transfer effect may be due to these same executive functions being used to process different (i.e., non-music) stimuli.”* (Moreno et al. 2011, p5).

### 2.9.3 Music and Language Skills

Some researchers have focused on the impact of more general musical activities on language and literacy skills (e.g. (McCarthy, 1985). Using rhyme, rhythm and repetition has been shown to facilitate the learning of vocabulary (Baechtold & Algier, 1986), particularly in poor readers (Newsom, 1979), and has subsequently led to improvement in reading, comprehension, attitudes and motivation. Musical activities have also been shown to assist in developing second language learning in children (e.g. (Kennedy & Scott, 2005) and in improving memory for a range of other materials including multiplication tables (Claussen & Thaut, 1997) and stories (e.g. (Allen & Butler, 1996). The direct impact of the use of music to improve literacy through the use of songs and singing has not been clearly demonstrated (e.g. (Ebisutani, Donlan, & Siebers, 1991)), although music lessons designed to develop auditory, visual and motor skills have benefited reading (Douglas & Willats, 1994), as have studies aimed at improving rhythmic skills (Long, 2007) and there is evidence of a relationship between phonemic awareness, simple reading ability and pitch discrimination (e.g. Anvari et al, 2002).

### 2.9.4 The relationship between music, EF and general intelligence.

Some studies have tried to tease apart the nature of the relationship between musical skill and EF. A recent study by (Dege, Kubicek, & Schwarzer, 2011) found that executive functions mediated the relationship between music lessons and intelligence. They tested children between the ages of 9 and 12 on five different executive function tasks taken from a Developmental NEuroPsychological Assessment (Korkman, Kirk, & Kemp, 2007) which included set shifting, selective attention, planning, inhibition and fluency. They also measured the children's fluid intelligence using a revised form of the Culture Fair Test (Weiss R. , 2006). The children varied widely in the amount of music training they had had prior to taking part in the study. Of the 90 children who took part, 33% had received no music instruction, 50% had between one and four years of instrumental lessons, and 17% had more than four years of instrumental lessons. Their results showed that the number of months of music lessons children had had significantly correlated with IQ, even when the factors of gender, parents' education and family income were held constant. A further hierarchical multiple regression analysis revealed that EF abilities accounted for 47% of the variance in IQ scores, with selective attention and inhibition being the most significant in mediating the association between music lessons and IQ. The authors concluded that music lessons influence IQ indirectly rather than directly, and that their findings support the hypothesis that music lessons enhance IQ by strengthening executive functions (Hannon & Trainor, 2007), (Schellenberg & Peretz, 2008)

However, other studies do not present such a clear-cut relationship between IQ, EF and music. Schellenberg (2011) conducted a study examining the association between music lessons and intelligence which also sought to determine whether the association is mediated by executive function. As with Dege et al's study, Schellenberg tested the IQ and EF skills of 106 9 to 12 year olds with varying musical experience. IQ measures used consisted of four subtests of the Weschler Abbreviated Scale of Intelligence and the five executive function tasks included digit span, verbal fluency, a Sun Moon Stroop test, The Tower of Hanoi task and the Wisconsin Card Sorting task. These assessed children's attention and working memory, fluency, inhibition, problem solving, planning and switching respectively. In this study the children who were musically trained had higher IQ scores than those who had no music experience, as had been found in previous studies (e.g., Schellenberg 2006). However, even though higher IQs were also predictive of an enhanced performance on all five measures of executive function, the association between music training and executive function skills was negligible. Schellenberg concluded that the relation between IQ and music training is not strongly mediated by executive function, and a more likely explanation for the association is that children with higher IQs are more likely to take up and persist with music lessons and to perform well on a variety of cognitive tests. (Schellenberg, 2011).

Taken together, the studies discussed in this chapter suggest potential cognitive benefits and transfer effects of musical training to EF skills in early childhood, adulthood and later life. Whether EFs act as a mediator between musical experience and IQ (with music lessons enhancing executive skills, which in turn improve IQ) is yet to be definitively determined. However, some studies (e.g. Dege, Kubicek, & Schwarzer, 2011; Schellenberg, 2006) have emerged which suggest that this may be the case, and future longitudinal work should yield interesting and hopefully clarifying results.

Some studies, such as that by Moreno et al. (2011), have focused on training auditory attention and discrimination skills and have not included training involving learning to play musical instruments. However, other studies have found no differences between musicians who play an instrument and classically trained vocalists when it comes to performance on EF tasks (Bialystok & DePape, 2009), which could suggest that general improvements in auditory discrimination and processing is a contributing factor to enhanced EF skills in musicians. Conversely, another skill that is universal to musicianship is the ability to sight read musical notation. Goolsby (1994) found that musicians who were skilled at ‘sight reading’ (performing a piece of music without having previously been familiar with it or having read the notation) had better eye fixation control in reading music and fixated on notes further ahead in the piece than novice sight readers. It was concluded that these musicians possessed an enhanced ability to monitor and rapidly shift their attention (Goolsby, 1994).

In summary, experience of musicianship has been demonstrated to have positive effects on EFs, but to date the relationship between music, EF and language is still being debated. Studies such as those reported here have, so far, included only hearing participants. Motivated by research findings that deafness is associated with delayed EF development (e.g. Botting et al., 2016; Hintermair, 2013; Kronenberger, Colson, Henning, & Pisoni, 2014; Marschark et al., 2016), the two studies in this thesis aim to test the hypothesis that musicianship might act as a protective factor for EF in deaf people. The two studies will address two research questions – firstly, do deaf musicians display the same or similar EF advantages as hearing musicians have been found to; and secondly, if these advantages are present in deaf musicians, is there the potential for music to improve the EF skills of deaf children (as has been demonstrated in hearing children, e.g. Moreno et. al, 2011) through the implementation of a training study. The study reported in Chapter 3 begins to answer these questions and is the first investigation of EFs in deaf musicians, comparing their EF abilities to hearing musicians and non-musicians, and deaf non-musicians.

# Chapter 3 STUDY 1: Comparing the Executive Function Skills of Adult Deaf and Hearing Musicians and Non-Musicians

## 3.1 Research Question and Hypothesis

The study presented in this chapter intends to explore further which mechanisms contribute to EF enhancement in musicians by investigating the performance of a group of deaf musicians on EF tasks in which hearing musicians have previously been found to outperform non-musicians. Fulford, Ginsborg, and Goldbart (2011) point out that whilst the term 'deaf musician' may initially be seen as an oxymoron, there are, in fact, many skilled and accomplished deaf musicians. Naturally, their sensory musical experience differs greatly from their hearing counterparts, with experiences ranging from full reliance on residual hearing to discriminate between tones, to non-auditory vibrational attending (Fulford, Ginsborg, & Goldbart, 2011). Whilst audition will certainly play a role in musicianship for some deaf musicians through their use of residual hearing, it can be argued that this is to a different extent than hearing people, with some deaf musicians relying more heavily on non-auditory attending (Fulford et al., 2011). An additional objective of this study is to contribute to the existing findings on the relationship between musical skill and EF, and to attempt to replicate findings of previous studies that have compared the EF skills of musicians and non-musicians.

### 3.1.1 Main objective of the study

This study aims to investigate the executive function skills of adult deaf musicians and to determine whether they demonstrate the same pattern of enhancements of cognitive control as previously reported in hearing musicians. Specifically, it aims to answer the following questions:

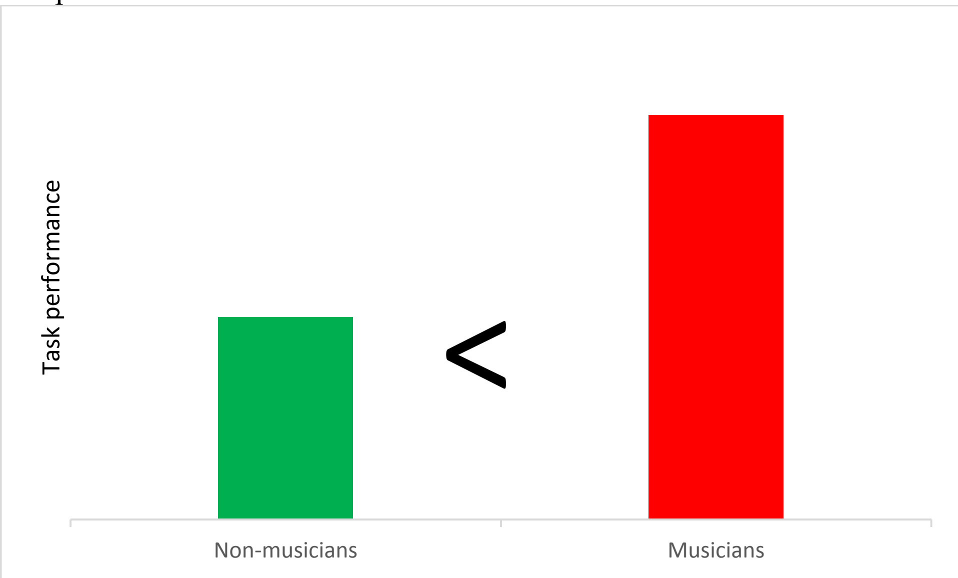
1) Do deaf musicians show the same pattern of enhancement of EF skills as hearing musicians?

2) Are the gains in some EF skills found in hearing musicians mediated by enhancements to auditory processing, or are they linked to the practiced cognitive control necessary for music learning and practice?

### 3.1.2 Predictions

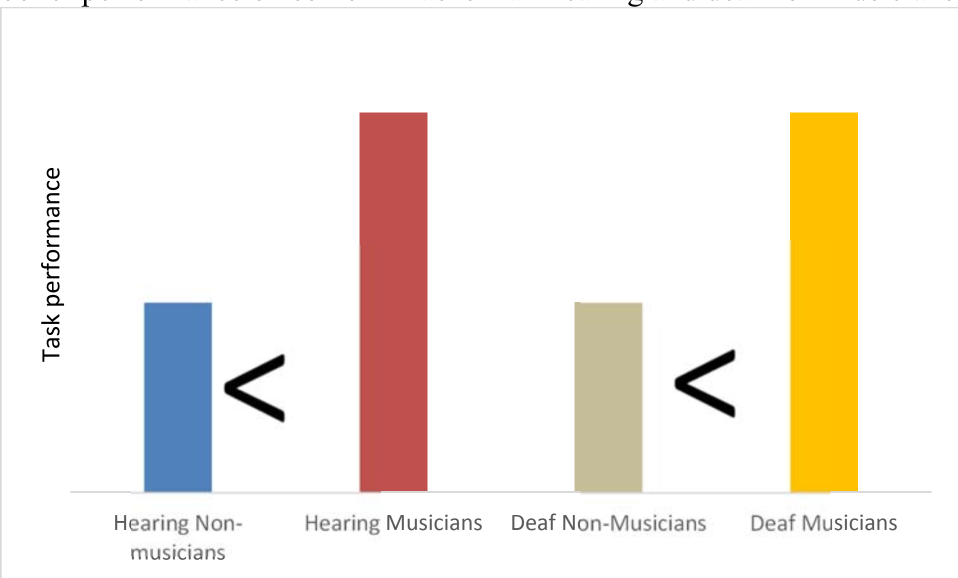
Prior to carrying out the study, predictions were made about the pattern of results expected depending on whether improvements in auditory or general cognitive control mediate the relationship between musicianship and EF. These predictions are illustrated in figures 3.1.2a, 3.1.2b, 3.1.2c and 3.1.2d.

Figure 3.1.2a Prediction 1: Musicians will have better performance on EF tasks in comparison to non-musicians.



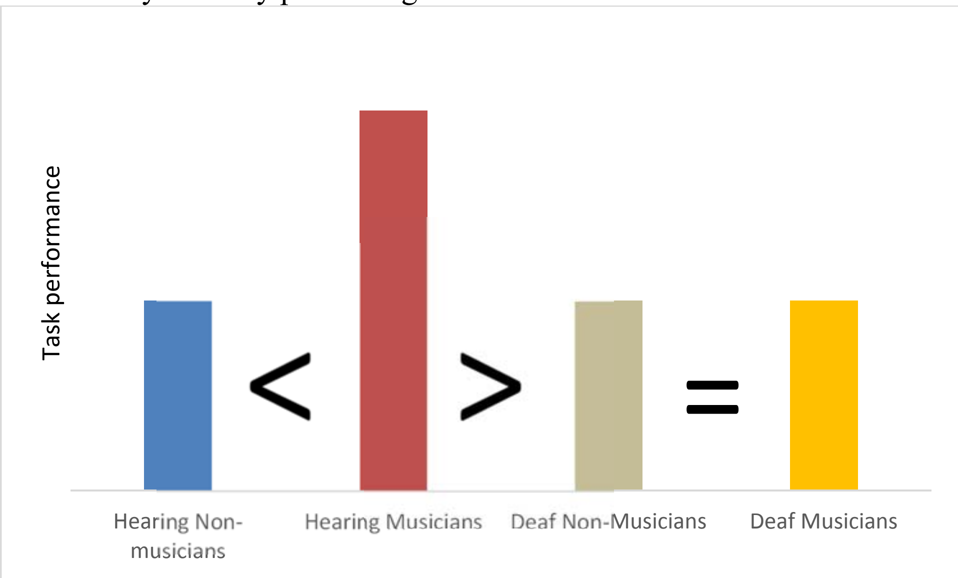

If gains in EF are due to specific practice of cognitive control, the following pattern of results with respect to the four groups is predicted (see Figure 3.1.2b).

Figure 3.1.2b. Prediction 2: Pattern of results if hearing and deaf musicians have better performance on some EF tasks than hearing and deaf non-musicians.



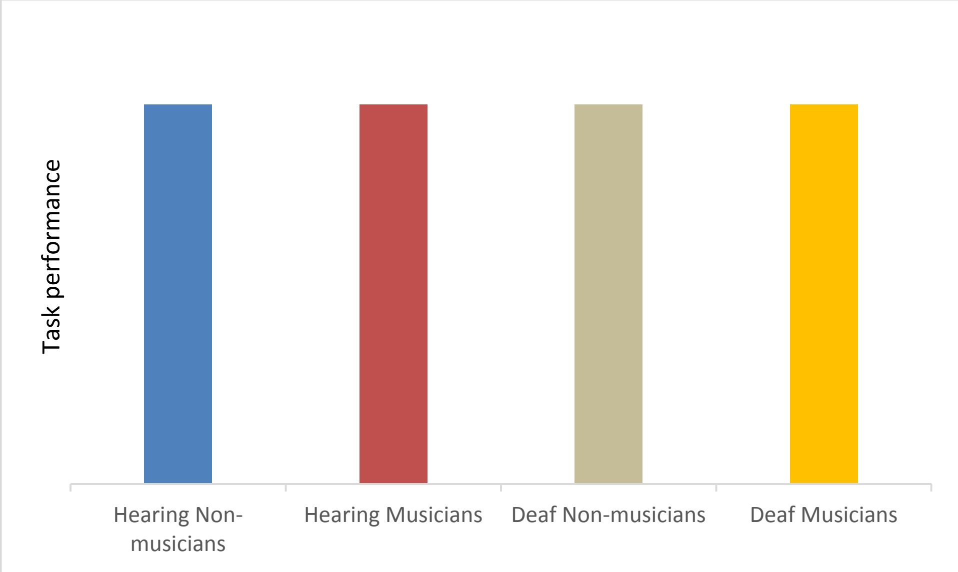
However, if EF gains through musical training are mediated by auditory processing, the following results would emerge (see Figure 3.1.2c), with only hearing musicians showing superior performance on EF tasks in comparison to the other three participant groups.

Figure 3.1.2c. Prediction 3: Pattern of results expected if EF gains are primarily mediated by auditory processing.




An alternative pattern of results may emerge if the null hypothesis is true and no differences in EF performance are found between any of the four participant groups, illustrated in figure 3.1.2d.

Figure 3.1.2d. Prediction 4: Pattern of results expected if the null hypothesis is true and there are no differences between non-musician and musician groups.




## 3.2 Methodology

### 3.2.1 Participants

Four groups of adults were recruited for the study: hearing non-musicians, hearing musicians, deaf non-musicians and deaf musicians. Participants were recruited through contacts within the deaf community, the author's personal contacts with musicians and through "D-LIST" – a participant database of members of the deaf community willing to take part in research, held at the Deafness Cognition and Language Research Centre (DCAL) at University College London.

While the pool of deaf participants for research is relatively small compared to the general population, the number of deaf musicians who have studied music to a high standard is even smaller. Therefore, care was taken to match participants across all groups on age, sex, and nonverbal IQ. Deaf musicians were recruited primarily to the study, and other participants were subsequently recruited to the 3 other groups who matched the age and sex of deaf musicians as far as was possible. 10 participants were recruited for each group, giving a total of 40 participants in the study. Ethical approval for the study was obtained from the UCL Research Ethics Committee and participants received information about the study, signing consent forms before taking part (see appendices II and III).

All participants completed a questionnaire giving detailed information about their hearing status, language use and musical experience (See Appendix I). The questionnaire was adapted from a previous study involving musicians with various degrees of hearing impairment (Fulford & Ginsborg, 2013). Information from deaf participants included: level of deafness (from mild to profound), use of hearing aids (and, for musicians, whether hearing aids are used during performance), age at which they lost their hearing (if not from birth), and experience of tinnitus. All participants answered the sections on musical background, which included whether or not they could play a musical instrument or read music. Some participants in the non-musician groups had been taught to read musical notation at school or had received some music tuition for a short time, but did not identify themselves as musicians or feel they would currently be able to play the instrument. However, all participants were encouraged to disclose all past musical tuition experience, the age at which they started, the duration of the tuition and the grade proficiency reached (i.e. Grades 1-8+). The musician groups comprised of those who currently play or sing on a daily or weekly basis, have grade 8+ proficiency on one or more instrument and/or possess an advanced qualification in music.

All participants were asked to state their first (native) language, which was English for all hearing participants or British Sign Language (BSL) and English for the deaf participants. They were also asked to list any other languages that they can speak or sign and to indicate their level of fluency: basic/school level, intermediate/conversational level or advanced/fluent. Participants who are fluent in another language are indicated in the following tables. The hearing participants who are fluent in a second language do not use them on a daily or weekly basis, and therefore were not considered to be “bilingual” according to the criteria used in previous studies (e.g. Bialstok, Craik, Green, & Gollan, 2009). The number of musicians and non-musicians who participated is shown in table 3.2.1-1, including details of the numbers of male and female participants in each group.

Table 3.2.1-1. Number of male and female participants in each participant group.

| GROUP | MALE | FEMALE |
|---|---|---|
| Hearing non-musicians | 4 | 6 |
| Hearing musicians | 4 | 6 |
| Deaf non-musicians | 5 | 5 |
| Deaf musicians | 4 | 6 |
| TOTAL | 17 | 23 |

Tables 3.2.1-2 to 3.2.1-5 provide details for the participants in each group (hearing non-musicians, hearing musicians, deaf non-musicians and deaf musicians) including their gender, age, non-verbal IQ (NVIQ), musical and language experience. An analysis of variance found no significant differences between all four participant groups for age ($F_{(3,36)}$=.036, p=.991) or NVIQ ($F_{(3,36)}$=1.044, p=.385). Additionally, there was no significant difference in the number of years of music tuition between the two musician groups ($t_{(18)}$=-.256, p=.801).

Table 3.2.1-2 The Means and SD of each participant group for age, years of musical tuition and NVIQ

| | | N | Mean | Std. Deviation |
|---|---|---|---|---|
| Age | Hearing non-musician | 10 | 35.50 | 14.238 |
| | Hearing musician | 10 | 35.20 | 10.891 |
| | Deaf non-musician | 10 | 36.40 | 12.563 |
| | Deaf musician | 10 | 34.60 | 12.240 |
| | Total | 40 | 35.43 | 12.066 |
| Years of music instruction | Hearing non-musician | 10 | 2.10 | 3.315 |
| | Hearing musician | 10 | 25.00 | 11.096 |
| | Deaf non-musician | 10 | .30 | .949 |
| | Deaf musician | 10 | 26.30 | 11.643 |
| | Total | 40 | 13.43 | 14.709 |
| Matrices T-score | Hearing non-musician | 10 | 62.00 | 6.307 |
| | Hearing musician | 10 | 64.30 | 2.830 |
| | Deaf non-musician | 10 | 60.20 | 6.303 |
| | Deaf musician | 10 | 61.30 | 5.250 |
| | Total | 40 | 61.95 | 5.373 |

Table 3.2.1-3. Participant details for the hearing non-musician group

| Participant code | Gender | Age (years) | NVIQ T-score | Past musical instruction? | Years of music tuition | Fluency in language other than English? |
|---|---|---|---|---|---|---|
| HN01 | F | 28 | 64 | YES | 5 | No |
| HN02 | F | 29 | 50 | YES | 3 | No |
| HN03 | M | 34 | 72 | NO | 0 | Mandarin Chinese (not used daily) |
| HN04 | F | 62 | 59 | NO | 0 | No |
| HN05 | M | 62 | 59 | YES | 10 | No |
| HN06 | M | 33 | 68 | NO | 0 | No |
| HN07 | M | 28 | 66 | NO | 0 | No |
| HN08 | F | 28 | 56 | NO | 0 | No |
| HN09 | F | 25 | 62 | YES | 3 | No |
| HN10 | F | 26 | 64 | NO | 0 | No |
| MEAN | | 35.5 | 62 | | 2.1 | |

Table 3.2.1-4. Participant details for the hearing musician group

| Participant code | Gender | Age (years) | NVIQ T-score | Past musical instruction? | Years of music tuition | Fluency in language other than English? |
|---|---|---|---|---|---|---|
| HM01 | F | 31 | 66 | YES | 22 | No |
| HM02 | F | 23 | 65 | YES | 15 | No |
| HM03 | F | 27 | 62 | YES | 24 | No |
| HM04 | M | 24 | 67 | YES | 19 | No |
| HM05 | F | 46 | 65 | YES | 20 | No |
| HM06 | F | 27 | 68 | YES | 15 | No |
| HM07 | F | 32 | 58 | YES | 15 | Native French speaker |
| HM08 | F | 41 | 64 | YES | 34 | No |
| HM09 | M | 53 | 65 | YES | 45 | No |
| HM10 | M | 48 | 63 | YES | 41 | No |
| MEAN | | 35.2 | 64.3 | | 25 | |

Table 3.2.1-5. Participant details for the deaf non-musician group

| Participant code | Gender | Age (years) | NVIQ T-score | Past musical instruction? | Years of music tuition | Fluency in language other than English? |
|---|---|---|---|---|---|---|
| DN01 | F | 32 | 68 | YES | 3 | BSL |
| DN02 | F | 62 | 64 | NO | 0 | BSL |
| DN03 | F | 27 | 68 | NO | 0 | BSL |
| DN04 | M | 48 | 65 | NO | 0 | No |
| DN05 | M | 28 | 50 | NO | 0 | BSL |
| DN06 | F | 30 | 58 | NO | 0 | BSL |
| DN07 | F | 26 | 62 | NO | 0 | BSL |
| DN08 | M | 51 | 59 | NO | 2 | BSL |
| DN09 | M | 28 | 56 | NO | 0 | No |
| DN10 | M | 32 | 52 | NO | 0 | BSL |
| MEAN | | 36.4 | 60.2 | | 0.5 | |

Table 3.2.1-6. Participant details for the deaf musician group

| Participant code | Gender | Age (years) | NVIQ T-score | Past musical instruction? | Years of music tuition | Fluency in language other than English? |
|---|---|---|---|---|---|---|
| DM01 | F | 28 | 66 | YES | 20 | BSL |
| DM02 | F | 33 | 68 | YES | 21 | BSL |
| DM03 | F | 60 | 61 | YES | 47 | No |
| DM04 | M | 50 | 58 | YES | 45 | BSL |
| DM05 | M | 27 | 62 | YES | 20 | BSL |
| DM06 | M | 25 | 62 | YES | 20 | No |
| DM07 | F | 28 | 64 | YES | 19 | BSL |
| DM08 | F | 31 | 66 | YES | 24 | BSL |
| DM09 | M | 42 | 54 | YES | 34 | No |
| DM10 | F | 22 | 52 | YES | 13 | BSL |
| MEAN | | 34.6 | 61.3 | | 26.3 | |

Table 3.2.1-7 provides details of the musical backgrounds of both the hearing and deaf musicians. ‘Perfect pitch’ (also known as absolute pitch) is the rare musical ability to identify the tone of a note purely by ear, without any other note being played for comparison or reference. ‘Relative pitch’ is the ability to identify a musical tone in relation to another one. Acquisition of either of these skills is an indication of an advanced level of musicianship.

All of the musicians who took part in the study had achieved a high level music qualification for their instrument, or vocal exams, from the Associated Board of the Royal School of Music (ABRSM). One deaf musician (DM06) had not taken graded music exams, but studied Advanced level music at college and was the founding member of a successful professional band.

Table 3.2.1-7. Musical background and qualifications of hearing musicians.

| **Participant** | **Perfect pitch?** | **Relative pitch?** | **Instrument(s)** | **Qualifications** | **Professional musician?** |
|---|---|---|---|---|---|
| HM01 | No | Yes | Flute and piano | Grade 8+ ABRSM A-level Music | No |
| HM02 | No | Yes | Flute and piccolo | Grade 8+ ABRSM, Mmus Flute Performance | Yes |
| HM03 | No | Yes | Piano and violin | Grade 8+ ABRSM, BA Music | No |
| HM04 | No | Yes | Piano, cello, organ, and singing | Grade 8+ ABRSM, BA Music, ARCO† | Yes |
| HM05 | No | No | French horn, piano, alto saxophone, and clarinet | Grade 7 ABRSM, A-level Music | No |
| HM06 | No | Yes | Flute and singing | Grade 8+ GCSE Music | No |
| HM07 | Yes | Yes | Piano and flute | Grade 7 ABRSM, BA Music | No |
| HM08 | No | Yes | Flute and piano | Grade 8+ ABRSM, BA Music | No |
| HM09 | No | Yes | Clarinet, bass clarinet, and saxophone | Grade 8+ ABRSM | No |
| HM10 | No | Yes | Clarinet, saxophone, bass guitar, and piano | Grade 8+ MA in Performance Practice | Yes |

| | | | | | |
|---|---|---|---|---|---|
| DM01 | No | No | Flute, piano, and drums | Grade 8+ ABRSM, BA Music | No |
| DM02 | No | Yes | Flute, piccolo, and recorder | Grade 8+ B.Mus and Diploma in Performance | Yes |
| DM03 | No | Yes | Singing and piano | Professional Performance Diploma, RNCM†† | Yes |
| DM04 | No | Yes | Piano and organ | Grade 8+ ABRCM, BA Music | Yes |
| DM05 | No | Yes | Trumpet, piano, and drums | Grade 8+ ABRSM, Performance diploma, BA Music | Yes |
| DM06 | Yes | Yes | Guitar, drums, and piano | A-level Music | No |
| DM07 | No | No | Drums and piano | Grade 7 ABRSM, A-level Music | No |
| DM08 | No | No | Saxophone, piano, and guitar | Grade 8+ ABRSM | No |
| DM09 | No | No | Piano | Grade 8+, BA Music | No |
| DM10 | No | No | Clarinet | Grade 7 ABRSM, GCSE Music | No |

†ARCO= Associate of the Royal College of Organists

†† RNCM= The Royal Northern College of Music

Table 3.2.1-8 provides information about the degree of deafness and auditory amplification devices used by the deaf musician group on a daily basis, and whilst playing music. None of the participants were cochlear implant users, but all of them used hearing aids in certain circumstances. This information is included in order to illustrate the variability in deaf musicians' preferences for hearing aid use whilst playing music. For example, participants DM06 and DM10 report no use of their hearing aids on a day-to-day basis, however they use their hearing aids whilst practicing and performing music. Conversely, participant DM05 chooses to remove their hearing aid when playing.

Table 3.2.1-8. Level and age of onset of deafness, hearing aid and cochlear implant usage of the deaf musician participant group

| Participant | Level of deafness | Age became deaf | HA/CI daily use? | HA/CI when playing music? |
|---|---|---|---|---|
| DM01 | Profound | Birth | Hearing aid | Hearing aid |
| DM02 | Profound | Birth | Hearing aid | Hearing aid |
| DM03 | Profound | 14 years old | Hearing aid | Hearing aid |
| DM04 | Profound | Birth | Hearing aid | Hearing aid |
| DM05 | Severe | Birth | Hearing aid | None |
| DM06 | Profound | Birth | None | Hearing aid right ear only |
| DM07 | Profound | Birth | Hearing aid | Hearing aid |
| DM08 | Severe | 3 years old | Hearing aid | Hearing aid |
| DM09 | Profound | Birth | Hearing aid | Hearing aid |
| DM10 | Profound | Birth | None | Hearing aid |

### 3.2.2 EF Tasks

The tasks used in this study are all commonly used in research studies which assess EF skill (Chan et al., 2008; Spreen & Strauss, 1998) and were all non-verbal. The tasks measured participants' working memory, inhibition, attention and switching skills and are explained in further detail below. Particular focus was given to inhibition and switching skills (with the inclusion of Flanker, Simon and Stroop tasks), as these are areas of EF for which musicians have previously been found to outperform non-musicians (e.g., Bialystok & Depape, 2009).

**Matrix reasoning subtest of the Wechsler Abbreviated Scale of Intelligence (WASI, 4th edition, 2008)**

This is a nonverbal measure of general intelligence and nonverbal fluid reasoning consisting of 35 items. The test items assess the participant's problem solving skills, including inductive and spatial reasoning. Participants are shown a pattern sequence and asked to identify the picture that completes the sequence from a choice of four. Participants' raw scores are converted to age-corrected T-scores which have a mean of 50 and a standard deviation of 10.

**Trail Making Test (Lezak, 1995) – Speed of Processing and Switching**

There are two parts to the Trail Making Test. In Part A, participants are given a sheet of paper with numbered circles from 1-25 and are required to "join the dots" in sequence. They are asked to do this as quickly and accurately as possible and without taking their pen off the paper and are timed in order to gather a baseline score for their speed of processing. Part B is more complex and is considered a test of executive functioning, as it requires participants to switch their attention between numbers and letters. Participants are presented with another sheet of circles containing numbers 1-25 and the letters A-L. They are asked to alternate between numbers and letters when connecting the circles in sequence (for example, 1-A, 2-B, 3-C etc.). The score for both parts A and B is the time they take to complete the task in seconds. An interference score is calculated by subtracting the time taken to complete part A from the time taken to complete part B.

**Spatial Span Subtest of the Wechsler Memory Scale–III[1]**

This test was administered as a measure of short-term visuospatial memory. Participants are shown a platform on which 10 blue cubes are randomly positioned. The experimenter points to increasingly long strings of blocks and the participant is required to copy the experimenter by pointing to the blocks in the same order (in the forward condition). Testing begins with two-block strings (with two trials at each level) and progresses up to nine blocks, or until the participant makes errors in both trials of a particular level.

[1] This task is also included in the child intervention study (Chapter 6).

In the backward span condition which is heavily loaded for executive working memory, participants are required to point to the blocks in the reverse order to the experimenter. As in the forward condition, the test begins with two-block strings and continues up to nine or until a level is failed.

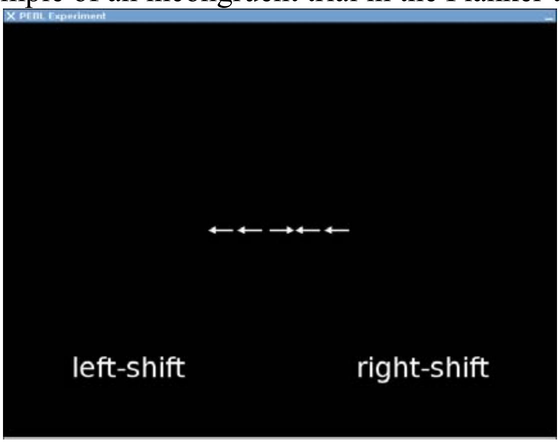
*Computerised Tasks*

All of the following EF tasks were presented on a Lenovo Thinkpad laptop, using 'PEBL' Psychology Experiment Building software (Mueller, 2012).

**Flanker (Test of Selective Attention and Response Inhibition)**

This is a reaction time task where participants need to focus on the direction of the central arrow in a set of five arrows. The surrounding arrow heads are either pointing in the same (congruent) or opposite (incongruent) direction (see figure 3.2.2a below). The participants respond by pressing the left or right shift keys on the computer keyboard to indicate the direction of the arrow head. There is also a neutral condition, where only the central arrow appears on the screen and is not flanked by any distractors. There are 12 practice items to ensure the participants understand the task, followed by 120 trial items consisting of 40 congruent, 40 incongruent and 40 neutral items. An excel output file from this task gives detail of participants' accuracy and reaction times for each trial.

Figure 3.2.2a An example of an incongruent trial in the Flanker task.



**Number Stroop (Inhibition)**

The Number Stroop Task is another test of inhibition. Participants are asked to respond to the number of characters displayed on the screen, whilst ignoring the actual identity of the character. For example, if the array "222" appears on the screen, the correct response would be "3" as there are 3 characters displayed. In this example, the participants are required to inhibit the impulse to respond "2". Responses are given by pressing keys 1, 2 or 3 on the computer keyboard. Additionally, there is a neutral condition where letters appeared instead of numbers. The letters appearing in the neutral condition are either M, G or Z.

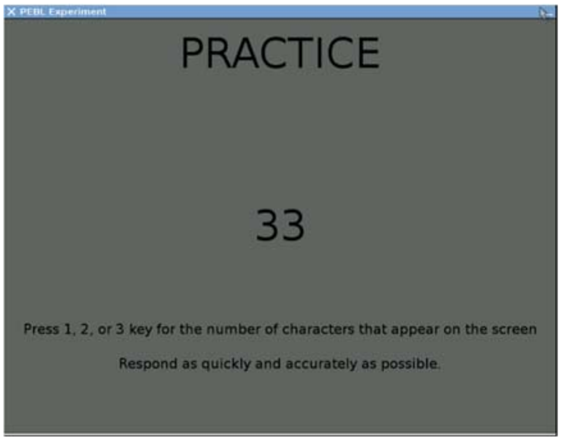
This task has 192 trials altogether, 24 of which are practice trials. The test itself consists of 56 congruent, 56 incongruent and 56 neutral trials, examples of which are shown below.

22 Congruent Condition (where the correct response is "2")

3 Incongruent Condition (where the correct response is "1")

MMM Neutral Condition (where the correct response is "3")

Figure 3.2.2b An example of an incongruent trial in the Number Stroop Task

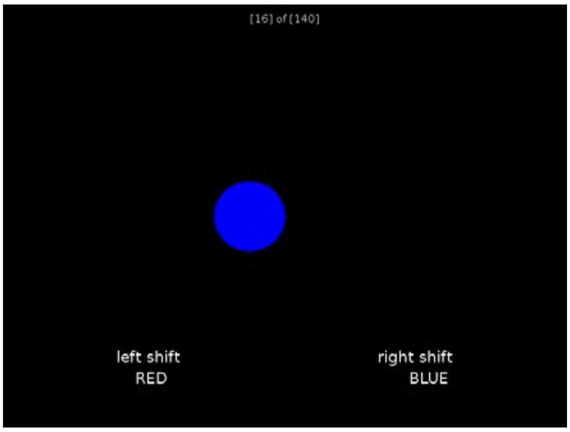



Participants' accuracy and reaction time in milliseconds for each trial are produced in an Excel output file.

**Simon Interference Task (Inhibition)**

In the Simon Interference Task participants have to make a rapid judgment of the colour of a stimulus while ignoring its horizontal position. A red or blue circle appears on the screen and the participants have to respond by pressing the left shift key for a red circle and the right shift key for a blue circle. The task consisted of 140 trials; 70 congruent (where the circle appears on the same side of the screen as the response key) and 70 incongruent (where the circle appears on the opposite side of the screen to the response key). Accuracy of participants' responses and reaction time in milliseconds were recorded.

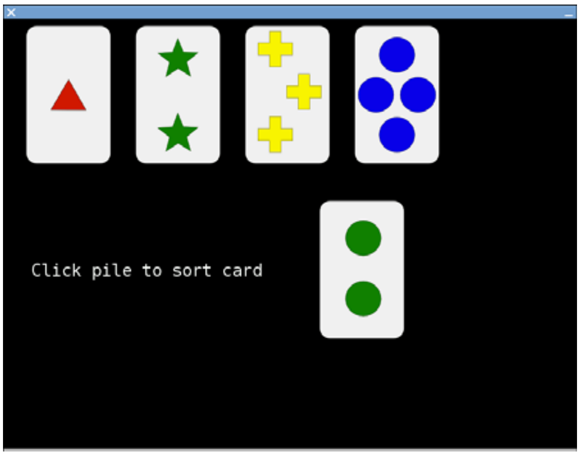
Figure 3.2.2c An example of an incongruent trail on the Simon Task




**Wisconsin Card Sorting (Switching and Updating)**

The Wisconsin Card Sorting Task is a frequently-used executive function task that measures set switching and updating ability. Participants are presented with four cards with different coloured shapes. The first has a single red triangle, the second two green stars, the third has three yellow crosses and the fourth four blue circles (see figure 3.2.2d).

Figure 3.2.2d A screenshot of the Wisconsin Card sorting task showing the four category piles and a card to be sorted




Participants are presented with another card and needed to determine which pile it belongs to. Cards can be sorted according to three different rules; colour, shape or number. However, participants do not initially know what the rule is. On each trial, the computer gives feedback to the participant about whether the card was sorted correctly or not, and through this process of elimination, the participant can work out the rule. After a while the programme changes the rule and the participant needs to abandon the ‘old’ sorting rule and determine the ‘new’ rule.

The traditional version of the Wisconsin Card sorting task utilized 64 paper cards for sorting. This computerised version also included 64 cards in a ‘pack’ and the computer runs through all of them twice, resulting in 128 trials. Output recorded from this task includes the percentage of correct trials, percentage of errors made, number of perseverative errors (i.e. the number of times a participant failed to adjust to the new rule and persisted with a previous rule) and number of non-perseverative errors made. Failure to maintain set is also recorded. These are occasions where the participant successfully deciphered the new sorting rule, but subsequently reverted to a previous rule in one of the following trials. With all the tests described the next section presents the findings of the investigation.

### 3.3 Results

Data from the four computerised tasks (Flanker, Simon, Number Stroop and the Card Sorting task) were retrieved in the form of individual Excel files. In order to analyse the reaction time data from these tasks, the data were ‘trimmed’ to remove trials where erroneous responses were made and to eliminate outliers. Responses removed had a duration <250ms and >900ms, (following guidelines suggested by Ratcliff, 1993), which accounted for 12% of the data.

Trial conditions in the computerised tasks which were congruent or neutral are treated as control conditions for the EF tasks and therefore data from these conditions will not be reported here. Incongruent trials and interference scores are the EF-loaded trial conditions and these data will be focused on in the analysis. However, overall scores will also be reported as the inclusion of these data allows for the comparison of general overall accuracy between the four participant groups on the tasks. As well as accuracy for EF trials, reaction time data from all four participant groups will also be reported where appropriate.

The data was analysed using 2x2 factorial ANOVAs to compare the main effects of musician and hearing status (ie. musician/non-musician and deaf/hearing) and the interaction effect between musician and hearing status on performance on each of the EF tasks.

### 3.3.1 Visuospatial Span

For overall spatial span scores (forwards and backwards conditions combined), the main effect of musician status was significant ($F_{(1,36)}$ =8.335, p=.007 $\eta_p^2$=.188) indicating a significant difference between the performance of musicians and non-musicians. The main effect for hearing status was not found to be significant, ($F_{1,36)}$=1.071, p=.308) between the hearing and deaf participants. The interaction effect was not found to be significant ($F_{(1,36)}$=.145, p=.705).

Table 3.3.1-1 Means and SD for Overall Visuospatial Span Scores

| Musician or Non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 15.80 | 3.011 | 10 |
| | Deaf | 15.20 | 3.011 | 10 |
| | Total | 15.50 | 2.947 | 20 |
| Non-musician | Hearing | 13.50 | 3.375 | 10 |
| | Deaf | 12.20 | 2.044 | 10 |
| | Total | 12.85 | 2.796 | 20 |
| Total | Hearing | 14.65 | 3.329 | 20 |
| | Deaf | 13.70 | 2.940 | 20 |
| | Total | 14.17 | 3.137 | 40 |

In the forwards span condition, a 2x2 factorial ANOVA revealed a significant main effect of musician status ($F_{(1,36)}$=9.016, p=.005, $\eta_p^2$=.200) between musicians and non-musicians. The main effect of hearing status was not significant ($F_{(1,36)}$=.499, p=.484) and no significant interaction was found ($F_{(1,36)}$=.499, p=.484)

Table 3.3.1-2 Means and SD for forwards Visuospatial Span Scores

| Musician or Non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 8.50 | 1.900 | 10 |
| | Deaf | 7.70 | 1.337 | 10 |
| | Total | 8.10 | 1.651 | 20 |
| Non-musician | Hearing | 6.40 | 2.459 | 10 |
| | Deaf | 6.40 | 1.174 | 10 |
| | Total | 6.40 | 1.875 | 20 |
| Total | Hearing | 7.45 | 2.395 | 20 |
| | Deaf | 7.05 | 1.395 | 20 |
| | Total | 7.25 | 1.945 | 40 |

However, in the backwards span condition, no significant main effect was found for musician status ($F_{(1,36)}$=2.946, p=.095). There was no significant main effect of hearing status ($F_{(1,36)}$=2.256, p=.142) and no significant interaction was found ($F_{(1,36)}$=1.657, p=.206).

Table 3.3.1-3 Means and SD for Visuospatial Span Backwards scores

| Musician or Non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 7.30 | 1.418 | 10 |
| | Deaf | 7.20 | 1.619 | 10 |
| | Total | 7.25 | 1.482 | 20 |
| Nonmusician | Hearing | 7.10 | 1.595 | 10 |
| | Deaf | 5.80 | 1.229 | 10 |
| | Total | 6.45 | 1.538 | 20 |
| Total | Hearing | 7.20 | 1.473 | 20 |
| | Deaf | 6.50 | 1.573 | 20 |
| | Total | 6.85 | 1.545 | 40 |

Figures 3.3-1 and 3.3-2 below show the average span scores of musicians and non-musicians and each of the four participant groups for forwards span, backwards span and overall scores on the visuospatial span task.

Figure 3.3-1. The average forwards, backwards and total spatial span of non-musicians and musicians

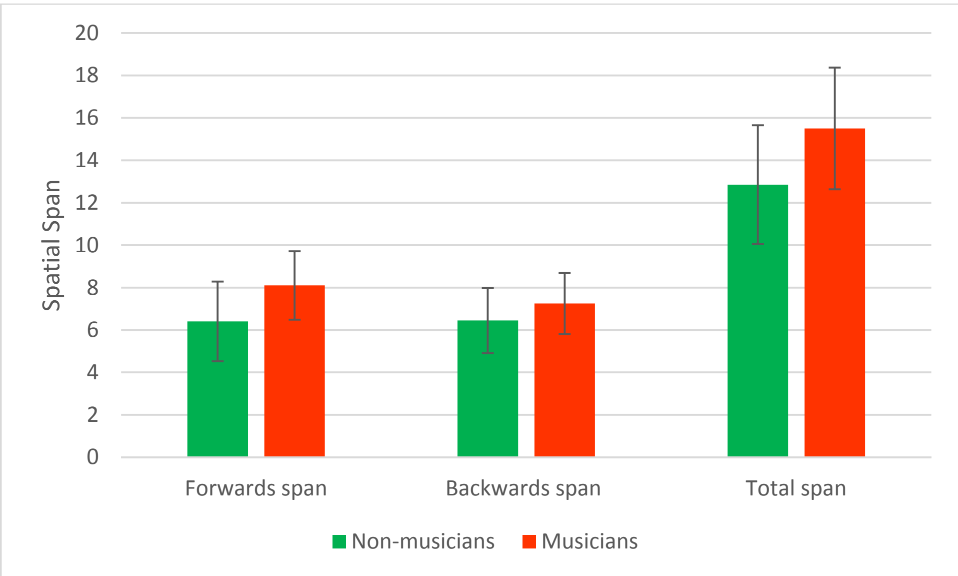
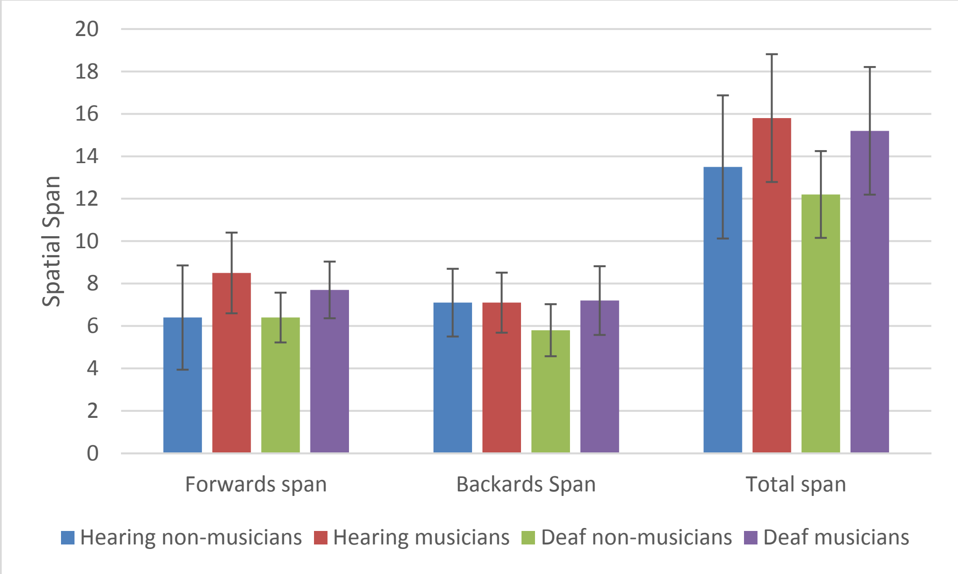


Figure 3.3-2. The average forwards, backwards and total spatial span for all participant groups




### 3.3.2 Trail Making Test

Participants were timed whilst completing both parts A and B of the trails task. Scores were recorded in seconds taken to complete the tasks. An interference score was calculated by taking the time to complete part A (the control task) from the time taken to complete part B (the task requiring cognitive flexibility).

When analysing participant performance on part B of the trail making task, a 2x2 factorial ANOVA revealed no significant main effect of musician status ($F_{(1,36)}$ =.004, p=.959) but a significant main effect of hearing status was found ($F_{(1,36)}$=4.386, p=.043, $\eta_p^2$ =.11). No significant interaction was found ($F_{(1,36)}$=.004, p=.950). These results show that the hearing participants performed significantly better on this task than the deaf participants regardless of musician status.

Table 3.3.2-1 Means and SD for Trail making task part B

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 34.20 | 8.176 | 10 |
| | Deaf | 41.00 | 8.393 | 10 |
| | Total | 37.60 | 8.786 | 20 |
| Non-musician | Hearing | 34.20 | 10.963 | 10 |
| | Deaf | 40.60 | 11.825 | 10 |
| | Total | 37.40 | 11.573 | 20 |
| Total | Hearing | 34.20 | 9.412 | 20 |
| | Deaf | 40.80 | 9.982 | 20 |
| | Total | 37.50 | 10.143 | 40 |

Once interference scores had been calculated for this test, a 2x2 factorial ANOVA revealed no significant main effect of musician status ($F_{(1,36)}$=.021, p=.885), but a significant main effect of hearing status was found ($F_{(1,36)}$=5.290, p=.027, $\eta_p^2$ =.13) There was no significant interaction ($F_{(1,36)}$=.526, p=.473)

Table 3.3.2-2 Means and SD for the Trail Making Test Interference Scores

| Musician or Non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 14.90 | 4.533 | 10 |
| | Deaf | 22.20 | 8.080 | 10 |
| | Total | 18.55 | 7.395 | 20 |
| Non-musician | Hearing | 17.00 | 8.097 | 10 |
| | Deaf | 20.80 | 9.028 | 10 |
| | Total | 18.90 | 8.571 | 20 |
| Total | Hearing | 15.95 | 6.476 | 20 |
| | Deaf | 21.50 | 8.370 | 20 |
| | Total | 18.73 | 7.903 | 40 |

Figures 3.3.2-1 and 3.3.2-1 below show the average time taken by musicians and non-musicians, and each of the participant groups for all conditions of the trail making test.

Figure 3.3.2-1. The average time in seconds for non-musicians and musicians to complete the trail making task

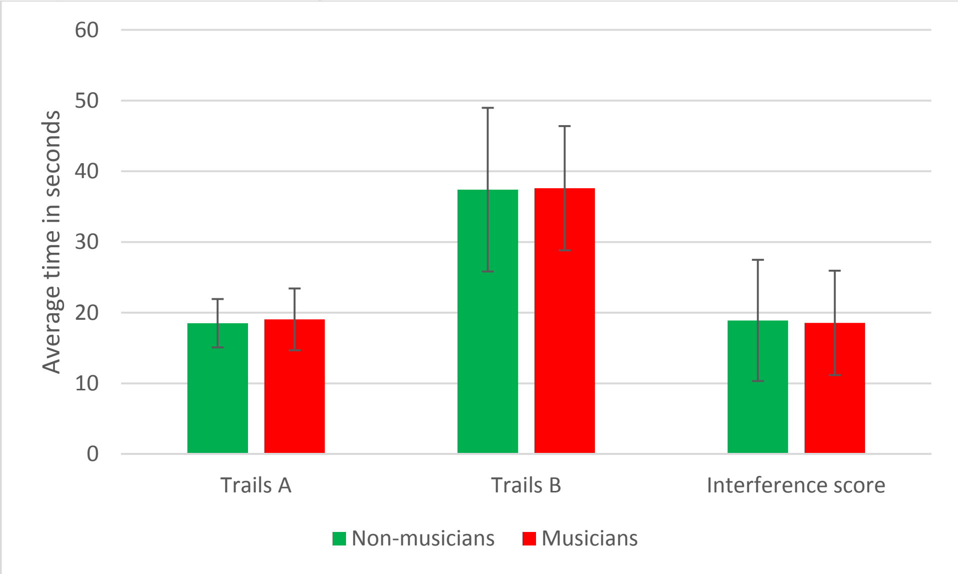
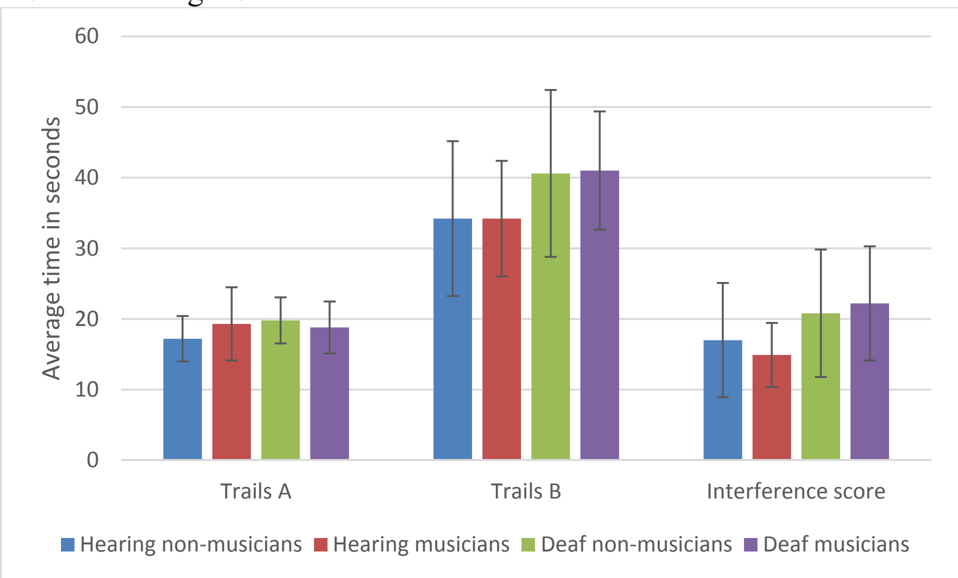



Figure 3.3.2-2. The average time in seconds for each participant group to complete the trail making task




### 3.3.3 Flanker Task

For overall scores on the flanker task, a 2x2 factorial ANOVA revealed a significant main effect of musician status ($F_{(1,36)}$=9.302, p=.004, $\eta_p^2$ = .21), and no significant main effect of hearing status ($F_{1,36)}$=.394, p=.534). No significant interaction was found ($F_{(1,36)}$=.008, p=.929). These results indicate that musicians performed better on this task regardless of hearing status.

Table 3.3.3-1 Means and SD for overall score on the Flanker Task

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 117.00 | 1.633 | 10 |
| | Deaf | 116.40 | 1.897 | 10 |
| | Total | 116.70 | 1.750 | 20 |
| Non-musician | Hearing | 113.70 | 4.270 | 10 |
| | Deaf | 112.90 | 5.021 | 10 |
| | Total | 113.30 | 4.555 | 20 |
| Total | Hearing | 115.35 | 3.573 | 20 |
| | Deaf | 114.65 | 4.107 | 20 |
| | Total | 115.00 | 3.816 | 40 |

For the EF-loaded incongruent trials, analysis again revealed a significant main effect of musician status ($F_{(1,36)}=20.021$, $p<.001$, $\eta_p^2=.36$). There was no significant main effect of hearing status ($F_{(1,36)}=.227$, $p=.637$) and no significant interaction was found ($F_{(1,36)}=.227$, $p=.637$). This indicates that musicians had better performance on the EF-loaded incongruent trials of this inhibition task, regardless of hearing status.

Table 3.3.3-2 Means and SD for Incongruent Flanker Trials

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 38.00 | .816 | 10 |
| | Deaf | 37.50 | .972 | 10 |
| | Total | 37.75 | .910 | 20 |
| Non-musician | Hearing | 35.40 | 2.066 | 10 |
| | Deaf | 35.40 | 2.271 | 10 |
| | Total | 35.40 | 2.113 | 20 |
| Total | Hearing | 36.70 | 2.029 | 20 |
| | Deaf | 36.45 | 2.012 | 20 |
| | Total | 36.57 | 1.999 | 40 |

Figures 3.3.3-1 and 3.3.3-2 show the average scores for musicians and non-musicians and all four participant groups on the different trial conditions of the flanker task.

Figure 3.3.3-1. Non-musicians' and musicians' performance on the three trial conditions of the flanker test

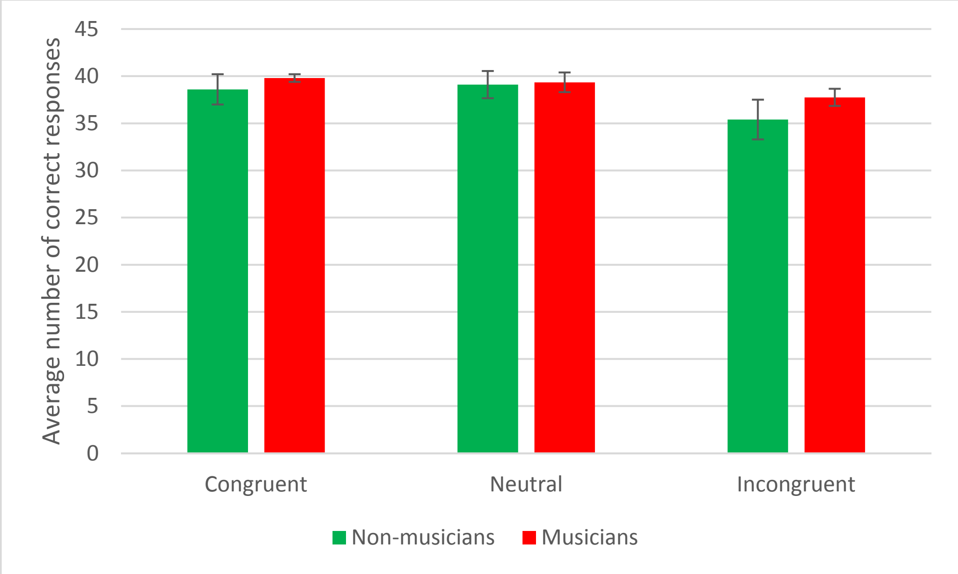
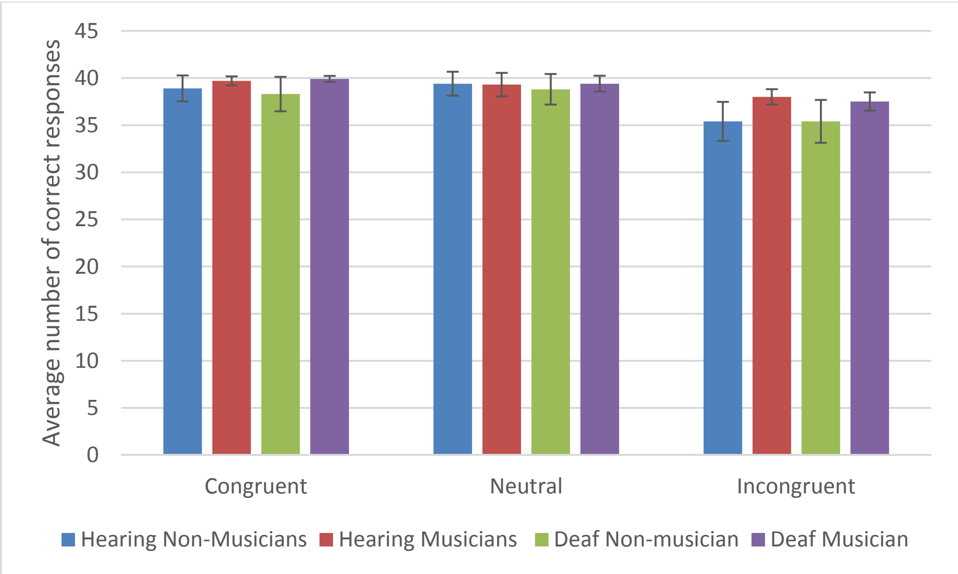



Figure 3.3.3-2. Performance of the four participant groups on the three trial conditions of the flanker test




*<u>Reaction times</u>*

Figure 3.3.3-3 shows the average reaction times (in milliseconds) of non-musicians and musicians for the three trial conditions of the flanker task. When comparing participants' reaction times on correct incongruent trials, no significant main effect was found for musician status ($F_{(1,36)}$=1.309, p=.260), or hearing status ($F_{(1,36)}$=.713, p=.404), and there was no significant interaction ($F_{(1,36)}$=.404, p=.529).

Table 3.3.3-2 Means and SD for the Flanker Task Incongruent trials reaction times

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 492.40 | 64.175 | 10 |
| | Deaf | 518.60 | 54.923 | 10 |
| | Total | 505.50 | 59.669 | 20 |
| Non-musician | Hearing | 523.90 | 50.452 | 10 |
| | Deaf | 527.60 | 53.392 | 10 |
| | Total | 525.75 | 50.593 | 20 |
| Total | Hearing | 508.15 | 58.461 | 20 |
| | Deaf | 523.10 | 52.920 | 20 |
| | Total | 515.63 | 55.558 | 40 |

Figure 3.3.3-3. Average reaction time of responses of non-musicians and musicians in each of the trial conditions of the flanker test

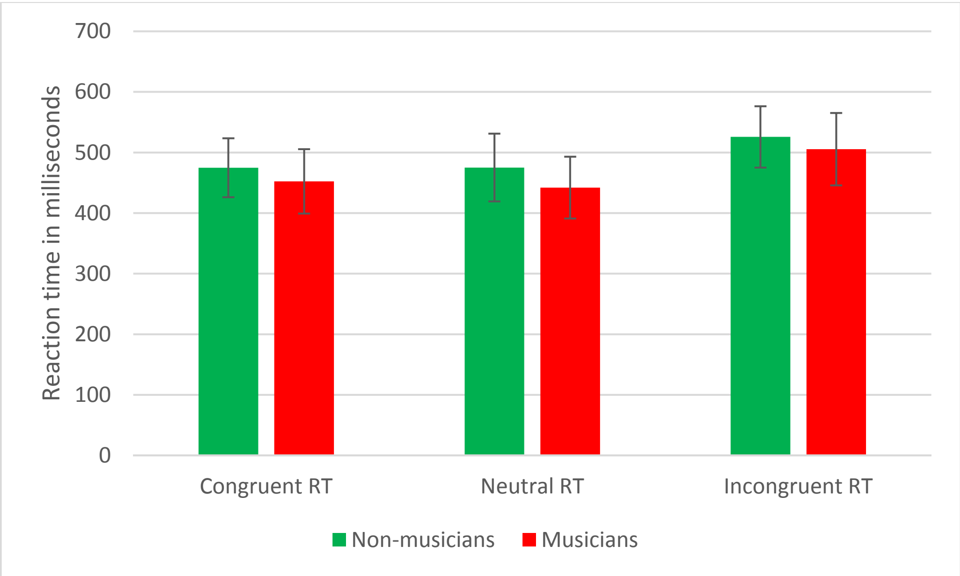
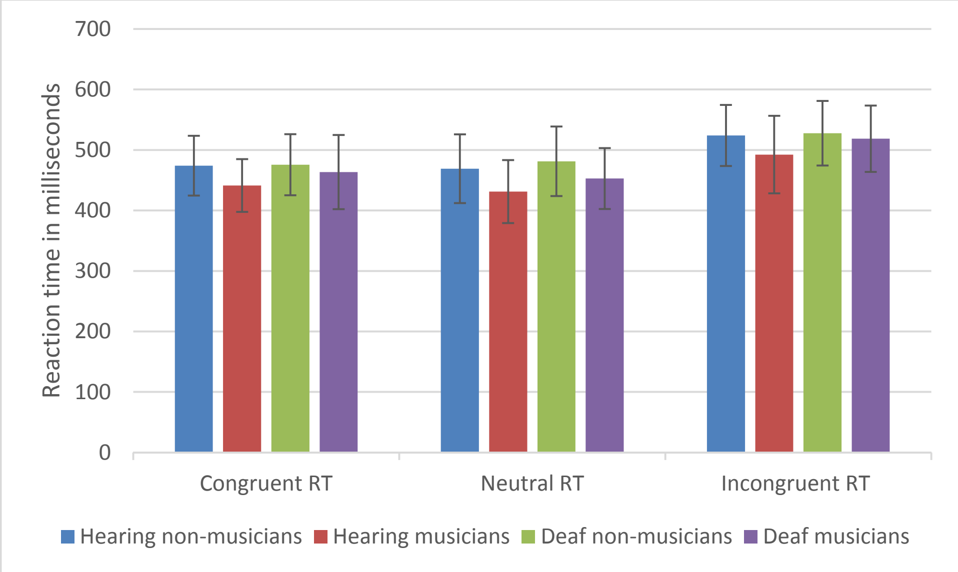


Figure 3.3.3-2. Average reaction time of responses for the four participant groups in each of the trial conditions of the flanker test




### 3.3.4 Number Stroop

Regarding overall scores for the number stroop task, a 2x2 factorial ANOVA revealed no significant main effect of musician status ($F_{(1,36)}$=3.388, p=.074), and a significant main effect of hearing status ($F_{(1,36)}$=6.842, p=.013, $\eta_p^2$=.16). There was no significant interaction ($F_{(1,36)}$=2.712, p=.108). These results indicate that for this task, hearing participants outperformed deaf participants, regardless of musician status.

Table 3.3.4-1 Means and SD for overall scores on the Number Stroop task

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 163.20 | 3.615 | 10 |
| | Deaf | 162.20 | 2.898 | 10 |
| | Total | 162.70 | 3.230 | 20 |
| Non-musician | Hearing | 163.00 | 3.742 | 10 |
| | Deaf | 158.60 | 2.675 | 10 |
| | Total | 160.80 | 3.888 | 20 |
| Total | Hearing | 163.10 | 3.582 | 20 |
| | Deaf | 160.40 | 3.283 | 20 |
| | Total | 161.75 | 3.657 | 40 |

For the EF-loaded incongruent trails, analysis revealed no significant main effect of musician status ($F_{(1,36)}$=.767, p=.387), and a significant main effect of hearing status ($F_{(1,36)}$=10.897, p=.002, $\eta_p^2$=.23). There was no significant interaction ($F_{(1,36)}$=2.401, p=.130).

Table 3.3.4-2 Means and SD for Incongruent trials of the Number Stroop Task

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 52.40 | 2.757 | 10 |
| | Deaf | 51.10 | 1.969 | 10 |
| | Total | 51.75 | 2.425 | 20 |
| Non-musician | Hearing | 52.90 | 2.807 | 10 |
| | Deaf | 49.30 | 1.636 | 10 |
| | Total | 51.10 | 2.900 | 20 |
| Total | Hearing | 52.65 | 2.720 | 20 |
| | Deaf | 50.20 | 1.989 | 20 |
| | Total | 51.43 | 2.659 | 40 |

Figures 3.3.4-1 and 3.3.4-2 show the performance of musicians and non-musicians and all four participant groups on the different trial conditions of the number stroop task.

Figure 3.3.4-1. Non-musicians' and musicians' performance on the Number Stroop task; the average scores in three trial conditions and overall total score

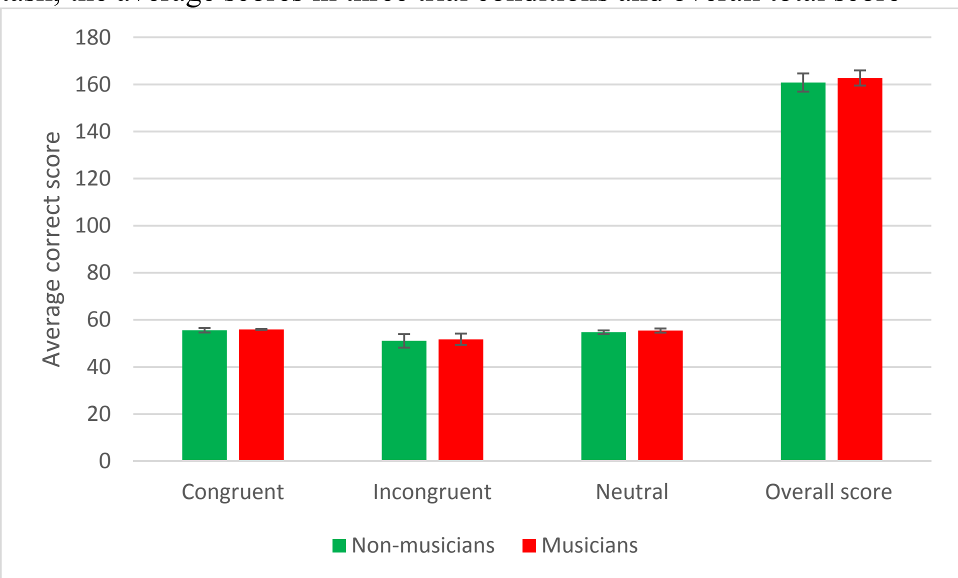
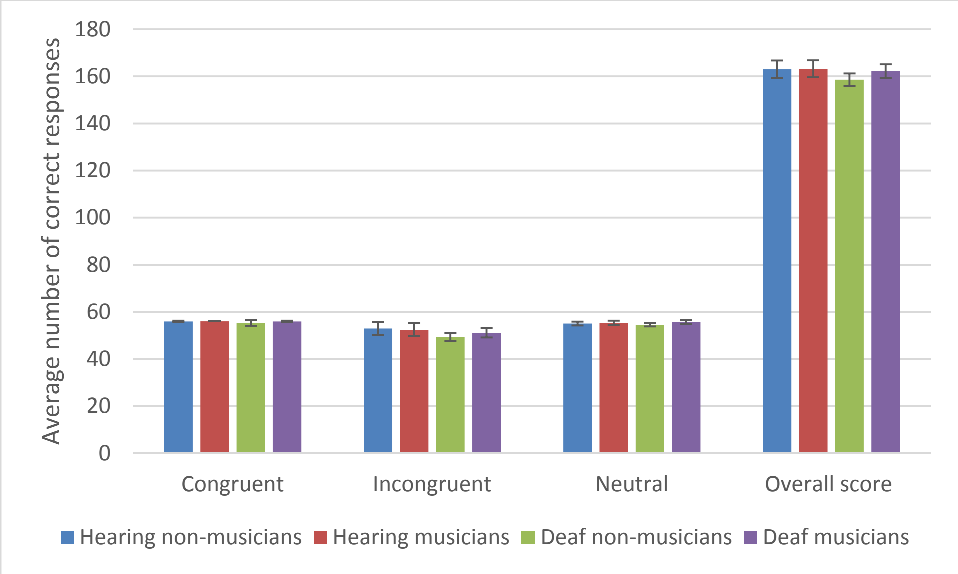


Figure 3.3.4-2 Performance of the four participant groups on the Number Stroop task; the average scores in three trial conditions and overall total score




*Reaction times*

Figures 3.3.4-3 and 3.3.4-4 show the average reaction times of non-musicians and musicians and each of the four participant groups for the three trial conditions of the number stroop task. When looking at participant reaction times for correct incongruent trials, analysis revealed no significant main effect of musician status ($F_{(1,36)}$=.350, p=.558) or hearing status ($F_{1,36)}$=.631, p=.432) and there was no significant interaction ($F_{(1,36)}$=1.731, p=.197)

Table 3.3.4-3 Means and SD for Number Stroop Incongruent Reaction Times

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 615.70 | 52.724 | 10 |
| | Deaf | 626.50 | 55.046 | 10 |
| | Total | 621.10 | 52.752 | 20 |
| Non-musician | Hearing | 630.70 | 85.849 | 10 |
| | Deaf | 587.00 | 63.056 | 10 |
| | Total | 608.85 | 76.661 | 20 |
| Total | Hearing | 623.20 | 69.764 | 20 |
| | Deaf | 606.75 | 61.068 | 20 |
| | Total | 614.98 | 65.248 | 40 |

Figure 3.3.4-3. Average reaction time of responses of non-musicians and musicians in each of the trial conditions of the number stroop task

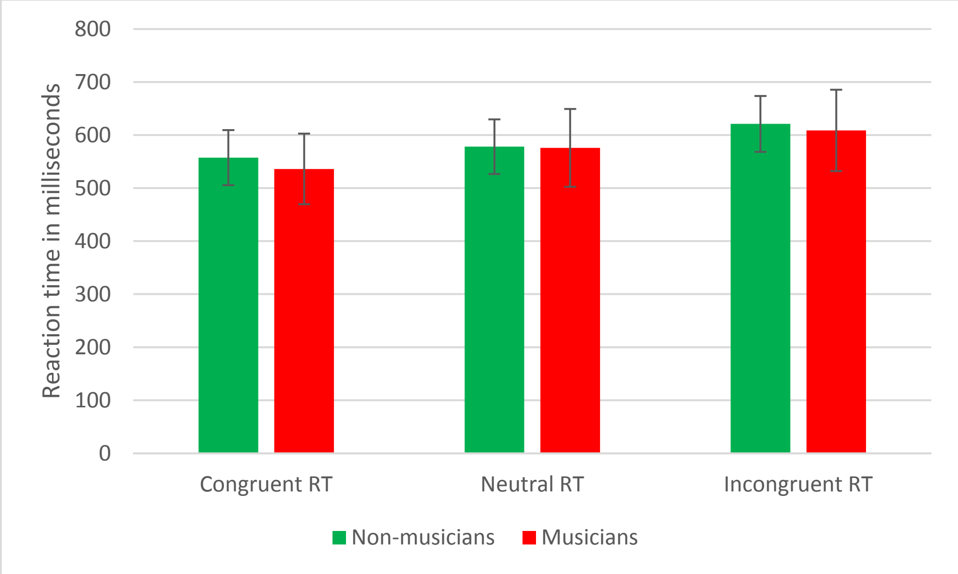
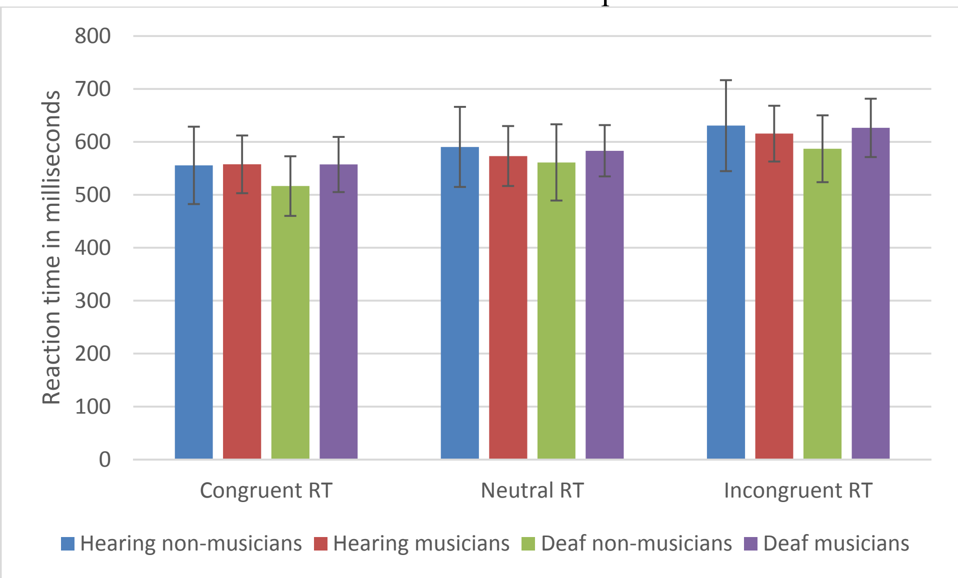



Figure 3.3.4-4. Average reaction time of responses for the four participant groups in each of the trial conditions of the number stroop task




### 3.3.5 Simon Task

For overall scores on the Simon task, 2x2 factorial ANOVA revealed a significant main effect of musician status ($F_{(1,36)}$=17.894, p<.001, $\eta_p^2$=.332) and no significant main effect of hearing status ($F_{(1,36)}$=.026, p=.873). No significant interaction was found ($F_{(1,36)}$=.072, p=.790). This suggests that musicians outperformed non-musicians on this task, regardless of hearing status.

Table 3.3.5-1 Means and SD for overall scores on the Simon Task

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 136.60 | 3.062 | 10 |
| | Deaf | 136.70 | 3.057 | 10 |
| | Total | 136.65 | 2.978 | 20 |
| Non-musician | Hearing | 132.90 | 2.885 | 10 |
| | Deaf | 132.50 | 2.799 | 10 |
| | Total | 132.70 | 2.774 | 20 |
| Total | Hearing | 134.75 | 3.462 | 20 |
| | Deaf | 134.60 | 3.575 | 20 |
| | Total | 134.68 | 3.474 | 40 |

For the EF-loaded incongruent trials, a 2x2 factorial ANOVA revealed a significant main effect of musician status ($F_{(1,36)}$=28.928, p<.001, $\eta_p^2$=.45). There was no significant main effect of hearing status ($F_{(1,36)}$=.108, p=.744), and no significant interaction was found ($F_{(1,36)}$=.976, p=.330).

Table 3.3.5-2 Means and SD for Incongruent Simon trials

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 58.30 | 1.567 | 10 |
| | Deaf | 58.60 | 1.647 | 10 |
| | Total | 58.45 | 1.572 | 20 |
| Non-musician | Hearing | 56.30 | 1.160 | 10 |
| | Deaf | 55.70 | 1.337 | 10 |
| | Total | 56.00 | 1.257 | 20 |
| Total | Hearing | 57.30 | 1.689 | 20 |
| | Deaf | 57.15 | 2.084 | 20 |
| | Total | 57.22 | 1.874 | 40 |

Figures 3.3.5-1 and 3.3.5-2 show the average performance of musicians and non-musicians and all four participant groups on the Simon inhibition task.

Figure 3.3.5-1. Non-musicians' and musicians' performance on the Simon task; average number of correct responses for the congruent and incongruent conditions

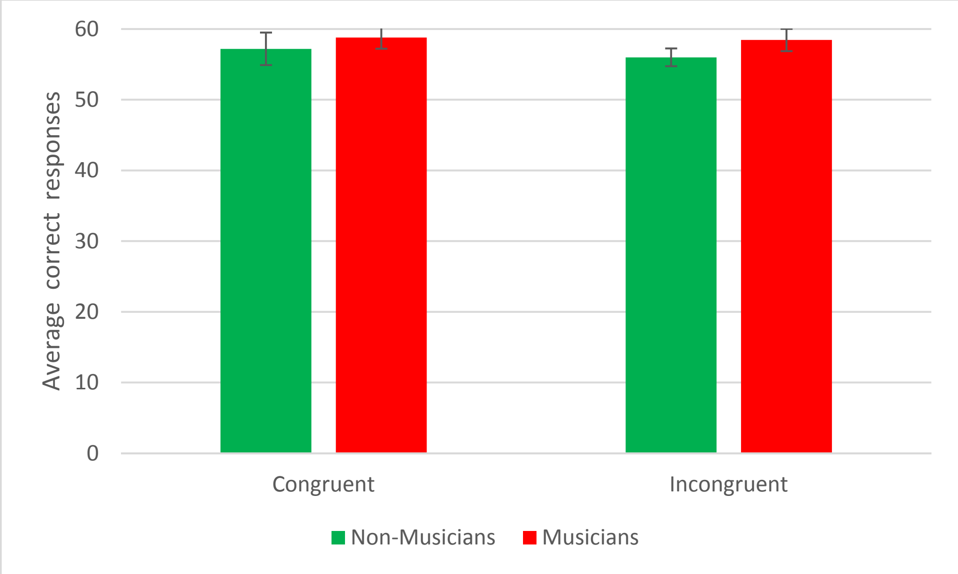
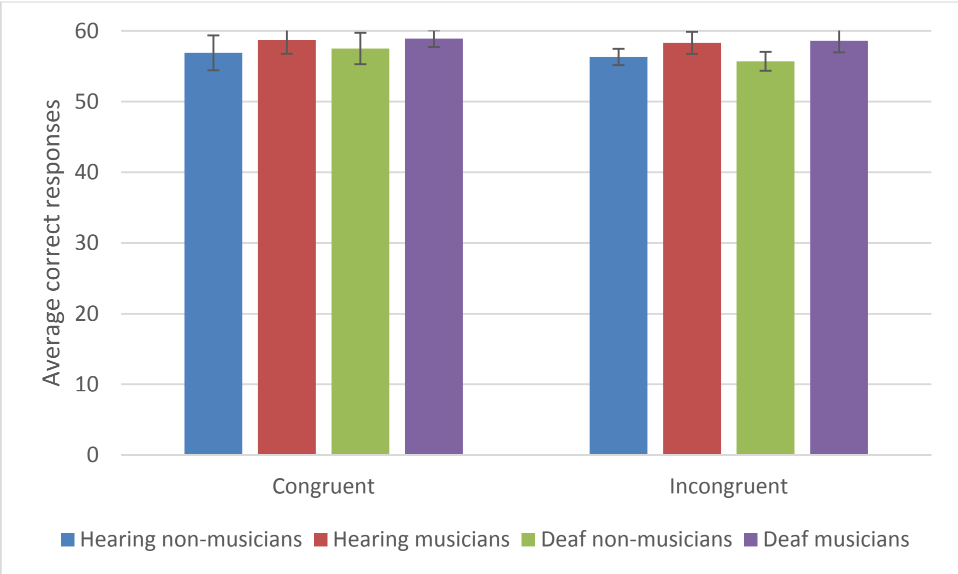



Figure 3.3.5-2. Performance of the four participant groups on the Simon task; average number of correct responses for the congruent and incongruent conditions




*Reaction time*

Figures 3.3.5-3 and 3.3.5-4 show the average reaction times of non-musicians and musicians for the three trial conditions of the Simon task. Analysis of participants' reaction times for correct incongruent trials found no significant main effect of musician status ($F_{(1,36)}$=.345, p=.561), however a significant main effect of hearing status was found ($F_{(1,36)}$=5.221, p=.028 $\eta_p^2$=.13). This suggests that while musicians (regardless of hearing status) had better accuracy on this task, the hearing participants had a significantly faster reaction time than deaf participants.

Table 3.3.5-2 Means and SD for Simon Task Incongruent Reaction Times

| Musician or non musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 466.50 | 62.701 | 10 |
| | Deaf | 500.50 | 48.033 | 10 |
| | Total | 483.50 | 57.090 | 20 |
| Nonmusician | Hearing | 475.20 | 27.535 | 10 |
| | Deaf | 509.30 | 43.433 | 10 |
| | Total | 492.25 | 39.481 | 20 |
| Total | Hearing | 470.85 | 47.342 | 20 |
| | Deaf | 504.90 | 44.798 | 20 |
| | Total | 487.88 | 48.651 | 40 |

Figure 3.3.5-3. Average reaction time of responses of non-musicians and musicians in each of the trial conditions of the number stroop task

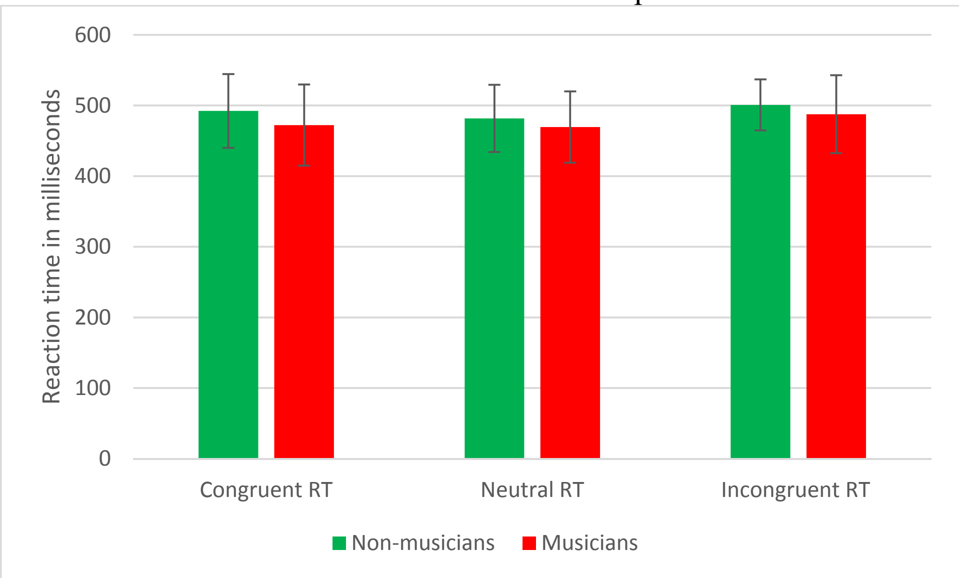
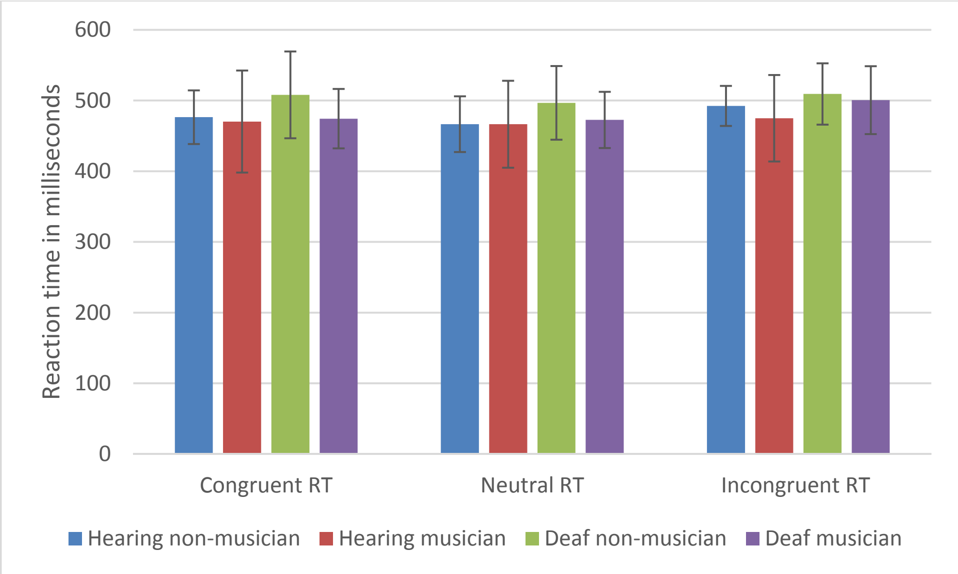


Figure 3.3.5-4. Average reaction time of responses for the four participant groups in each of the trial conditions of the Simon interference task.




### 3.3.6 Wisconsin Card Sort

One of the participants, Deaf musician DM04, was unable to complete this task due to colour-blindness which impaired his ability to distinguish between yellow, green, and red stimuli. Therefore, for this task the Deaf musician group has N=9, and the 'Musician' group (disregarding hearing status) has N=19.

The first set of analyses for this task looked at the percentage of correct moves made by participants. A 2x2 factorial ANOVA found no significant main effect of musician status ($F_{(1,35)}$=.406, p=.528), however, a main effect of hearing status was revealed ($F_{(1,35)}$=7.823, p=.008, $\eta_p^2$=.183) No significant interaction was found ($F_{(1,35)}$=3.535, p=.068).

Table 3.3.6-1 Means and SD for % correct responses on the Wisconsin Card Sorting Task

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 85.02 | 2.996 | 10 |
| | Deaf | 77.30 | 6.497 | 9 |
| | Total | 81.36 | 6.239 | 19 |
| Non-musician | Hearing | 80.86 | 4.354 | 10 |
| | Deaf | 79.35 | 6.134 | 10 |
| | Total | 80.11 | 5.235 | 20 |
| Total | Hearing | 82.94 | 4.216 | 20 |
| | Deaf | 78.38 | 6.219 | 19 |
| | Total | 80.72 | 5.705 | 39 |

Analysis of the percentage of perseverative errors made by participants revealed no significant main effect of musician status ($F_{(1,35)}$=.713, p=4.04); or hearing status ($F_{(1,35)}$=3.493, p=.070); and no significant interaction was found ($F_{(1,35)}$=1.094, p=.303).

Table 3.3.6-2 Means and SD for % perseverative errors on the Wisconsin Card Sort Task

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 9.27 | .681 | 10 |
| | Deaf | 12.68 | 5.794 | 9 |
| | Total | 10.88 | 4.269 | 19 |
| Non-musician | Hearing | 11.48 | 1.296 | 10 |
| | Deaf | 12.45 | 4.475 | 10 |
| | Total | 11.96 | 3.244 | 20 |
| Total | Hearing | 10.37 | 1.519 | 20 |
| | Deaf | 12.56 | 4.995 | 19 |
| | Total | 11.44 | 3.768 | 39 |

Analysis of the percentage of non-perseverative errors made by participants revealed no significant main effect of musician status ($F_{(1,35)}$=.005, p=.941); or hearing status ($F_{(1,35)}$=3.278, p=.079); and no significant interaction was found ($F_{(1,35)}$=.728, p=.399).

Table 3.3.6-3 Means and SD for % non-perseverative error on the Wisconsin Card Sort Task

| Musician or non-musician | Hearing status | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Musician | Hearing | 4.67 | 3.717 | 10 |
| | Deaf | 8.86 | 6.641 | 9 |
| | Total | 6.65 | 5.580 | 19 |
| Non-musician | Hearing | 6.13 | 4.733 | 10 |
| | Deaf | 7.63 | 4.279 | 10 |
| | Total | 6.88 | 4.459 | 20 |
| Total | Hearing | 5.40 | 4.209 | 20 |
| | Deaf | 8.21 | 5.399 | 19 |
| | Total | 6.77 | 4.970 | 39 |

Figures 3.3.6-1 to 3.3.6-4 show the percentage of correct responses and types of errors made by musicians, non-musicians and all four participant groups on the Wisconsin cards sorting task.

Figure 3.3.6-1. The percentage of correct responses and percentage of errors made by non-musicians and musicians on the card sorting task

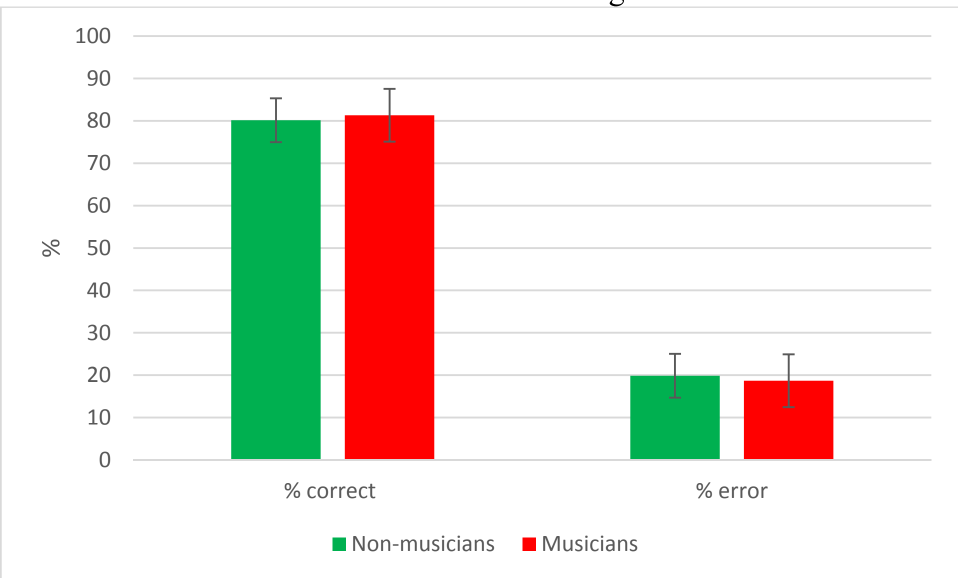


Figure 3.3.6-2. The average number of perseverative responses, errors, non-perseverative responses and failure to maintain set made by non-musicians and musicians

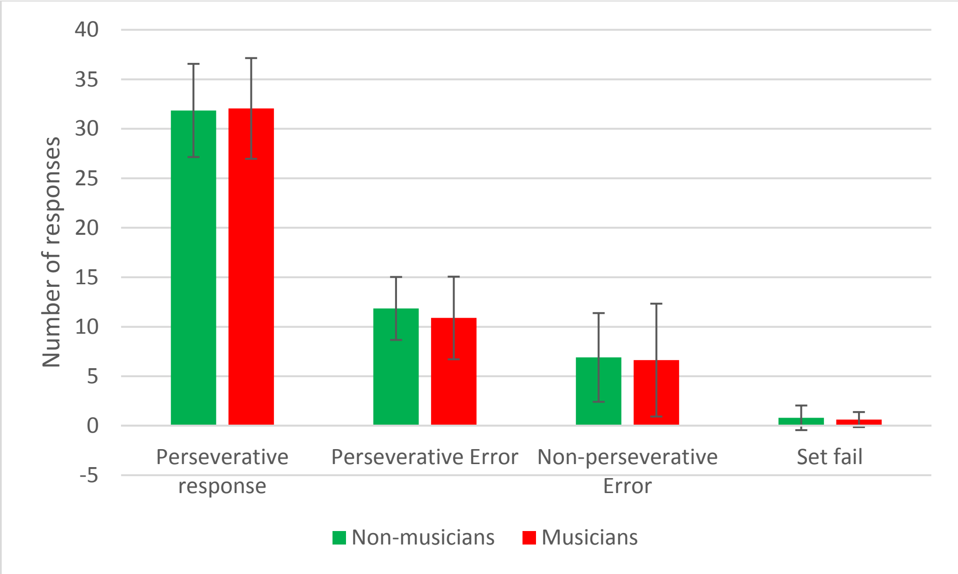



Figure 3.3.6-3. The percentage of correct responses and percentage of errors made by the four participant groups on the card sorting task

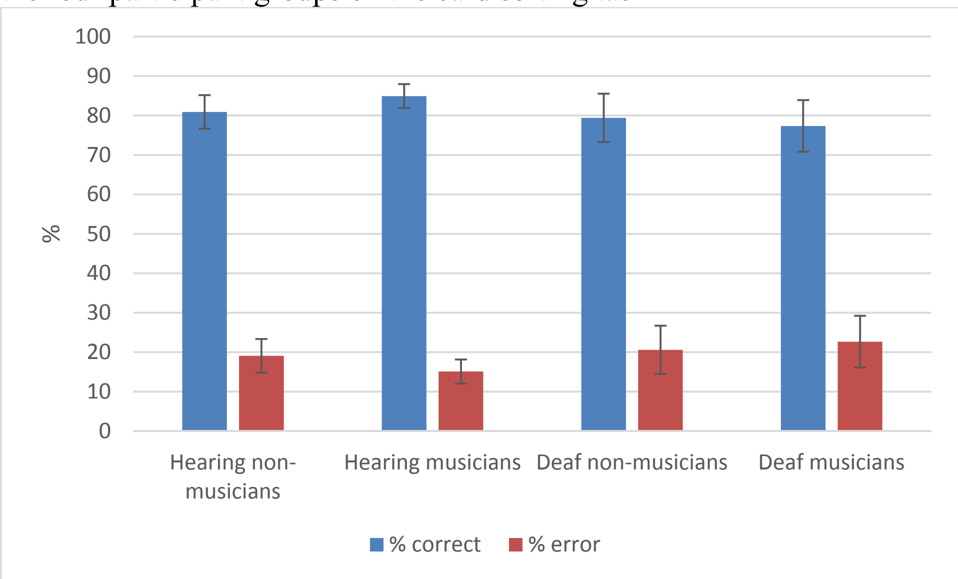
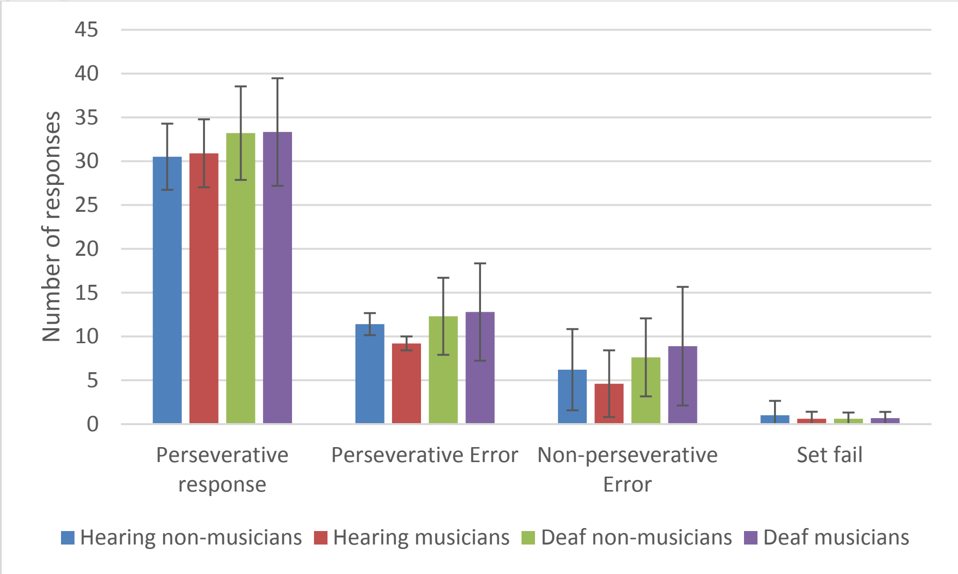


Figure 3.3.6-4. The average number of perseverative responses, errors, non-perseverative responses and failure to maintain set made by the four participant groups.



### 3.3.7 Summary of Study 1 results

As a large number of tests were administered and a large number of group comparisons were made, able 3.3.7 provides a summary of the significant effects found across all of the EF tasks. Shaded areas indicate significant main effects of musician status or hearing status.

Table 3.3.7 Summary table of significant differences found across the EF tasks

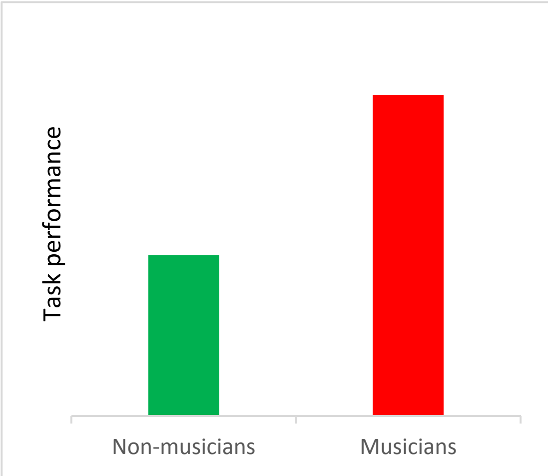
| Assessment | Executive Function | Musician Mean (SD) | Non-musician Mean (SD) | Hearing Mean (SD) | Deaf Mean (SD) | Significance | Partial η2 |
|---|---|---|---|---|---|---|---|
| Visuospatial span (Overall) | Working Memory | 15.50 (2.95) | 12.85 (2.80) | 14.65 (3.33) | 13.70 (2.94) | p=.007 | 0.19 |
| Visuospatial span (Forwards) | Working Memory | 8.10 (.37) | 6.40 (.42) | 7.45 (2.40) | 7.05 (1.40) | p=.005 | 0.2 |
| Flanker (Overall) | Inhibition (control) | 116.70 (1.75) | 113.30 (4.56) | 115.35 (3.57) | 114.65 (4.12) | p=.004 | 0.21 |
| Flanker (Incongruent) | Inhibition | 37.75 (.91) | 35.40 (2.11) | 36.70 (2.03) | 36.45 (2.01) | p<.001 | 0.36 |
| Simon (Overall) | Inhibition | 136.65 (2.98) | 132.70 (2.77) | 134.75 (3.46) | 134.60 (3.58) | p<.001 | 0.33 |
| Simon (Incongruent) | Inhibition | 58.45 (1.57) | 56.00 (1.26) | 57.30 (1.69) | 57.30 (2.08) | p<.001 | 0.45 |
| Number Stroop (Overall) | Inhibition | 162.70 (3.23) | 160.80 (3.89) | 163.10 (3.58) | 160.40 (3.28) | p=.013 | 0.16 |
| Number Stroop (Incongruent) | Inhibition | 51.75 (2.43) | 51.10 (2.90) | 52.65 (2.72) | 50.20 (2.66) | p=.002 | 0.23 |
| Number Stroop (Incongruent RT) | Inhibition | 483.50 (57.09) | 492.25 (39.48) | 470.85 (47.34) | 504.90 (44.80) | p=.028 | 0.13 |
| Card Sorting (% Correct) | Cognitive Flexibility | 81.36 (6.34) | 80.11 (5.24) | 82.94 (4.22) | 78.38 (6.22) | p=.008 | 0.18 |
| Trails Part B | Cognitive Flexibility | 37.60 (8.79) | 37.40 (11.57) | 34.20 (9.41) | 40.80 (9.98) | p=.043 | 0.11 |
| Trails Interference Score | Cognitive Flexibility | 18.55 (7.40) | 18.90 (8.57) | 15.95 (6.48) | 21.50 (8.37) | p=.027 | 0.13 |

### 3.4 Discussion

This study aimed to investigate whether deaf musicians show the same pattern of enhancement of executive control as found in previous studies of hearing musicians. This question is interesting because, to date, no other study has considered how deafness may modulate the impact of musical training on EF skills. Previous studies (reviewed in chapter 2, section 2.9) discuss brain plasticity with regards to EF, and the potential for musical tuition to enhance particular EFs, such as inhibition and cognitive flexibility. This study adds to the debate surrounding music, plasticity and EF by including a unique group of musicians with the additional variable of deafness. The secondary aim of the study was to address the question of whether enhanced areas of EF in musicians are due to improved auditory temporal processing skills, or if they are mediated by improvements in domain-general cognitive skills linked to music learning and practice. Including deaf musicians and deaf non-musicians as participant groups again allows us to untangle this question as we can look at music learning experience in the context of reduced auditory stimulation.

There are three main findings from this study. The first is that, for the many of the EF tasks, significant differences are found between the performance of non-musicians and musicians, regardless of hearing status. For many of the EF tasks, the pattern supported by the data is that of prediction 1 (figure 3.1.2a, repeated below). Musicians achieved significantly higher overall scores for tasks involving visuospatial working memory and inhibitory skills (i.e. the Visuospatial Span, Flanker, and Simon tasks), however, no differences were found between groups on one of the inhibition measures - the Number stroop task. There was no significant difference between non-musicians' and musicians' performance on the Wisconsin card sorting task, a measure of cognitive flexibility. As with Bialystok's (2009) study, no differences were found between non-musicians and musicians for the trail making task, indicating that both groups had comparable processing speeds.

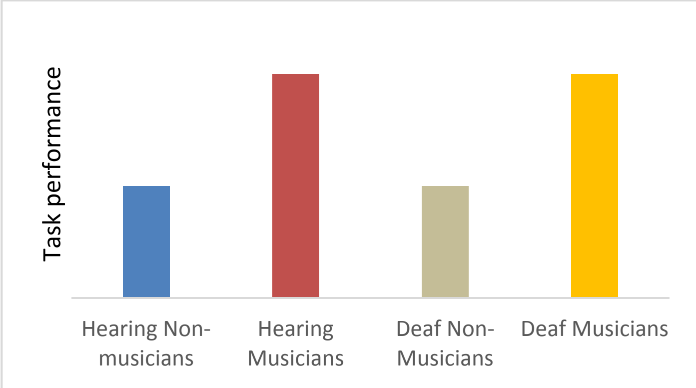
Figure 3.1.2a Prediction 1: Musicians will have better performance on EF tasks in comparison to non-musicians.




The second finding of the present study relates to the pattern of performance between the four participant groups. Of particular interest in the comparison of the four participant groups is whether any EF advantage found for musicians is driven mainly by the hearing musician group, or whether deaf musicians also show the same EF advantage over non-musicians. For the visuospatial span task (measuring visuospatial working memory), both groups of musicians achieved a significantly higher score than the deaf non-musicians. However, it was the group of hearing musicians that performed significantly better than both of the non-musician groups in the forward span condition, while there was no significant difference between the deaf musicians and other groups in this condition.

Analysis of data from two of the inhibitory tasks - the Flanker and Simon tasks - revealed that both hearing and deaf musicians had higher accuracy than the two non-musician groups for overall score and on the EF-loaded incongruent trials. These findings support the prediction made in figure 3.1.2b in section 3.1.2 (repeated below). The full implications of these findings will be described in the general discussion in Chapter 7.

Figure 3.1.2b. Prediction 2: Pattern of results if hearing and deaf musicians have better performance on some EF tasks than hearing and deaf non-musicians.




The third finding of note from this study is that for some tasks there was no significant difference in performance between the two musician groups and two non-musician groups. Given the significant differences in performance found between groups of musicians and non-musicians on the Flanker and Simon tasks, it is perhaps surprising that neither group of musicians showed a significant advantage in the Number Stroop task when compared to non-musicians. In this task, both groups of musicians *and* the hearing non-musicians outperformed the deaf non-musicians in terms of overall score. Furthermore, the hearing non-musicians and hearing musicians outperformed the deaf non-musicians on the EF-loaded incongruent trials in Number Stroop task. However, there was no significant difference in performance between the deaf musicians and the two hearing groups. The data indicates that the deaf non-musicians had poorer performance on this particular task in comparison to all of the three other participant groups.

Notably, there was no significant difference between musicians' and non-musicians' performance on the Wisconsin Card Sort task. However, the data from the four participant groups showed that hearing musicians performed the task more accurately than both of the deaf groups and also made fewer perseverative errors than the deaf musician group. While there appears to be no beneficial effect of music tuition on performance on the card sorting task, the difference between the two groups of musicians is indicative of a difference between the performance of deaf and hearing participants on this task. This is the only task in which the hearing musicians have better performance than the deaf musicians.

No significant differences were found for reaction time between the four groups on any of the computerised tasks. A discussion of the results showing improved accuracy but not reaction time for musicians on some tasks will be made in Chapter 7, however this important result suggests that there was no effect of fine motor response time between the groups. Improved fine motor skills and dexterity may have been a potential benefit for musicians who play instruments and began tuition in early childhood, particularly for the Number Stroop task, where responses involved three computer keys (Wantanabe, Savion-Lemieux, & Penhune, 2007).

While findings in previous research investigating the links between music and EF have been varied, this study contributes to the literature as the first to include deaf individuals. The findings of this study support previous research which suggests music training may result in functional plasticity in musicians' brains in cognitive areas such as inhibition and working memory; and not purely in auditory processing skills. In this instance, visuospatial working memory and inhibitory skills have emerged as areas of cognitive benefit to musicians, including those with limited access to auditory information, supporting the hypothesis that musical training and practice has domain-general effects, enhancing executive control even for tasks that bear no obvious relation to music.

However, this study (along with other comparative studies involving long-term musicians) is limited in its ability to demonstrate a causal link between musical training and enhanced EF. It is entirely possible that musicians are a self-selecting group, whose advantages in some areas of EF were present prior to their musical training. Furthermore, it may have been their stronger inhibitory and attention skills which drew them to becoming musicians and enabled them to be conscientious and disciplined in order to persist with hours of practice. Therefore, while music appears to be a promising activity with the potential to improve areas of EF, only training studies are able to determine any causal effects**.** The finding that deaf musicians have better performance on some EF tasks than non-musicians deserves replication and potentially provides a basis for further investigation through the implementation of music training studies involving deaf individuals. Additionally, as there is some evidence that musical training improves performance on EF tasks in hearing children (Janus, Lee, Moreno, & Bialystok, 2016; Moreno, Bialystok, Barac, Schellenberg, Cepeda, & Chau, 2011) the current study supports the prediction that music training might also enhance EF skills in deaf children, a group that is at risk of delayed EF development. This prediction, (and the findings from the adult musician study) motivated the main study of this thesis. The following chapters will describe the development, implementation and evaluation of a music-based EF intervention for deaf children.

# Chapter 4 STUDY 2: A music-based Executive Function Training Study with Deaf Children.

This Chapter will introduce the main study of the thesis; the creation, implementation and evaluation of an EF intervention designed for primary school aged deaf children. It will explain the rationale for the study, the research questions it aims to address, and how it will contribute to the current literature on deaf children's EF skills and EF interventions and the association between EF and musical training.

## 4.1 Rationale for Study 2

The study described in the following chapters reports on the creation, implementation and evaluation of a music-based EF intervention for deaf children. It has been established (discussed in section 2.6 of this thesis) that deaf children's EF skill and academic achievement often falls behind that of their hearing peers. Discussion continues regarding the causes for the discrepancy in achievement, with the potential impact of language delay on EF development and subsequent sufficient access to education being key issues. While these issues are being discussed and debated, there is great need for evidence-based intervention studies with this group.

While the literature may be mixed, there are numerous studies that show links between music, language and executive functions (e.g. Dege, Kubicek, & Schwarzer, 2011; Patel, 2009; Moreno & Bidelman, 2014). The results of study 1 indicate that musical training also holds potential benefits to EF for deaf people, just as it does for hearing people. However, as study 1 was a comparative study not a training study, the findings fall short of being able to claim a causal link between music training and enhanced EF. This second study aims compliment the first, by investigating the potential for a music-based EF study to improve EF skills in deaf children. Several studies in the past have looked at the effect of musical training on hearing children's EF skills (e.g. Hurwitz, Wolff, Bortnick, & Kokas, 1975; Moreno, et al., 2011), however very little is known about its potential benefits for deaf children. This study will contribute to exisitng knowledge by approaching the examination of links between music and EF from the perspective of deafness.

### 4.2 Aims of Study 2

Building on previous studies of EF and music, the current study seeks to evaluate the effectiveness of a music-based EF intervention for deaf children and aims to address the following research questions:

1. Does the intervention have a positive effect on deaf children's EF skills?
2. Which children benefit the most? (Children with poor EF, or higher ability children? Is there a pattern to EF improvement?)
3. Are some areas of EF more 'trainable' than others?

### 4.3 Using music as an intervention tool

There are additional practical reasons for using music as a tool to deliver EF training to primary school-aged children. In designing an intervention that would be attractive, practical and cost-effective for schools, music offers a viable platform around which to build an EF intervention programme. Many schools are equipped with basic musical instruments and resources, resulting in minimal to no expense to school boards, were they to adopt an intervention of this kind. Music making requires a mixture of EF skills including attention, planning and anticipation, flexibility and inhibition. However, the social aspect of music is also beneficial and rewarding for children, and this is likely to be an attractive additional element for schools.

Another consideration that needs to be made prior to the creation of an EF intervention is who are the people most likely to be carrying it out? In the case of the current study, teachers of the deaf, music teachers and classroom teaching assistants would be the most likely group of practitioners to lead the intervention under normal, non-experimental conditions. They are people who have built relationships with the children and are best placed to know the children's abilities and how to challenge them. With this consideration as starting point, close collaboration with teachers working with deaf children was essential during the development of an EF intervention for deaf children. The following section describes the findings from a questionnaire sent to teachers of the deaf and other professionals working with deaf children throughout the

UK, regarding their experiences, usage and opinions of currently available EF interventions

## 4.4 Practitioners' Awareness and Use of Current Executive Function Interventions: A Survey of Teachers of the Deaf and Others Working with Deaf Children.

There are a variety of curriculum "add-ons", full-scale curricula and computerised training software for EF training currently available to schools, other academic institutions and the general public. Before embarking on the design for an intervention tailored towards improving EF skills in deaf children, it was necessary to establish the familiarity of Teachers of the Deaf and those who work with deaf children on a regular basis with EF interventions that already exist. By including Teachers of the Deaf and other professionals at an early stage of the study, an overall picture of deaf children's current exposure to EF interventions could be established. Feedback from those working with deaf children was essential in order to determine what strategies they felt have been useful or not, and also what barriers may exist to delivering or maintaining certain interventions. To this end, an online questionnaire was developed to gather data on professionals' current experience of EF interventions.

### 4.4.1 Questionnaire Design

The questionnaire consisted of 16 questions, which used a mixture of multiple choice and open-ended responses. The first five questions collected contact and background information from respondents including their name, contact email, profession and the name of the school that they work at. There was an option for respondents to complete the questionnaire anonymously, as it was felt that more people would respond and answer questions honestly if they did not have to identify themselves. However, participants were given the option to be included in a prize draw for a £10 Amazon gift voucher, for which they needed to provide their name and email address.

Questions six to eight asked respondents about the modes of communication used at the schools they work at/visit, such as British Sign Language (BSL), Sign supported English (SSE), Total Communication, Makaton[2] or spoken English. They were also asked about the number of deaf children who attend the school and the age range of the children that they work with.

Questions nine to twelve focused on the respondents' experience of executive function interventions. Question nine asked whether they have been trained in or used any specific curriculum additions, for which a list of interventions are given. They were also given the option to include another intervention that may not be on the list. The next open-ended question allowed the respondent to provide a brief overview of their experience with EF curriculum additions (if any), and their opinion of the intervention. Questions eleven and twelve had the same format as nine and ten, but referred to computer-based interventions.

Question thirteen was not about specific interventions, but asked about individual strategies used by the respondents and their school to help promote EF skills in their students. This open-ended question was included in order to record any examples of teacher-recommended interventions and activities that were not included in the questionnaire or are necessarily available as an "off the shelf" product. Examples provided in response to this question may potentially inform the design of an EF intervention for deaf children.

Finally, respondents were asked about the number of music and exercise classes children in their school take part in every week, and whether they would be interested in taking part in training aimed at improving deaf children's EF skills.

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[2] Makaton is a communication system which uses manual signs and pictorial symbols to support spoken language. The signs and symbols are used in conjunction with speech and follow spoken word order. Makaton is used with children with a variety of special needs who have particular difficulty with spoken communication.

### 4.4.2 Method

The questionnaire was created using the web–based survey tool "Opinio", supplied by University College London's Information Services Division. A link to the questionnaire (see appendix IV), along with background information about the study was emailed to members on a mailing list for the British Association of Teachers of the Deaf (BATOD). Recipients were encouraged to forward the link to colleagues, including Teaching Assistants and Speech and Language Therapists. The link was also sent out through Twitter, and was targeted at professionals who work with deaf children in the UK.

Overall, 134 people contributed their responses to the questionnaire and, of these, 76 completed every question. It was not compulsory to answer every question as some such as "how many hours per week do children in your school spend taking part in exercise classes?" might not necessarily have been known by all respondents.

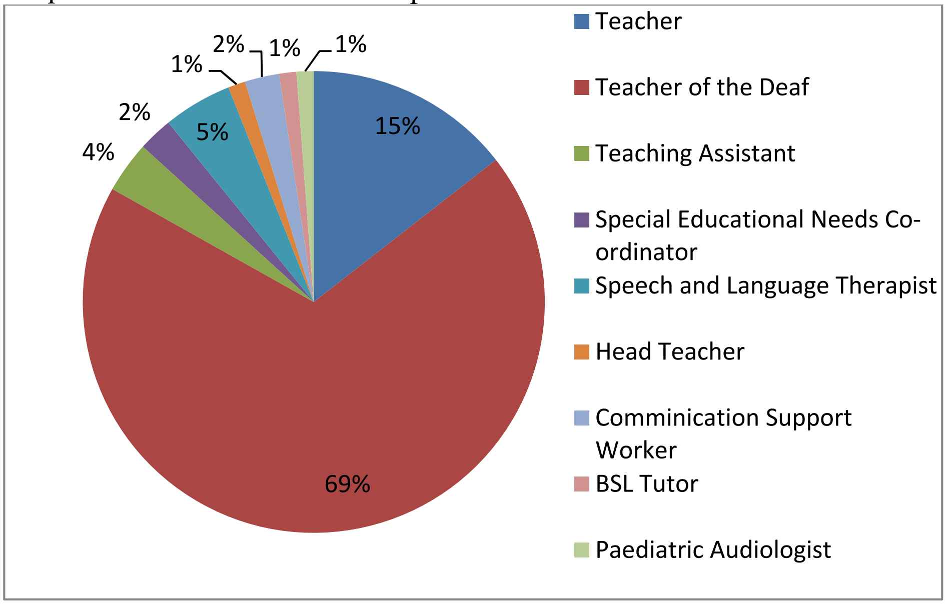
### 4.4.3 Results

Questions one, two and four were optional and referred to the respondent's name, contact details and the school at which they worked. Those data were kept confidential and are not relevant for data analysis.

<u>Question 3: Profession</u>

Question 3 asked respondents to indicate their profession. Available options were Teacher, Teacher of the Deaf, Teaching Assistant, Special Educational Needs Co-ordinator, Speech and Language Therapist or 'Other'. 84 people gave responses for this question and 50 refrained. Those who selected 'other' included a Paediatric Audiologist, BSL Tutor, Head Teacher and two Communication Support Workers. Graph 4.4.3-1 shows the profession of respondents.

Graph 4.4.3-1 Profession of Respondents



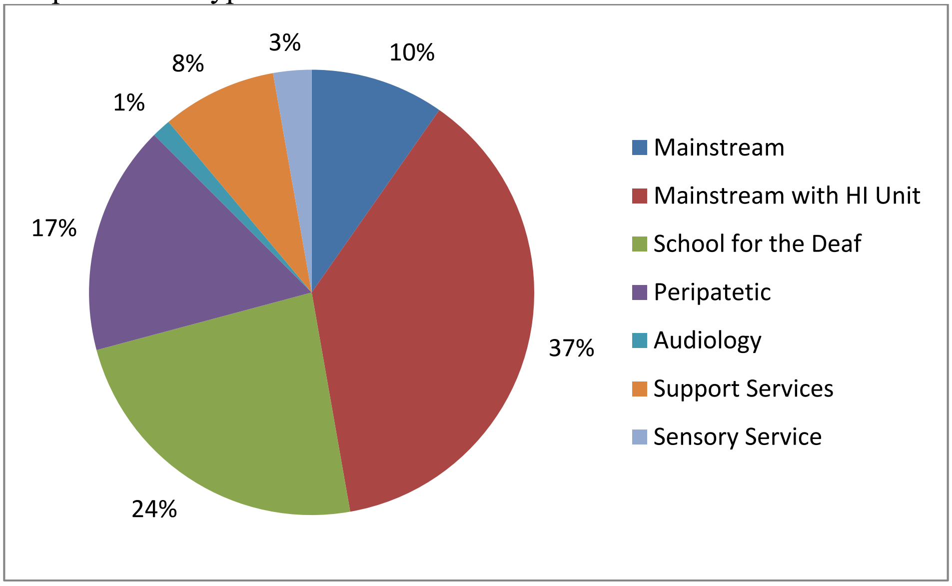

As shown in graph 4.4.3-1 above, the majority of respondents (69%) were Teachers of the deaf. This is likely due to the fact that the link to the questionnaire was initially sent out to the BATOD mailing list. However, it should also be noted that 50 respondents did not provide information about their profession.

Question 5: Type of School

Question 5 referred to the type of school that the respondent worked in, whether mainstream, a mainstream school with a hearing impaired unit, or a specialist school for the Deaf. There was also the option to select "other" if the respondent worked for another service.

78 people gave information about the type of school that they worked in. Many of the teachers of the deaf who responded were peripatetic and therefore worked in a variety of schools with differing numbers of children on their caseloads. Graph 4.4.3-2 shows the type of school environment the respondents worked in, including a few who were not based in schools but in audiology departments or sensory services.

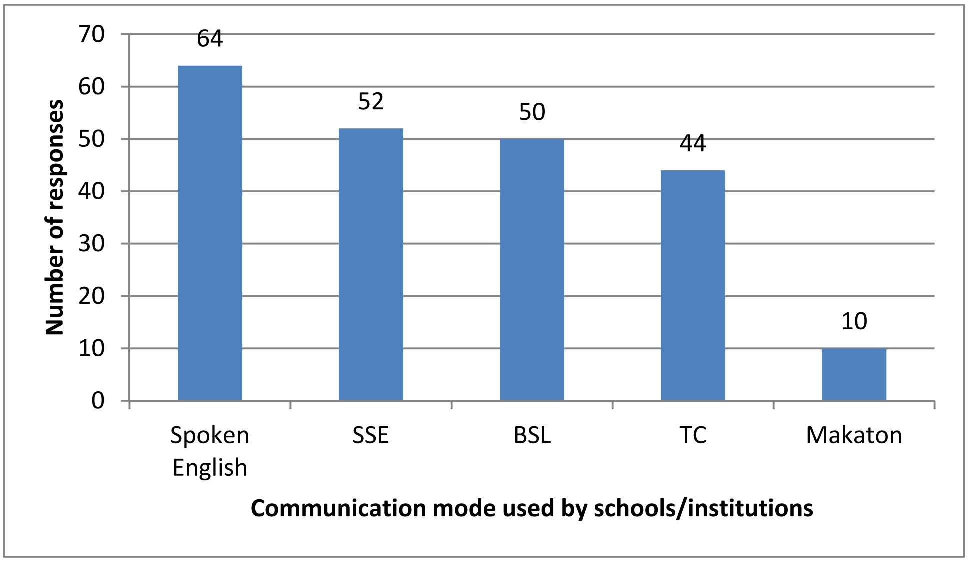
Graph 4.4.3-2 Type of School




Question 6: Communication

82 respondents provided information about the modes of communication used in the children's schools and these are shown below in Graph 4.4.3-3. Given the heterogeneity of the population of deaf school children in the UK, (with many schools using several modes of communication depending on the preferences of each child) respondents were encouraged to select as many communication modes as were relevant.

Graph 4.4.3-3 Communication Modes



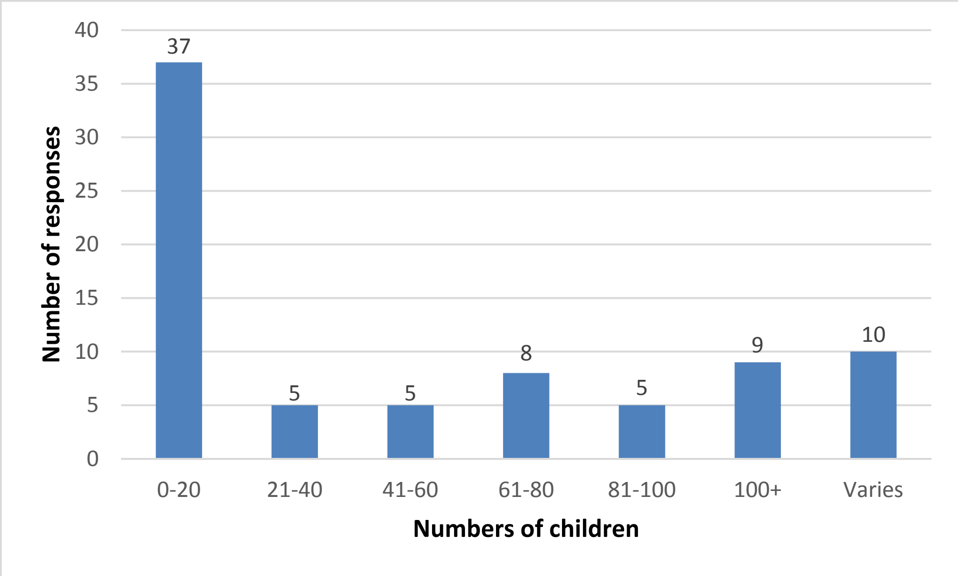
The data collected from this question complements the data from question 5, with a large number of children exposed to spoken English reflecting the fact that 47% of respondents reported working in mainstream schools or mainstream schools with a hearing impaired unit.

Questions 7 and 8 – Numbers of deaf children and age range

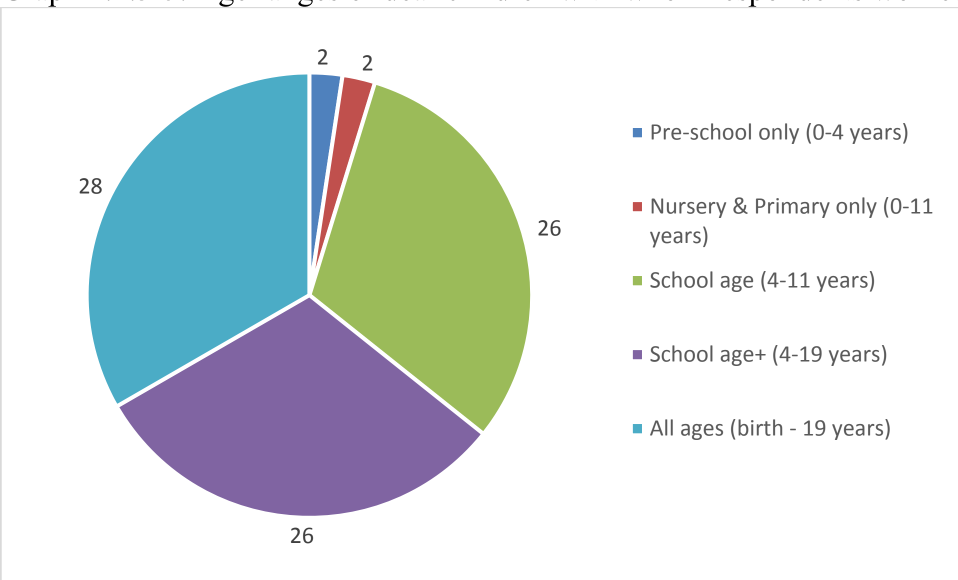
There was a lot of variation in the number of deaf children the respondents worked with. Many teachers of the deaf were peripatetic, working with deaf children in many different schools sometimes across a wide geographical area. As a result, some teachers reported contact with well over 100 children on their caseload. In contrast, others reported a caseload of around twelve children with whom they worked more closely. Others still worked with between three and nine children on a regular basis.

Those who worked in specialised schools for the deaf typically had contact with between 60-80 deaf children (see graph 4.4.3-4). Another respondent reported working at 8 mainstream schools, each of which had one deaf child in attendance. This illustrates d/Deaf children's vastly different educational experiences, as well as the different experiences and teaching environments of teachers of the deaf. How much time and what kind of relationship they had with each child was hugely variable. Those who were based in a single school typically taught children within a particular age range (of infant, junior or senior school age). The majority of the peripatetic teachers worked with children from the age of diagnosis of deafness (which could be from birth) up until the age of nineteen.

Graph 4.4.3-4 Numbers of deaf children with whom respondents worked




Graph 4.4.3-5. Age ranges of deaf children with whom respondents worked



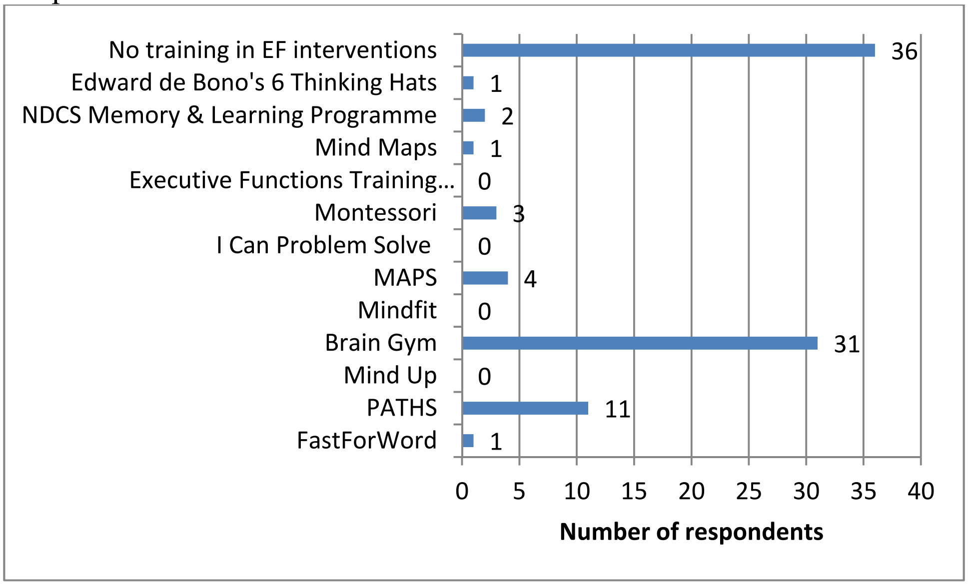

<u>Question 9 – Curriculum Interventions</u>

Question 9 asked respondents about their familiarity with curriculum-based interventions, specifically whether they had received training in or used any of a selection of well-known interventions. Once again, respondents were given the option to add any other interventions if they were not on the list. Overall, 73 people responded to this question, the results of which are illustrated in graph 4.4.3-6. The following curriculum interventions were included on the questionnaire or were added to the list by respondents.

a) **Promoting Alternative Thinking Strategies (PATHS).** PATHS is an educational programme delivered by teachers and counsellors, designed to help children develop self-control, problem solving skills, emotional awareness and self-esteem.
b) **Mark's Activity Programme Service (MAPS).** An activity programme based in Kent for people with physical and/or learning disabilities, aimed at developing skills such as turn taking, negotiating and social skills
c) **Mind Maps** – A technique frequently used by teachers to help children visualise, organise and prioritise information.
d) **I can problem solve (ICPS)** – A primary school programme developed for children from the age of four years onwards, explicitly teaching alternative thinking skills.
e) **Montessori** – Teaching techniques and resources developed by Maria Montessori designed to foster independence and self-motivation by using a child-centred approach to education.
f) **MindUp** – Developed by the Hawn Foundation, the MindUp programme focuses on developing children's emotional literacy and social skills, with the aim of helping them to manage stress, foster resilience, and improve their attention skills.
g) **Edward de Bono's Six Thinking Hats** – Developed by the de Bono group, LLC, Six Thinking Hats is a strategy for group discussion and thinking, providing a framework for clear thinking. Each metaphorical coloured hat is representative of a different element of thinking. These are 'Process' (blue), 'Facts' (white), 'Feelings'(red), 'Creativity'(green), 'benefits'(yellow) and 'cautions'(black).
h) **Brain Gym** – The Brain Gym program claims to improve academic performance, spatial and listening skills and hand-eye coordination through a series of repeated physical activities.
i) **The National Deaf Children's Society (NDCS) Memory and Learning Programme**. Developed by researchers at the University of Oxford, the

NDCS Memory and Learning Programme is a teacher-led programme for deaf children aged 5-11 years. It consists of 3 teacher-led games accompanied by three web-based games, designed to improve deaf children's controlled and automatic attention skills which are important for working memory performance.

Graph 4.4.3-6 Curriculum Interventions




<u>Question 10 – Feedback on Curriculum-based Interventions</u>

Question 10 asked respondents to comment on their experience of using curriculum-based EF interventions, in particular, whether or not they found them valuable and how often they implemented them. This question was included in order to gather valuable feedback and opinions on existing EF interventions from their target users, and to gauge how many practitioners use them with deaf children. Responses were extremely variable, due to the different working environments and roles of responders. Some were familiar or aware of some interventions but had been neither trained in or used them, whilst others were not familiar with any of the interventions. Many commented that they had used certain interventions in the past, but rarely implemented them now. A couple of the respondents highlighted certain EF tools that they found to be useful, particularly the PATHS and Brain Gym programmes. All of the comments and responses can be found in Appendix V, however a selection of responses include the following:

On PATHS:

*"PATHS has proved useful but it's very difficult to do something like this when you're only in a school for an hour at a time."*

*"I have used an adapted version in Primary (yr5/6) and with hearing SEN children yr 7. Worked better with Yr 5/6 as they were willing to share personal experiences which helped to think of strategies."*

*"We use Paths with year 1 upwards regularly. We value it very highly and teach it once a week but use the path emotions boxes regularly."*

*"I received training from RNID in 1997 when a deputy head in a school for the deaf. We used this in the curriculum. Success varied according to consistency of use, the age group it was applied to. Over time the fundamental principles of PATHS are replicated or adapted for use e.g. in Circle Time and promoting self-esteem and emotional literacy."*

On Brain Gym:

*"I did Mind Gym a while back with hearing pupils - it was quite good fun, but I am not sure that pupils made measurable progress with it."*

*"Used some brain gym exercises when I was mainstream teacher. They did seem to help the children settle. Have also seen Activate (brain gym type thing) used in some schools and this again seemed to help them settle."*

*"I have used Brain Gym. Useful to focus children and provide time to move then calm. Very put off by claims such as that if you massage your earlobes it will give you inspiration etc. Find this aspect complete rubbish which undermines some good aspects."*

On other interventions:

"[I] *find Mind Mapping a most useful tool both personally and as a means of developing children's thinking, recording and memory skills."*

*"I have in the past used FastForWord for improving the processing skills of pupils suffering from Auditory Processing Disorder and Auditory Neuropathy, with positive results. When I taught in mainstream school I used Brain Gym and found that Reading Levels jumped as the pupils used the hook up exercises before beginning their silent reading tasks, it also improved balance skills enormously. I am a Mindfulness Awareness Practitioner and often use this with my older deaf pupils when they are stressing about exams and course work deadlines. Varied results, but a calming effect!"*

In providing respondents the opportunity to respond freely regarding their experience of curriculum interventions, more qualitative information was gathered about perceived effectiveness of the interventions, in addition to quantitative data regarding training and experience.

Question 11 – Computer-Based Interventions

Question 11 had the same format as question 9, but this time referred to computerised interventions. 69 responses were recorded for this question and are shown in Graph 4.4.3-7. There were an extremely low number of professionals reporting any familiarity with computerised interventions, with only 7 claiming to use them. None of the respondents reported receiving training in any computerised interventions at all. Overall, respondents appear to be more familiar with curriculum-based EF interventions than computer-based ones. The computer-based interventions included in this question comprised of the following:

a) **FastForWord –** FastForWord is an educational software programme aimed at improving memory, processing speed and attention skills in children, with a particular focus on enhancing their 'phonological awareness' skills.

b) **Read Write Gold** – Read Write Gold is a literacy support programme produced by Texhelp for people with dyslexia or other special educational needs. It provides phonetic spelling tools, text checking and speech feedback features.

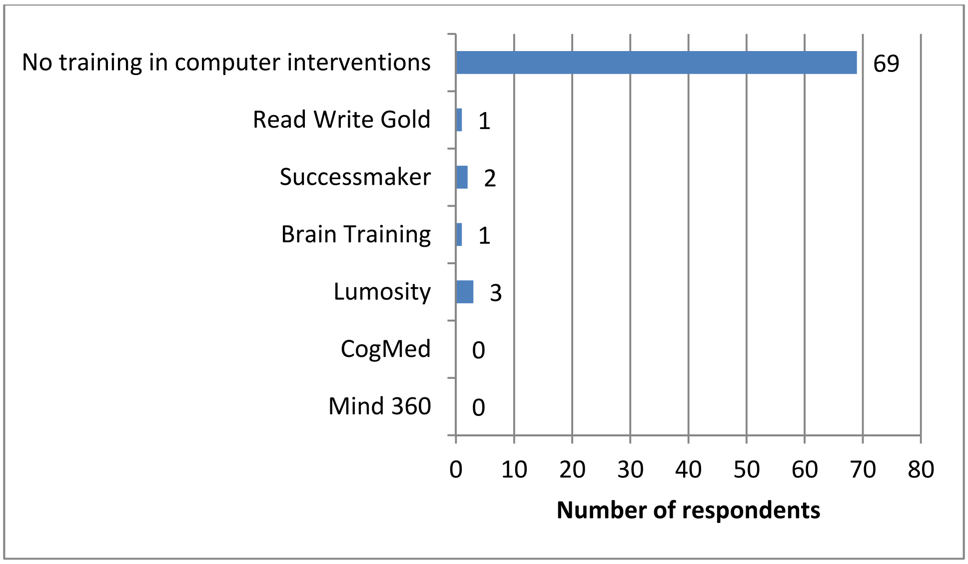
c) **Successmaker** – Developed by Pearson, Successmaker provides online game-based training for children in reading and maths.

d) **Lumosity** – Lumosity is one of the most popular online programmes available as a web-based app and is designed for both children and adults. It includes games aimed at improving cognitive flexibility, problem solving skills, attention, processing speed and memory.

e) **CogMed** – Produced by Pearson, CogMed is a working memory training programme with a computer game design. Children undertake 25 online training sessions lasting around 30 minutes each, completing child-friendly working memory games. It is available for preschool aged children, those at primary and secondary school, and a third version of the programme is available for adults.

f) **Mind 360** – Available online and as an app, Mind 360 produces a series of 'brain training' games aimed at improving memory, attention, reasoning and EF skills.

Graph 4.4.3-7 Computer Based Interventions



Question 12 – Feedback on Computerised Interventions

Like question 10, respondents were next invited to comment on their experience of using computer-based EF interventions. There was a marked difference in the number of responses, with the majority commenting that they have no experience of computerised EF interventions. However, four respondents provided positive feedback, reporting that computerised EF interventions were used weekly with some pupils and had been helpful in developing their memory skills. One respondent commented on time pressures and restrictions in schools, impacting the practicality of using these programs. Some of the comments made by respondents include the following:

*"I myself have trialled Lumosity, but as all systems, this is a good, but very expensive tool."*
*"I have used Lumosity on my own iPhone. The problem with using any of these programs is when to have the time with such a full curriculum and the pressures of Ofsted etc."*

*"Not a clue."*

*"Weekly with some pupils"* [Referring to Read and Write Gold]

*"Used as a fun starter activity or at the end of a lesson as a reward"* [In reference to Successmaker]

*"Brain training was good to help develop memory skills with pupils"*

*"None used"*

*"I'm not familiar with any of the above"*

As with the curriculum interventions, experience and use of computerised interventions varied between respondents.

Question 13

This open-ended question asked respondents to give examples of skills taught in their schools to help boost children's EFs and the types of resources they use. This provided the opportunity for respondents to describe any recommended individual strategies that may not be part of any of the specific intervention programmes referred to in previous questions. A wide variety of examples were provided, ranging from visual timetables, writing frames, timers, target sheets and PECS (The Picture Exchange Communication System, a series of pictorial cards used to help with communication, planning and goal directed behaviour), to memory and thinking skills games. Despite relatively few respondents reporting knowledge of computerised EF interventions, several revealed that ipad apps, many of which are free, are becoming popular to use in schools, particularly as a reward for good work or behaviour. Other non-resource based strategies reported included explicitly discussing problem-solving strategies with children and getting children to explain their thinking and how they strategize in order to work out problems. Responses to this question provided a useful starting point in considering the design of an EF intervention specifically for deaf children, a selection of which include the following:

*"Visual aids for vocabulary, using packages such as communication in print goal setting, timers, role reverse 'student as teacher,' thinking hats etc"*

*"Target Setting, Tick charts to organise work, revision time tables, Visual timetables, writing frames, time limits"*

*"Small toy to 'display' the skill / task / theme which also signifies one exercise has ended and another begins. This has picture and word. Picture /word clues to pre-teach which are gradually removed. Involvement in target setting."*

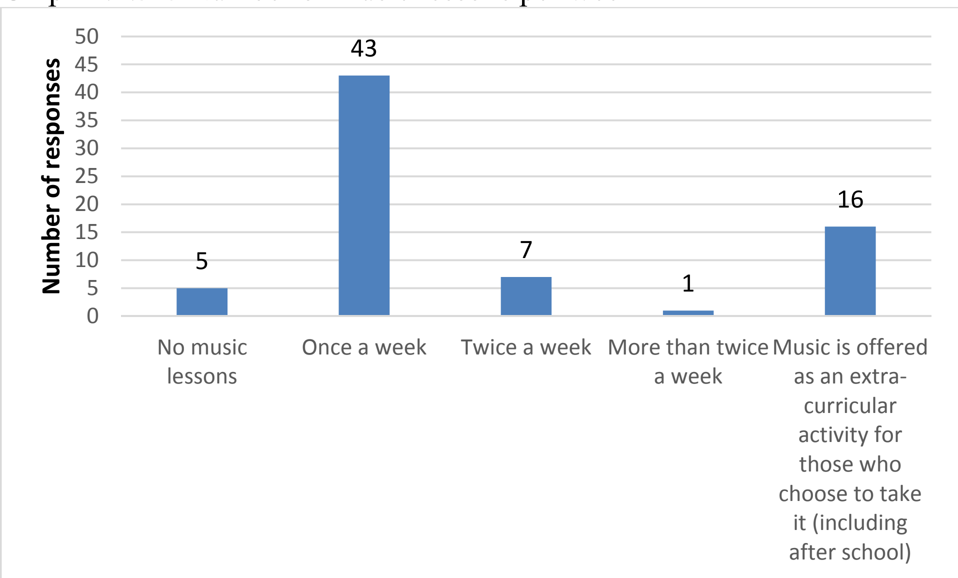
*"Visual timetables, timers, reward charts, visual books to determine what's going to happen now, next and later. PECS"*

*"All classrooms have visual timetables, we use sand timers to give definite end times for different activities, all children have individual targets written on the wall, reviewed regularly and changed when achieved."*

Question 14 – Number of music lessons per week

It has already been established that various pursuits can be beneficial to EF (see section 2.8.4), music training and sport being two commonly noted activities. While both music and physical education (PE) are included in the National Curriculum, there can be some variation between schools in the number of hours children spend in these classes each week. Deaf children often have additional classes such as speech and language therapy, extra literacy, or sign language classes which need to be timetabled into their school day. This can sometimes result in the children missing some PE or music classes. Question 14 asked participants to indicate how many times a week the deaf children they work with take part in music lessons. 63 participants answered this question and their responses are detailed in Graph 4.4.3-8 below.

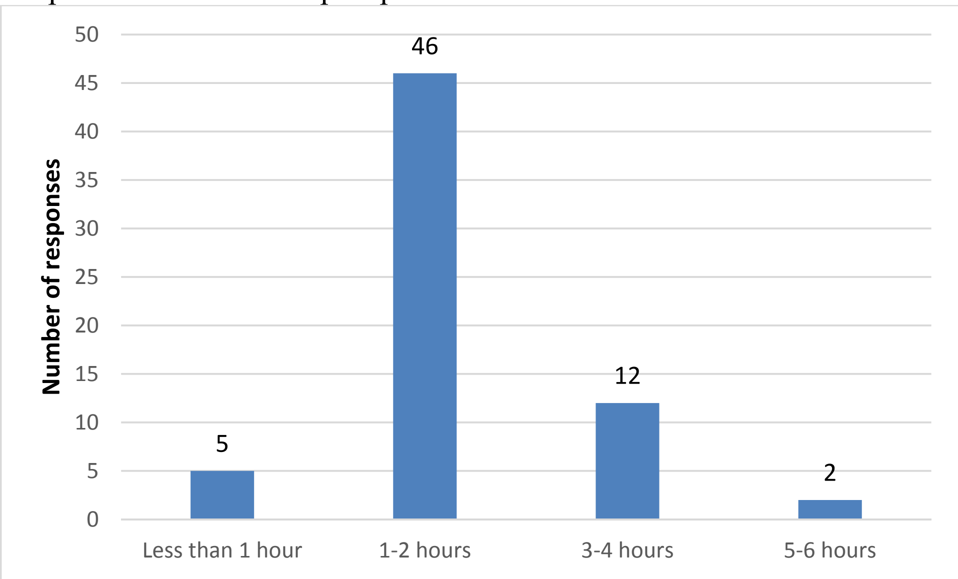
Graph 4.4.3-8 Number of music lessons per week



Question 15 – Number of hours of exercise and sport per week

Question 15 asked participants to report the number of hours that children in their school spend taking part in exercise programmes and sports. 65 participants answered this question, and their responses are shown in Graph 4.4.3-9 below.

Graph 4.4.3-9 Hours of sport per week




Question 16 – Interest in training

The final question asked participants whether they would be interested in taking part in training aimed at improving deaf children's cognitive skills. 74 participants responded to this question, the majority (66) indicating that they would like to receive training and 8 declining. This indicates a clear interest and need for EF interventions designed specifically for deaf children and willingness from professionals to undertake further training in this area.

### 4.4.4 Discussion

In general, there was a good response rate to the questionnaire, demonstrating the eagerness of Teachers of the Deaf and other professionals to share their experiences and suggestions for effective support of the development of EF in deaf children. Flexibility in question responses (i.e. enabling respondents to skip questions they are unable to provide answers for) enabled input from a wide range of professionals to be collected.

A prominent finding from the questionnaire was the difference between reported levels of experience and use of curriculum and computer-based EF interventions. Respondents reported little knowledge of computer-based intervention programmes, and in some cases noted that they were used as a reward, rather than as a full programme of training. This is likely to change in the future, with the increased use of technology in classrooms and availability of tablets and apps which enable programmes to be tailored to individual children's needs.

Based on responses regarding knowledge and use of existing EF interventions, it does not appear to be the case that curriculum interventions are frequently implemented in their entirety, or necessarily used consistently. However, several respondents stated that they use specific elements of these interventions (features of PATHS were mentioned in particular) with children on a more regular basis. Further discussion with teachers during the design phase of the current EF intervention made clear that professionals "cherry pick" and share with colleagues the activities or elements from interventions that they find the most effective. Another finding of note was the high level of familiarity respondents had with "Brain Gym" in comparison to other programmes. This programme was widely promoted in the 1990s, but has more recently been at the centre of controversy due to a lack of stringent research evidence for its beneficial claims (Goldacre, 2006). Lack of peer-reviewed research evidence, and strong criticism of the design of the few studies that do support the programme's effectiveness (Hyatt, 2007), have led to "Brain Gym" being broadly discredited. Responses to the current questionnaire reveal a mixed response to the programme, with some teachers praising the activities, maintaining that they help to focus and calm the children, and others being critical of the more unusual claims of some elements (e.g. "*Very put off by claims such as that if you massage your earlobes it will give you inspiration etc. Find this aspect complete rubbish which undermines some good aspects.*"). Through discussions with teachers, the author is aware that many professionals who work with children know about the disagreement within the scientific community surrounding this programme, and as a result are understandably wary of the claims of new (sometimes costly) programmes. Collaborative, cross-disciplinary work between researchers, teachers, and other professionals is needed to increase trust and faith in the efficacy of educational interventions. With this in mind, the author sought input and feedback from a variety of teachers and other professionals working with deaf children during the design phase of the intervention (further detail of this will be covered in chapter 5).

According to respondents, the majority of deaf children they work with receive between 1-2 hours of PE a week, with 12 respondents reporting that their children receive between 3-4 hours of exercise and activity a week. Whilst measured on a different scale (number of lessons as opposed to number of hours), the majority of respondents reported children taking part in music lessons once a week. 7 respondents reported music participation as occurring twice a week and 1 more than twice a week. As the length of a lesson in primary and secondary school is no normally longer than 1 hour in duration it appears that, in general, deaf children participate in PE classes more frequently than music classes.

An important result of questionnaire study was the finding that the majority of respondents would like to take part in executive function intervention training for deaf children, demonstrating an interest and training need in this group. One respondent remarked *"I know from experience how much thinking skills are affected by deafness, I see it every day"* Anecdotal evidence and feedback such as this provides motivation for the development of an EF intervention designed specifically for deaf children.

Having sought the views and responses of professionals working with deaf children, findings from the questionnaire indicate key elements that need to be considered in the design of an EF intervention. Firstly, an intervention which consists of stand-alone activities offers flexibility to teachers and the opportunity to adapt an intervention to suit the needs of individual children and classes. Whilst many interventions are designed as full programmes, it appears that in practice they are seldom implemented this way, and this should therefore be considered in future intervention designs. Another consideration is the time involved for training teachers in the intervention and the amount of time necessary to carry out the activities with the children, as highlighted by two respondents – "*PATHS has proved useful but it's very difficult to do something like this when you're only in a school for an hour at a time.*"… "*The problem with using any of these programs is when to have the time with such a full curriculum and the pressures of Ofsted etc.*" This suggests that short activities that do not need a large amount of preparation would be desirable. Finally, after further discussion with teachers, concerns over the cost of new interventions was revealed to be a potential factor for take-up. A cost-effective intervention that could be incorporated into the current curriculum would be more likely to be implemented when applied in an ecologically valid classroom environment. Whilst the availability of educational technology increasing and is likely to become more prominent in the future, it does not appear to be currently favoured by teachers as a means of improving EF skills at the moment. These findings influenced the design of the intervention which will be described in the following chapter, where the design, development and implementation of a music-based EF intervention for deaf children will be described in detail. The experimental study design will be outlined first, followed by an in depth description of the development of the EF intervention.

# Chapter 5 INTERVENTION STUDY DESIGN

The following chapter describes the design, piloting and administration of a music-based EF intervention designed for deaf children. It describes the recruitment of schools and children to the study and provides information about their school environment and background. The chapter begins with a description the process of creating a music-based EF intervention for deaf children, and what the intervention consisted of. The design of the control activity, art classes based on the theme ‘The Seasons’, is also covered. This is followed by detailed information about the various assessments used to determine the EF and language skills of the children who took part in the study. Finally, there is a description of how the study was carried out and a discussion of associated methodological issues.

## 5.1 Intervention Design

It was decided that primary school aged children (between the ages of 7 and 11) would be the targeted for the intervention study, and the design of the various activities took this into account. There were several reasons for choosing this age group. Firstly, the required focus needed to engage with activities for a prolonged period of time is undoubtedly more challenging for younger pre-school children, while primary school aged children are more accustomed to a more structured classroom environment. Secondly, EF assessments are more readily available for this age range, particularly tasks which require minimal language (see discussion in section 5.4) which is an important consideration for assessing deaf children who may have a wide range of language abilities. Additionally, one of the first large-scale investigations of deaf children’s EF skills in the UK focused on children within this age-range, using similar EF assessments (Botting, et al., 2016) – an additional strength this intervention study is that it complements the large scale study.

The activities included in the intervention were drawn from a variety of sources. Some were already established activities that are used in various educational settings; others were specifically designed for the study and were variations on activities in other curriculums. The EF curriculums drawn on included ‘Mind Up’ (The Hawn Foundation, 2011), ‘Tools of the Mind’ (Bodrova & Leong, 1996) and Music and the

Deaf's music curriculum for deaf children. Advice and feedback on the intervention was given by both Deaf and hearing professionals, including two specialist music instructors for deaf children, two Teachers of the Deaf, a Primary music Teacher, and a Special Educational Needs Co-ordinator who was familiar with the use of EF activities with primary school aged children.

### 5.1.1 Music and the Deaf

Music and the Deaf (MaTD) are a UK based charity providing opportunities for deaf people to take part in music. They have several centres throughout England, and run workshops and classes for deaf children and adults. They recognise the social and mental health benefits of music and the fact that many deaf children are excluded from music-making in schools. They also provide advice and training to schools, teachers and other organisations who want to know how to incorporate music into the lives of deaf and hearing impaired children and adults. The charity has produced music curriculums designed for deaf children which complements the National Curriculum for music. The MaTD curriculums are split into primary and secondary school age groups and include a wealth of resource ideas and materials for music teachers. Music notation cards, notation trees and ideas for some for music making activities in the Music Intervention were borrowed and adapted from the MaTD's primary school curriculum.

### 5.1.2 Piloting the Intervention with MaTD

Activities from two sessions of the intervention were piloted at a weekend class run by Music and the Deaf in Camden. The class consisted of 7 children (5 boys) aged 8-13 with varying degrees of deafness, ranging from severe to profoundly deaf. Four were cochlear implant users and 3 hearing aid users. Activities piloted included 'Sevens', the Naughty Orchestra and the children creating their own rhythm using music notation cards. The children understood the activities without requesting much clarification, and were motivated and happy to take part in the activities. The leader of the Camden MaTD group also provided feedback and advice on the intervention lesson plans. The main objective for piloting these games was to ensure that they were engaging and enjoyable enough to hold the children's attention whilst still being challenging for them. Additionally, it was a valuable exercise to determine whether the author would be able to deliver the activities without the support of additional adults if necessary.

### 5.1.3 Input from specialist Deaf school

Advice was sought from experienced Teachers of the Deaf and music teachers who work with deaf pupils. A visit was arranged with a specialist school for deaf children in Brighton, in the south of England. They have excellent music facilities for their students and put on regular performances. Children who attend the school are encouraged to take part in music classes and have the opportunity to learn to play an instrument. Several of their students enter guitar examinations on the “Rock School” programme and have had very good success. The school’s music teacher demonstrated some of the teaching methods he used to teach children different rhythms using ‘boomwhacker’ sticks – coloured hollow cylinders of differing lengths, each tuned to a different pitch. The children demonstrated their drumming skills and techniques for learning new rhythms using colour coding on their music scores. Teachers from this school provided feedback on early drafts of the EF intervention, providing practical suggestions for its implementation.

### 5.1.4 Differentiation and flexibility within the intervention

As discussed in Chapter 2, (section 2.8.1), an essential component of EF interventions is that they need to be consistently challenging (Diamond, 2012). However, motivation needs to be maintained and therefore a balance is needed in the design to ensure that tasks are challenging, but not so challenging that the children cannot cope or become disheartened and resistant to continuing with them. Creating a motivating/challenging balance was an essential consideration during the design phase of the intervention, so differentiated versions of the activities were developed. Details of the differentiated activities are included beneath the descriptions of intervention components below.

Consequently, after discussion with teachers, it was decided that children would be grouped by ability (as determined by the teachers) rather than by age. As deaf children are an extremely heterogeneous group with varying language abilities, their cognitive, academic and social abilities are not necessarily commensurate with their chronological age. Therefore the resulting groups included children of differing ages, but similar ability levels.

## 5.2 Components of the Music Intervention

This section provides a detailed description about each component activity in the music intervention, including how the activities were differentiated for children who would find the original activities too challenging.

Opening the sessions

In order to maintain structure across the intervention, each session began and ended with the same activities. The 'Pass the Rhythm game' opened the sessions with the main goal of focusing the children's attention.

"*Pass the Rhythm game"*

Whilst sitting in a circle, the facilitator claps out a rhythm and 'passes' it on to the next student in the circle until it has passed all the way around the circle. The facilitator then increases the complexity of the rhythm and continues passing on the rhythms until they are too complex for the majority of children to continue with. In later sessions, rhythms can be played on instruments rather than clapping, as this makes the game a bit more challenging.

> Differentiation: Simpler rhythms can be used. If children preferred the follow the leader game (see below) this could be substituted here.

After the activity ended, the facilitator explained the main activity of the day to the children.

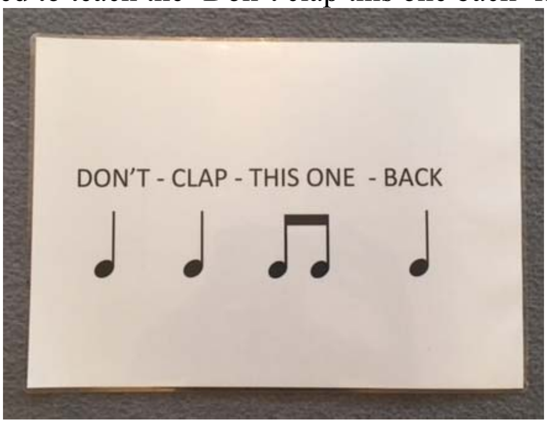
Ending the sessions

Every session ended with a game of “Don’t Clap This One Back”, with the children seated at a table. This game focuses on children’s attention and inhibition skills.

*“Don’t clap this one back”*

The facilitator claps a range of rhythms, no more than 4 beats long, using hands, body, and the table and the children copy the rhythms. However if the teacher claps the rhythm 'Don't clap this one back' – (♩♩♫♩) the children are instructed not to copy, hence, ‘don't clap it back’. Every time one of the children claps the rhythm when they aren't supposed to, the facilitator gets a point. If the children managed to inhibit the impulse to clap and are correct in not responding, the children get a point as a team. At the end of the game, if the children had beaten the facilitator by correctly inhibiting their responses 10 times, they received a prize (their choice of stickers, colouring pencils or small puzzles). The potential to win a prize as a team often motivated the children to pay attention through to the end of the session, and to work as a team.

Figure 5.2-1. Card used to teach the ‘Don’t clap this one back’ rhythm




Differentiation: Instead of the ‘don’t clap this one back’ rhythm, a simpler rhythm was chosen. CROTCHET CROTCHET CROTCHET. This is much more distinctive, and is relatively easier to remember and distinguish from other rhythms.

Follow the Leader

This game is commonly used in schools, particularly with young children or those with special educational needs. It requires the co-ordination of several EF skills, including planning from the leader and monitoring, attention, and inhibition from the other participants.

A child is chosen to act as "Detective", and has to leave the room. Whilst they are outside, another person (a child or adult) is chosen to be the Leader. The other children have to copy the actions of the Leader (such as clapping, stomping feet, changing facial expressions) while the leader changes their actions frequently. The Detective re-enters the room and has to work out who the Leader is by carefully watching the group and trying to determine who is leading the action changes. Therefore transitions need to be subtle and participating children need to pay attention and adapt to the new action of the Leader quickly. This activity aims to train attention and cognitive flexibility skills. All of the children took turns as the Leader and the Detective.

> Differentiation: The concept of the game may be hard for some children with language delays or difficulties to immediately grasp. Adults can initially model the roles of Leader and Detective to help clarify the rules and aim of the game. Larger movements, with less subtle transitions, can also be used.

The Body Orchestra

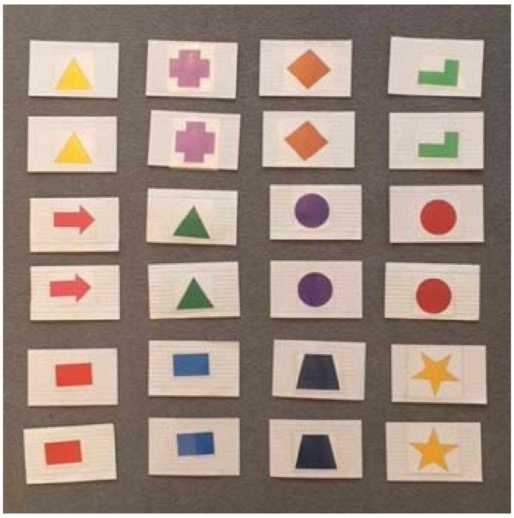
This activity focused on training working memory and attention skills. Three sets of associated cards were produced for this game. The first set included five musical instruments, the second five pictorial representations of a body movement, and third, five animals (See figure 5.2-2 below).

The facilitator goes through each card with the children, identifying the picture and discussing the associations between them. For example, "Can you be like a BIG elephant and stamp your feet?"… "Imagine you are playing a great big drum, how do you play it? BOOM!" The children are taken through all of the physical actions associated with the animals and instruments and are told that they need to remember them. The cards are then mixed up and lain face down on a table or on the floor. Children take it in turns to choose three cards each. Unlike a standard memory card game, where participants need to match pictures that are the same, in this game children are required to find the three items that correspond with each other. Each time the game was played, children were reminded of the association between the instrument, animal and action. The game trains working memory as children needed to remember which action accompanies which animal and instrument.

Figure 5.2-2. “Body Orchestra” cards

Differentiation: There were different levels of differentiation available for this game. Differentiation 1) Instead of 3 associated cards, children played the game with just instrument and animal cards, excluding the additional ‘body’ element. 2) The game was played with music and animal cards, however children were only required to match two cards with the same picture, instead of matching cards that were associated. 3) Another set of 24 cards with different coloured shapes were produced and children had to simply match two cards with the same shape and colour. This was a straightforward memory card game that all of the children were familiar with. Children were able to ‘work their way up’ through differentiation levels making it increasingly challenging for them once they had mastered the easier level.

Figure 5.2-3. Differentiated version of the “Body Orchestra” game, using simple coloured shapes



The Naughty/Good Orchestra

The first time that this activity is introduced, the facilitator discusses the role of a conductor with the children. Concepts and some musical terminology such as loud (*forte*), quiet *(piano)*, fast *(allegro)* and slow *(largo)* are introduced. More able children are introduced to the Italian musical terminology and those with lower language skills focus only on the English terminology. They are shown pictures of orchestras and understand that it is the conductor’s job to make sure everybody plays and stops playing at the same time. The facilitator then uses a conductor’s baton to demonstrate the various gestures and signals that mean quiet, loud, fast, slow, and stop.

Initially, the children will be ‘the orchestra’ and are able to choose an instrument from the instrument box (See materials list in Appendix IX). After exploring the instrument for a few minutes and learning how it works, the children then play a simple rhythm and follow the directions of the conductor. The children need to attend to the changing requests of the conductor. Once children have mastered all of the four concepts, they take turns being the conductor.

In later sessions, the concept of the Good/Naughty Orchestra is introduced. Children are now familiar with the role of the conductor, and the facilitator explains that when they are being a ‘Naughty Orchestra’ they need to do the opposite to what the conductor is requesting. The Naughty orchestra requires inhibition and working memory skills, as children are required to do the opposite of what they are instructed to do. When the facilitator is the conductor, they are able to give directions in quick succession in order to increase the difficulty of the game and make it more challenging.

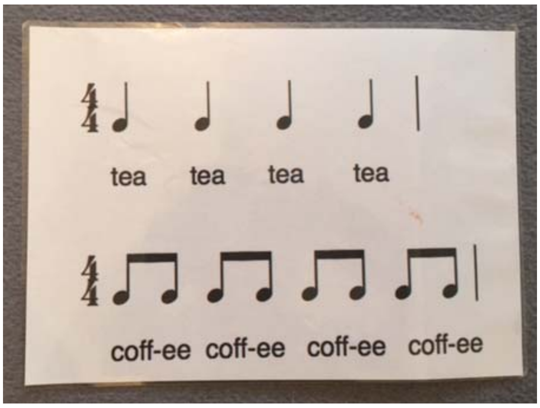
Switching between the conditions of being a ‘Good’ or ‘Naughty’ orchestra adds an extra EF load as children are required to switch between two sets of rules (follow or disobey) and inhibit their behaviours accordingly.

> Differentiation: Some children may find it harder to master the ‘Naughty Orchestra’ in particular as it requires inhibition. If necessary, slow down the rate of change between fast/slow/loud/quiet instructions.

<u>Making Our Own Music</u>

This session introduces musical composition to the children and requires planning skills. Two sets of notation cards were made for this activity. Each set included a breve note, two semibreves, four crotchets, eight quavers, sixteen semiquavers, and two crotchet rests The notation cards could be arranged on the table in front of the children to create different simple rhythms. All rhythms were in 4/4 “common” time, meaning they consisted of the equivalent of four crotchet beats in a bar. Resources provided by Music and the Deaf included music notation sheets with associated words, which helped to demonstrate the lengths of notes to the children. For example, a crotchet note can equate to a word with a single syllable, such as ‘tea’, and two quavers to a two syllable word, such as ‘coffee’ (see figure 5.2-4). As the sessions progressed, children were introduced to the other notes and learnt the difference in their durations.

Figure 5.2-4. Example of a card used to teach basic music notation




Introducing children to basic musical notation enabled them to create simple rhythms for others to play. This requires planning and working memory. Children were able to arrange the notes on the table to create their own rhythms. The other children and facilitator could then tap the rhythms on the table or play them on their instruments. The child who created the rhythm had to decide whether or not their rhythm had been played correctly.

In later sessions, the facilitator created various rhythms using the notation cards and tapped them out on the table, occasionally making an intentional error. The children had to decide whether the rhythm being played matched the notation cards in front of them, or whether the facilitator had made a mistake.

> Differentiation: These sessions can be easily differentiated. The activity can be limited to simple 4 beat crotchet rhythms and quaver rhythms only, and can be beaten by hand on the desk (instead of using instruments) so that children understand the relationship between the two types of ‘slow’ and ‘faster’ notes.

The Memory Tray Game

This well-known game aimed to train working memory, and required children to recall as many items as they could from a tray containing 20 music-related items. It had two parts to it. The facilitator presented the children with a tray covered with a cloth. The facilitator removed each item individually from underneath the cloth and asked the children to name the instrument or item and explain how it is used. Once all of the items on the tray had been examined, the facilitator removed the cloth and allowed the children 1 minute to look at and attempt to memorise all of the items. The cloth was then placed back over the items and the children had to recall (either verbally, written or through sign language) as many items as they could. When the children couldn't recall any more items, the cloth was removed and the children were shown any items they had forgotten.

In the second part of the activity, the children had one minute again to memorize the items before they were covered over again with a cloth. The facilitator then took the tray away and removed two of the items. They returned the tray to the children, removed the cloth, and the children had to examine the tray and determine which items were now missing.

> Differentiation: In differentiating this activity, fewer items can be used and items that are more common to the children can be included (for example, pencils, erasers, eye glasses). The number of items can be increased over sessions in order to increase the difficulty.

Musical N-back

This activity was developed for this intervention and is a rhythmic version of the N-Back task. It requires working memory, monitoring and attention. The N-back (standing for "number-back") tasks are established EF training and assessment tasks which require the participant to hold items in memory that were presented a certain number of items ago. For example, in a 3-back task, a shopping list may be recited and the participant has to start reciting the list starting 3 items prior to the current one, whilst still attending to and memorising the ongoing list. For the intervention version the facilitator begins with a very simple action (for example clapping). As they change their action to something else (such as stomping their feet), this is the children's cue to begin with the first clapping action. This is a 1-back. After a couple of successful trials, children can attempt a 2-back. The maximum goal is to reach 3-back (any more is too complex for the age group).

> Differentiation: Instead of an N-back style of activity, the similar and familiar activity "granny went to market" could be played instead. The shopping list starts with one child and as they go around in a circle, each child adds another item to the shopping list. They need to recall the whole ever increasing list from the beginning each time it is their turn. The 'Switch' element can be introduced whereby the facilitator says or signs "Switch!" and the turns pass back around the circle in the opposite direction. This helps to keep the children alert and motivated.

<u>The Rhythm Machine/ "Sevens"</u>

The Rhythm Machine (which came to be known as "Sevens") is a clapping game which involves the children learning how to clap a simple seven beat repetitive rhythm. Similar to playground game "patty-cake" it starts with simple hand clapping movements and builds to become more complex. There are four rounds to Sevens, as detailed below:

1. Seven taps on the table
2. Alternate tapping table and hand clap seven times
3. Tap table, hand clap followed by finger click, repeated twice
4. Tap table, cross hands table tap repeated twice, hand clap, finger click, hand clap, table clap.

It takes around 2 sessions for the children to learn all of the steps to the game. Once they have mastered this, they can start to clap the sequences in a round. One child starts the sequence, and when they move on to the second step (alternate tapping table and hand clap), another child begins with the first step. Simultaneously clapping even simple different rhythms requires excellent inhibition and selective attention skills. Children are required to attend to their own playing, and then the group as a while whist maintaining their rhythm. This requires monitoring and flexibility. Working memory is also employed as they need told the next stage of the sequence in mind. For children who excel at this activity, an added level of complexity can be added if they are asked to perform the sequence in reverse order as well.

> Differentiation: The activity is very complex, especially for children with motor problems. It is simple to differentiate as it can be played with just the first two levels (tapping the table and hand claps). Additional stages can be added as the intervention program continues if the children master the easier stages and require more of a challenge.

### 5.2.1 A "Music-based" Intervention

Whilst the intervention reported here is described as "music-based" it is important to acknowledge that many of the activities included in the session could be described as more "rhythm-based". However, this description of the intervention was resisted, as it was felt that whilst there is no focus on pitch in the intervention (to avoid particular access issues for the participants), the "rhythm-based" description is too limiting as it does not take into account other musicianship skills (such as conducting, playing together and observing others), that form a strong part of the intervention. This issue will be discussed further in Chapter 7.

## 5.3 Control Activity Design

The control activity was carefully designed to ensure it involved the same amount of time and adult contact as the EF intervention, but did not specifically focus on or include executive-loaded activities. Previous studies have established art as an appropriate control comparison to music and have not found any EF advantage from these activities (e.g. Moreno et al., 2011). To ensure continuity within the art sessions, the theme of "the seasons of the year" was chosen. This provided two sessions on each season, an additional session where the children produced a rainbow collage and another where they made a themed folder to contain their artwork. There was no need for differentiation for the control activity as all sessions were accessible to children of every level of ability, however each activity needed to engage to all children between the ages of 7-11 years. Children were shown pictures and examples of the finished artwork and they had guidance for the tasks, but were generally left to complete activities independently.

Ideas for each art activity were drawn from the author's previous teaching experience, a children's art activity book (Watt, 2008), and the websites Pinterest and parent and teacher resource website 'Activity Village' (www.activityvillage.co.uk). The full lesson plans for the control sessions can be found in Appendix X.

## 5.4 Assessments

Assessments of the participating children's EF and language skills were made at the start of the study (as a baseline), post-intervention and post-control. There were 5 weeks between each of the testing sessions. The following sections describe in detail the EF and language assessments that were included in the study.

### 5.4.1 EF assessments

**Behaviour Rating Inventory of Executive Function (BRIEF) Checklist (Gioia, Isquith, Guy, & Kenworthy, 2000)**

Prior to the start of the study, teachers and/or parents of participating children were asked to complete the BRIEF checklist. This is an 86 item questionnaire which provides detailed information about 8 different aspects of children's EF, arranged into individual scales. The respondent is presented with sentences about the child's behaviour such as "*Tries the same approach to a problem over and over even when it does not work*" and is asked to respond by circling N (never), S (sometimes) or O (often). The questions are designed to address children's ability to initiate behaviour, inhibit undesirable responses, demonstrate emotional control, shift attention, monitor progress, plan and organise themselves and their possessions and use working memory.

BRIEF scales

1) *Inhibition*

Items on the inhibition scale correspond to the child's ability to suppress undesirable behaviours and impulses. Items on the scale include "Interrupts others" and "Gets out of seat at the wrong times"

2) *Shift*

This scale examines the child's ability to be flexible and adapt to new and different situations. It also includes items regarding problem solving. Examples include "Becomes upset with new situations" and "Resists or has trouble accepting a different way to solve a problem with schoolwork, friends, chores etc."

3) *Emotional Control*

The emotional control scale focuses on the child's ability to regulate their emotional responses, with question items such as "Overreacts to small problems" and "Has explosive, angry outbursts".

4) *Initiate*

Self-generation of ideas and the child's independent initiation of tasks is included on the Initiate scale. Examples of these questions include "Needs to be told to begin a task even when willing" and "Has trouble coming up with ideas for what to do in play or free time"

5) *Working Memory*

The Working Memory scale asks respondents to judge how well the child can hold tasks and information in memory when completing activities that involve more than one step. For example, "When given three things to do, remembers only the first or last" and "Has trouble with chores or tasks that have more than one step".

6) *Plan/Organise*

The Plan/Organise scale items refer to how well a child manages task demands, plans their tasks and organises their time. Items include "Has good ideas bust can not get them on paper" and "Forgets to hand in homework, even when completed"

7) *Organisation of Materials*

This scale includes items regarding the child's general organisation of their belongings, at school and at home. Examples of these scale items include "Can not find things in room or school desk" and "Leaves messes that others have to clean up"

8) <u>*Monitor*</u>

The final scale, Monitoring, contains items relating to the child's ability to reflect on their actions and completed tasks. Items include "Does not realise that certain actions bother others" and "Makes careless errors".

Raw scores for the first three scales, (inhibition, shifting and emotional control) are summed to produce a composite called the "Behavioural Regulation Index (BRI)". Initiation, working memory, planning and organisation, and monitoring scores are combined to produce a "Metacognition Index (MI)". The test developers refer to the BRI as representative of a child's ability to *"shift cognitive set and modulate behaviour via appropriate inhibitory control"* (p.20). This is seen as a precursor to metacognitive problem solving – skills that constitute the MI. The MI is interpreted as *"the ability to cognitively self-manage tasks and reflects the child's ability to monitor his or her performance.,,* [it] *relates directly to a child's ability to actively problem solve in a variety of contexts"* (p.21). The combination of BRI and MI composites provides a "Global Executive Composite (GEC)" for each child. The GEC is an overall summary measure comprising all eight clinical scales mentioned. Examining each of the specific subdomains of EF in this way is valuable as it provides a detailed overview of each child's potential EF strengths and weaknesses, as reported by their parents and teachers.

The BRIEF has been found to be a generally reliable checklist, with internal consistency of checklist items for both Parent and Teacher forms of the BRIEF being high (Chronbach's alpha ranging from .80 to .98), moderate interrater reliability and has previously been used in studies involving deaf children (e.g. Kronenberger, Colson, Henning, & Pisoni, 2014; Hall, Inge-Marie, Bortfeld, & Lillo-Martin, 2016; Hintermair, 2013).

As well as using the BRIEF, in order to properly assess the children's various EF skills other measures of EF were included in testing. Some of the measures were well-established EF tests and others were comparatively new or adapted for use with deaf children. Whilst there are many assessments currently available to assess EF skills of children and adults very few have been used with deaf adults and children

(Marschark & Hauser, 2008). Therefore, relatively little is known about the typical performance of deaf individuals on these tasks, except for those used in the last few years (discussed in chapter 2, section 2.6). A recent longitudinal UK study tracked the development of deaf children's EF over the course of 3 years (Marshall, et al., 2015 and Jones, et al., 2016). The study involved deaf children between the ages of 6 and 11 from around the UK with a variety of socioeconomic backgrounds and language experiences. As the current study is linked to this larger project, the tests used in the current study came from this large study. The author was trained in administering the EF assessments in both BSL and spoken English and gained experience in carrying out the assessments though assisting in data collection for the large study. Therefore tester familiarity with all the tasks was already established before the current study commenced. These assessments have now been used with a large cohort of deaf children in the UK, and were therefore considered to be the most appropriate for use in this PhD. A summary of each facet of children's EF tested and the corresponding assessment used to measure it is outlined in table 5.4.1-1, followed by a detailed description of each of the measures.

Table 5.4.1-1 Summary table of EF and language measures used.

| Executive Function/Language | Measure |
|---|---|
| Visuospatial Working Memory | Corsi Blocks |
| Executive loaded Visuospatial Working Memory | Odd One Out |
| Inhibition | Sun Apple Task |
| Cognitive Flexibility/Planning | Tower of London Task |
| Cognitive Flexibility/Switching | Colour Trails |
| Non-verbal Fluency | Design Fluency |
| Verbal Fluency | Semantic Fluency |
| Processing Speed | Symbol Search |
| Behavioural Regulation & Metacognition | BRIEF Questionnaire |
| Narrative skills (BSL or English) | BSL Narrative skills task |
| Vocabulary | Expressive One Word Picture Vocabulary Test |
| Non-verbal IQ | WASI Matrices |

**Working Memory Measures**

Two measures of working memory were included in the testing battery: one measure of visuospatial working memory (a Spatial Span task) and one with more complex executive-loaded working memory (The Odd One Out task).

**The Odd One Out Task (Henry, 2001)**

The 'Odd One Out' Task is a test of executive-loaded visuospatial working memory. Children are presented with three shapes on a power point slide. Two of the shapes are identical, one of them different. Children are asked *"which shape is the odd one out?"* and to point to the different shape. The following slide has a grid with three empty boxes, and the child is asked to point to the location of the previously identified 'odd one out' shape. Children are dissuaded from verbalising to help them remember the location of the shapes (for example, by repeating the location to themselves "right, middle, right," etc) and are not allowed to use their hands to mark the location and thus aid their recall. Prior to starting the test, children complete two practice trials to ensure they have adequately understood the task.

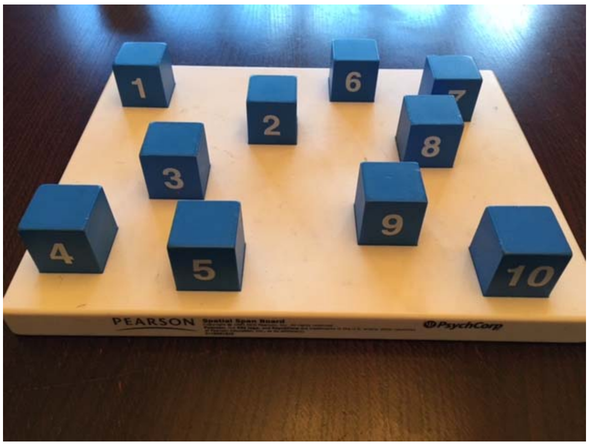
Complexity is increased after four trials, when children are asked to recall the position of the missing shapes after being presented with two pairs of stimuli on teach trial. After four more trials, complexity increases again to three stimuli to recall, and continues up to a maximum of six stimuli per trial. The test is stopped when children make an error on two (or more) trials in a set.

**Spatial Span Task (Wechsler & Naglieri, 2006)**

The Spatial Span Task is a measure of visuospatial working memory. The children are presented with an array of ten blue blocks mounted on a platform in an irregular pattern (see figure 5.4.1-1). They are instructed to tap the blocks in the same order as the examiner (who is able to see numbers on each of the blocks to aid in the administration of the test). As with the adult study (Chapter 3), testing began with two block strings, (with two trials at each level), then increased up to nine block strings, or until the child make errors in both trials of a particular level. The child's score consists of the number of correct trails achieved before the task ends or is discontinued.

A second 'backwards' condition requires the children to tap the blocks in the reverse order to the examiner (starting with the last block that the examiner tapped), and is scored in the same manner as the 'forward' condition. Other memory tasks (such as digit span tasks) include a backwards condition as it is believed that this condition places greater demand on working memory. However, it has been argued that this is not necessarily the case in the spatial span task (Weiss, Saklofske, Prifitera, & Holdnack, 2006)  Both conditions on this task require the child to maintain the visual memory trace of each trail until it is time for them to replicate it. If the child performs better on the backward condition than the forward, it suggests that they are better at recalling a visual trace from the 'end point', as opposed to the origin as they are starting with the most recent information observed. After observing the performance of several different clinical groups on this task, Weiss et al. report that children who have difficulties associate with attention and executive control have poorer performance in the forward condition compare to the backward condition.

Figure 5.4.1-1. Spatial Span task apparatus (tester's viewpoint)

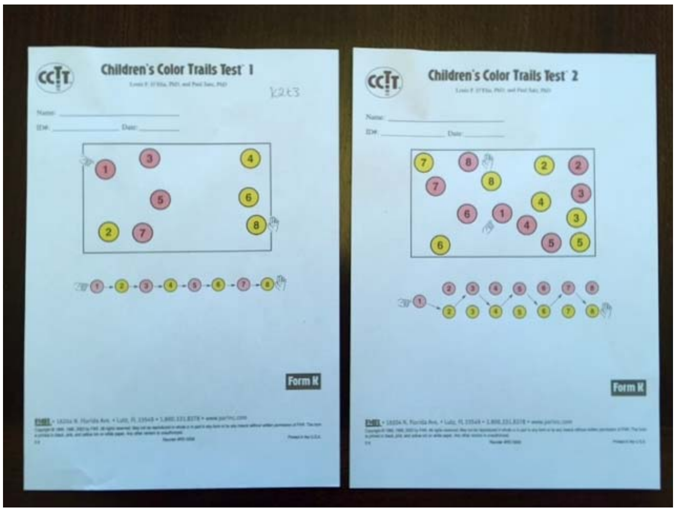


**Flexibility/Switching**

**Colour Trails Task (CCTT, Llorente et al., 2003)**

As a measure of cognitive flexibility, children were given the colour trails task (CCTT). There are two parts to the test (see figure 5.4.1-2). The first task requires the children to connect 15 numbered circles of alternate yellow and pink colours whilst the tester times them. This provides a baseline time of the children's performance on the task. In the second part of the test, the children are presented with 30 circles numbered 1-15, fifteen of which are yellow and fifteen pink. The children are instructed to start on the yellow colour and then "connect it to the next number which is a *different* colour". This requires the children to remember the rule of switching between colours as they connect circles, and to ignore the distractor circles. The tester was careful not to use the words 'pink' or 'yellow' when giving instructions in accordance with the task protocol. The children are timed on this task, and any colour or number errors they make are noted on their score sheet to be included in later analysis. The child's score on the task consists of the time taken to complete each task, and an interference score is calculated by taking their time to complete the second task from their baseline time on the first task.

Figure 5.4.1-2. Guidance instruction sheets for Colour Trails 1 and 2



**Symbol search (WISC-III; Wechsler, 1991)**

Symbol Search (Wechsler, 1991) was included in the test battery as a measure of processing speed and flexibility. Children are asked to determine whether either one of two target symbols are present in a string of 5 symbols. If either target symbol was present, the children have to circle 'YES', or circle 'NO' if they are not present. The tester demonstrates the task to the child with two trial items, then the child is given two practice trails to complete by themselves. They are then presented with a sheet of trials and instructed *"look carefully and complete as many of these as you can before I tell you to stop."* The child is then timed and given two minutes to complete as many trials as they can. The child's score on this task consists of the number of correct trials completed in two minutes.

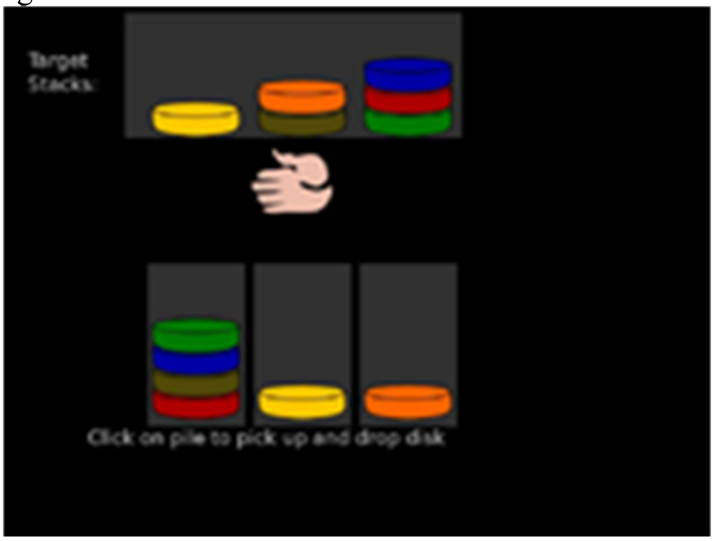
**Planning**

**Tower of London (Shallice, 1982)**

The Tower of London task was administered on a laptop using PEBL Test Battery Software (Mueller, 2011). This assessment is a traditional problem solving and planning task which tests the child's ability to make and follow plans. It is a task which is regularly included in EF test batteries (Shallice, 1982).

The children are presented with two sets of coloured disks, arranged across three columns (see figure 5.4.1-3). The tester explains to the child – *"Look at the disks with different colours. These disks here [pointing to the top array] belong to the computer. You can not move them. These desks here [pointing to the lower array] belong to you. You need to make your disks look the same as the computer's."* To ensure the child understands how to complete the task, the tester assists the child with the first trial (which is subsequently excluded from data analysis). The tester tells the child to *"click on the red disk"* and then showed them where to put it. *"Can you see, that is the same as the computer's? Now, can you make the rest the same by yourself? Try to use as few moves as possible and do it as fast as you can"*. If the child struggles on the first trial, the tester is able to assist them and give prompts until they complete the trial. On all subsequent trials no assistance is given other than encouraging prompts (e.g. *"You are nearly there"*) to encourage the children to keep going. There are eight trials, and achievement is measured by time taken to complete the task, the number of moves taken to complete each trial, and the number of extra moves (i.e. moves made on top of the minimum possible) taken to complete each trial.

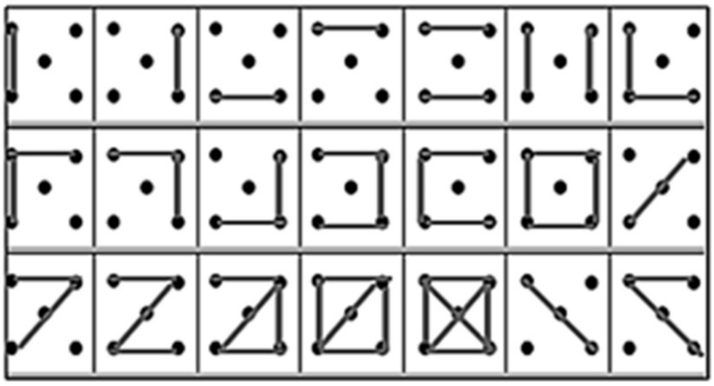
Figure 5.4.1-3. Screen shot of the Tower of London Task




**Design Fluency (NEPSY-II, Korkman et al., 2007)**

The design fluency task, taken from the NEPSY-II battery (Korkman et al., 2007) is designed to measure planning, flexibility and self-monitoring skills. The design fluency task has two conditions. In the first condition children are presented with an array of dots set out in a square structure and are told that they need to create different designs by joining the dots. The tester demonstrates the task, emphasising that they can join as many or as few dots as they pleased (although it has to be at least two) and that every design they create needs to be different. The tester demonstrates two example designs on a practice sheet, and then asks the child to create two more different designs. At this stage, if the child replicates a previous design, they are reminded that every design needs to be different. The child is then presented with an array of 35 boxes of dots, and told to "draw as many designs as you can, until I tell you to stop". The tester times the child and instructs them to stop after one minute. The child's score on this task is the number of unique and accurately drawn designs they produce in one minute. An example of the fixed array condition of the design fluency task is shown in figure 5.4.1-4 below.

Figure 5.4.1-4 Example of the fixed array of the Design Fluency Task



In the second condition, the children are presented with dots arranged in an irregular array and are given the same instructions as the first condition. Whilst the irregular array of dots still provide a structure upon which children base their designs, the irregular pattern requires greater self-monitoring in order to ensure reproductions of previously drawn designs do not occur. Again, the tester demonstrates two examples of drawing designs and asks the child to complete the practice sheet with two more original designs. Once it is clear the child has understood the task, they are presented with an array of 35 boxes of irregularly positioned dots and asked again to *"draw as many designs as you can, until I tell you to stop"*. The tester then times the child and instructs them to stop after one minute. As with the structured array, the child's score consists of the number of unique and accurately produced designs they produce in one minute.

**Inhibition**

**The Sun-Apple Task (Simon, 1990)**

The Sun-Apple task was administered as a measure of children's inhibition skills. It is based on the "Simon effect", which refers to the increased time required to respond to incongruent items (Simon, 1990). The task is presented on a Lenovo laptop and is run using "Presentation" software (Neurobehavioural Systems, Inc., 2013) which controlled the presentation and timing of the stimuli. Stickers are placed on ‘S’ and ‘K’ keys of the laptop keyboard, the left side with a picture representation of an apple and a picture of a sun on the right. Children follow the instructions as they are presented on the screen, or alternatively, the instructions are signed to them. They are told to keep one index finger on the ‘apple key’ and one on the ‘sun key’ and whenever they see a sun or an apple on the screen to press the corresponding key. There are three practice trials to ensure the child understands the task and are able to respond in adequate time (i.e. their responses are neither too slow or haphazard and fast). The test trials then begin. There are 16 congruent trials (where the apple or sun are presented on the same side of the screen as the response key), and 16 incongruent trials (where the items are presented on the opposite side of the screen to the response key, requiring the children to inhibit incorrect automatic responses and placing a higher load on their EF). The children’s scores on this task consist of their percentage accuracy on both congruent and incongruent scores and their reaction response times to the stimuli.

### 5.4.2 Language Assessments

**Semantic fluency (Ruff, Light, Parker, & Levin, 1997)**

Semantic fluency tasks are frequently administered as a measure of lexical organisation and verbal fluency, and are often used during neuropsychological screenings for EF and language skills (Ruff, Light, Parker, & Levin, 1997) Children are told they would have one minute to produce the names of as many different animals as they could think of. Their responses can be either signed or spoken and are video recorded for later analysis. Children’s scores on this task are the number of items they produced in one minute after repetitions and irrelevant responses were excluded.

**British Sign Language Narrative Skills Test (Herman et al., 2001)**

The British Sign Language Narrative Skills Test is one of the few language assessments currently available for use with deaf children who communicate using sign language. It is a narrative elicitation task whereby children are asked to watch a video of a short story acted out by two children. There is no language involved in the story (verbal or signed) and all interactions between characters are gestures or mime.

Prior to administering and scoring the test, the tester must have completed a certified training course and be able to communicate fluently in BSL to a minimum of stage 2 proficiency as assessed by the Council for the Advancement of Communication with Deaf People (CACDP). Deaf children often have frequent contact with adults with varying levels of sign language proficiency, and are adept at adjusting their language to match that of their conversational partner. Therefore, if a child who uses sign language was to be assessed by an adult with basic level signing skills, the child may adjust their signing to make themselves understood, or use SSE instead of BSL, resulting in a test score that is not indicative of their true narrative potential.

Before viewing the video, children are told that they are going to watch a short story and, after it finishes, they will need to tell the tester what happened. The children are then left alone in the room to watch the video. Once the video has finished, the tester returns to the room and gives the child the opportunity to watch it a second time if they want to. They then ask the child to re-tell the story to them as they haven't seen the video (the aim is to get the child to tell the story to a person who doesn't know what they are talking about and therefore implies that a certain level of detail is needed). After the child has produced their story, they are asked three questions which relate to the story; *1) What items were on the tray? 2) Why did the boy throw the spider?* and *3) Why did the girl tease the boy?* These questions are asked to ensure that the children have a good understanding of the story, and to determine whether they can infer the underlying motivations of the story characters' actions. The child's spontaneous narrative and responses are filmed in order to be analysed at a later date. The narratives scores are a composite of the following four components; 1) narrative content (the number of events the child recalls and produces), 2) narrative structure (the way the child orders the events of the story, sets the scene, and concludes the story), 3) BSL grammar (consistent and grammatically correct use of BSL, including use of classifiers, role shift and spatial location) and 4) children's responses to the 3 questions.

The normative data for the test was gathered from children who were native signers from deaf families and deaf children from hearing families who have had early exposure to sign language through either BSL/English or Total communication educational programmes.

Children's Spoken Narratives

Deaf children who communicate using spoken English also watched the same video and completed the same narrative task and their spoken spontaneous narratives and question responses were video recorded. As BSL and English have very different grammar systems, a separate but equivalent scoring system was necessary in order to assess the spoken narratives. The scoring system used to assess the oral narratives in this study, was taken from a recent large-scale study into the investigation of the narrative skills of deaf children who use spoken English (Jones, et al., 2016). As with the BSL scoring system, children's narratives were scored in terms of content, structure, and in these cases, English grammar.

**The Expressive One Word Picture Vocabulary (Bronell, 2000)**

A measure of the children's vocabulary was obtained using an adapted version of the Expressive One Word Picture Vocabulary Test (EOWPVT). Children are asked to name a series of pictures, the majority of which are nouns, however items also include verbs (such as eating or sewing) and category labels (e.g. fruit and toys). They are given four practice items to ensure they understand the test, and then begin the test on the number item appropriate for their age, as determined by the test instructions. Children were able to give either spoken or signed responses to pictures presented to them and the test was discontinued after the children made errors or didn't respond to six consecutive items, in accordance with the testing instructions. As the original test was developed in America, some minor substitutions were made on three items due to cultural differences between the commonality of some picture items in the USA and UK. For example, a picture of a badger was substituted for a racoon, the symbol for 'prescription' was changed to one appropriate for the UK, and a more familiar picture of a windmill was used as it was felt that children in the UK would not necessarily recognise the current target picture.

## Non-verbal IQ

### Matrix reasoning NVIQ – (Wechsler, 1999)

Children completed the Matrix reasoning subtest of the Wechsler Abbreviated Scale of Intelligence (WASI, Wechsler, 1999) as a control measure of their non-verbal IQ. In this test the children are shown a pattern with a missing section have to choose the correct pattern piece that fits the missing section from five possible choices. They are given two practice items first to ensure that they understand the task, then begin the test at an age appropriate item as determined by the test instructions. The test is discontinued after they reach the age appropriate stopping point, or if they make four errors within five consecutive items.

# Chapter 6 EF INTERVENTION METHODOLOGY AND RESULTS

### 6.1.1 Participant Recruitment

The intervention study was conducted following a nationwide longitudinal study of EF skills in deaf children by a team at the Deafness Cognition and Language Research Centre (Marshall, et al., 2015; Jones, et al., 2016). Some teachers from participating schools expressed an interest in taking part in further research and were keen to suggest children in their classes who might benefit from an EF intervention. Three schools in the London area were approached to take part in the project and were sent information about the rationale for the study and what it involved. They were provided with a copy of the intervention and were asked for their feedback. Teachers were asked to identify children between the ages of 7-11 who they believed would benefit from the intervention. Therefore, children with additional special needs were not excluded from the study as they are arguably the group who are in most need of EF interventions, appear to benefit from EF intervention the most (Diamond, 2012), and would be the likely recipients of this kind of training in a school setting. Ethical approval for the study was obtained from UCL Research Ethics Committee, prior to approaching schools. Information about the study was sent to parents via teachers (see Appendix VI) who then completed forms giving their consent for their children to take part in the study (see Appendix VII and VIII). Children were also asked if they were happy to take part in the sessions prior to them starting.

Table 6.1.1-1. Distribution of participants across schools

| | School A | School B | School C | Total |
|---|---|---|---|---|
| Number of children | 5 | 3 | 8 | **16** |
| Boys | 3 | 2 | 4 | **9** |
| Girls | 2 | 1 | 4 | **7** |

**Descriptions of Schools**

All three schools are mainstream schools with specialist provision for deaf children. 'School A' is a primary school in south east London with five deaf children in their primary school and six in the infant school. The school has a total communication (TC) policy with BSL, SSE and Spoken English being used. The children spent their mornings in the specialist centre with a Teacher of the Deaf teaching them the core subjects English, literacy and maths, where they received additional support from deaf and hearing learning support assistants (LSAs). In the afternoons they attended mainstream classes supported by LSAs who used sign language

School B is a mainstream primary school based in south east London. Seven deaf children attend the school and they participate in all mainstream classes and activities. The children are educated orally, however some sign language is occasionally used. A Deaf Tutor visits the deaf children once a week, providing lessons in sign language and deaf culture.

School C is a mainstream primary school on the outskirts of east London. Like school A, it has a TC child-led policy and uses a combination of BSL, SSE and spoken English when teaching children, depending on the child's preference. There are specialist deaf and hearing Teachers of the Deaf and LSAs at the school who support the children. During the morning, the deaf children are taught in small groups at the learning support unit for the core curriculum topics – literacy and mathematics. The deaf children attend mainstream classes and activities in the afternoon, supported in class by the LSAs and Teachers of the Deaf.

**Testing Conditions**

Children were tested individually in a quiet classroom. On some occasions other children were present in the room but were working on silent tasks or tests and had been instructed not to distract interfere with the testing. Depending on the child's preferred language, instructions were delivered in either spoken English, sign supported English or British Sign Language. All children were given the same instructions, however due to the low language levels of some children, instructions sometimes needed to be adjusted. For example, on the 'Odd One Out' task some children were asked "which one is different?" as the term 'odd-one-out' was problematic. Likewise, in both SSE and BSL, children were asked to identify the 'different' shape

### 6.1.2 Participant Information

Due to the aforementioned wide variation in language experience, preferred method of communication and educational experiences of deaf children, matching participants with appropriate control participants is extremely difficult. A within-subjects design whereby each child took part in both the music intervention and art (control) sessions was adopted, enabling each child to act as their own control. Single subject designs are frequently used in intervention studies which involve atypical populations, as they provide a powerful tool for determining the effects of different treatment conditions (e.g. see Swanson & Sachse-Lee, (2000) for a meta-analysis of single-subject interventions).

Children undertook a baseline assessment to determine their EF and language performance prior to starting the study. At schools A and C, the children involved in the study were divided into two groups, according to ability. The groups were relatively equal in number, and were decided after consultation with teachers. Table 6.1.2-1 below shows the division and numbers children into different groups.

There were three children from school B taking part in the study, therefore there was only one group run at this school. They began with the music intervention for five weeks and concluded with five weeks of art control sessions. At schools A and C, both group sessions were run concurrently. Table 6.1.2-1 below details the gender, age and language preference of each participant. The average age of the children was 9 years 3 months, with a standard deviation of 1.17. It also indicates whether they participated in the control condition first, followed by the intervention (C-I), or completed the intervention activities before taking part in the control condition (I-C).

Table 6.2.1-1. Age, gender and language preference, and order of conditions for participants

| Participant Number | Gender | Age | Language Preference | Intervention Order |
|---|---|---|---|---|
| 1 | F | 9.07 | BSL | C-I |
| 2 | M | 9.03 | ENGLISH + SSE | C-I |
| 3 | M | 10.06 | BSL | C-I |
| 4 | M | 10.01 | SSE | I-C |
| 5 | F | 7.11 | SSE | I-C |
| 6 | M | 9.06 | ENGLISH | I-C |
| 7 | F | 8.06 | ENGLISH | I-C |
| 8 | M | 8.06 | ENGLISH | I-C |
| 9 | F | 10.11 | ENGLISH + SSE | C-I |
| 10 | M | 10.00 | BSL | C-I |
| 11 | M | 10.10 | ENGLISH + SSE | I-C |
| 12 | F | 7.02 | ENGLISH | I-C |
| 13 | M | 7.00 | ENGLISH | I-C |
| 14 | F | 9.01 | BSL | C-I |
| 15 | M | 8.02 | ENGLISH + SSE | C-I |
| 16 | F | 10.05 | ENGLISH + SSE | I-C |

**Language Background and Profiles**

Information about the children's language exposure and family background is provided in table 6.1.2-2 below. A high proportion of children participating in the study are exposed to various spoken languages at home in addition to English and have been raised in a multilingual environment. Around 15% of deaf children in education in the UK have English as an additional language (Cline & Mahon, 2010), the majority of whom live in inner cities and come from hearing families. This is represented in the current participant sample who live in East and South East London and are variously exposed to Punjabi, Urdu, Turkish, Bengali, Romanian, Polish, Vietnamese and Somali at home, in addition to English at home and at school.

Table 6.1.2-2. Language background of deaf children participating in the study.

| Participant number | Age | Deaf family members | Languages spoken/signed at home | Parent-child language preference | Age exposedto sign | Hearing aids and cochlear implant usage | Additional Diagnosis? |
|---|---|---|---|---|---|---|---|
| 1 | 9;07 | No | Punjabi & English | SSE | 5 | None (Cochlear implant not used) | Global developmental delay |
| 2 | 9.;3 | No | English | English | 8 | BAHA | Cleft palate |
| 3 | 10;06 | No | English | SSE | 3 | Cochlear Implant | Neonatal Abstincence Syndrome |
| 4 | 10;11 | No | English &Bengali | English | 8 | Hearing aids | None |
| 5 | 10 | No | Polish | SSE & Polish | 8 | Cochlear Implant | Severe language delay |
| 6 | 9;01 | No | English & Somali | English & Somali | 5 | Hearing aids | None |
| 7 | 8;02 | No | Romanian | English | 7 | Cochlear Implant | None |
| 8 | 10;01 | Mother | English & BSL | BSL | 0 | Hearing aids | None |
| 9 | 7;11 | No | English & Urdu | SSE & English | 3 | Hearing aids | None |
| 10 | 9;06 | No | English & Vietnamese | English | 4 | Cochlear Implant | None |
| 11 | 8;06 | No | English | English | 4 | Cochlear Implant | Language impairment |
| 12 | 8;06 | No | English &Turkish | English | 4 | Cochlear Implant | None |
| 13 | 10;10 | Uncle & Aunt | English & Somali | English & Somali | 9 | Hearing aids | None |
| 14 | 7;02 | Cousins | English & Urdu | English | 4 | Hearing aids | None |
| 15 | 7 | Cousins | English & Urdu | English | 4 | Hearing aids | None |
| 16 | 10;05 | No | English | English | 5 | Cochlear Implant | None |

At baseline testing, the Expressive One Word Picture Vocabulary Test (EOWPVT; Bronwell, 2000) and the BSL Narrative Production Test (Herman et al., 2004) was administered to all of the children. Children who preferred to communicate in spoken English were scored on the oral version of the narrative production test (as described in section 5.4.2). Table 6.1.2-3 shows the participants' scores on the vocabulary test and narrative production test, and whether the test was administered in BSL or spoken English. Information about each child's age and ability group is also included.

Table 6.1.2-3 Vocabulary and Narrative Production Scores

| Participant Number | Age | Ability Group | Test Language | Vocabulary T-scores | Narrative Content Percentile | Narrative Structure Percentile | Narrative Grammar Percentile |
|---|---|---|---|---|---|---|---|
| 1 | 9;07 | Lower | BSL | 25 | N/A | N/A | N/A |
| 2 | 9;03 | Lower | BSL | 31 | 10 | 25 | 10 |
| 3 | 10;06 | Lower | BSL | 32 | 10 | 25 | 25 |
| 4 | 10;11 | Lower | ENGLISH | 33 | 25 | 10 | 5 |
| 5 | 10;00 | Lower | BSL | 20 | N/A | N/A | N/A |
| 6 | 9;01 | Lower | BSL | 38 | 10 | 10 | 10 |
| 7 | 8;02 | Lower | BSL | 30 | 25 | 25 | 10 |
| 8 | 10;01 | Higher | BSL | 35 | 25 | 25 | 10 |
| 9 | 7;11 | Higher | BSL | 35 | 25 | 25 | 10 |
| 10 | 9;06 | Higher | ENGLISH | 61 | 75 | 25 | 50 |
| 11 | 8;06 | Higher | ENGLISH | 34 | 10 | 5 | 5 |
| 12 | 8;06 | Higher | ENGLISH | 46 | 95 | 95 | 50 |
| 13 | 10;11 | Higher | ENGLISH | 43 | 75 | 50 | 25 |
| 14 | 7;02 | Higher | ENGLISH | 41 | 25 | 25 | 10 |
| 15 | 7;00 | Higher | ENGLISH | 40 | 90 | 75 | 10 |
| 16 | 10;05 | Higher | ENGLISH | 47 | 50 | 50 | 10 |

**Vocabulary**

Children's raw vocabulary scores were converted into T-scores (with a mean of 50 and a standard deviation of 10). Cells highlighted in grey indicate scores that are one or more standard deviations below the mean. All of the children in the lower ability group had a vocabulary score that was one standard deviation or more below the mean

**Narrative Production**

Children's raw scores on the content, structure and grammar components of the narrative skills test were converted to percentile scores.

Narrative production test scores are unavailable for two of the children (participants number 1 and 5), as their level of sign language production was too low to enable adequate scoring. It should also be noted that child number 11 has particularly low scores for both vocabulary and all three components of the narrative skills test. This child has specific language difficulties recognised by her teachers and speech and language therapist, although no formal diagnosis of SLI has been made. While her language production scores are low, her non-verbal IQ and EF abilities appear unimpaired, as measured by the BRIEF (reported later in section 6.3). This child was included in the 'higher ability' group as she attended school B in which there were three children participating in the study, and were therefore not split into ability groups.

Many of the children whose narrative skills were assessed using BSL received low scores on this test, particularly for grammar. However, it was sometimes the case that while teachers reported children's first or preferred language to be BSL, on meeting the children it became clear that they used SSE or TC more frequently. This is reflected in their narrative scores and may account for a proportion of their poor scores for BSL grammar.

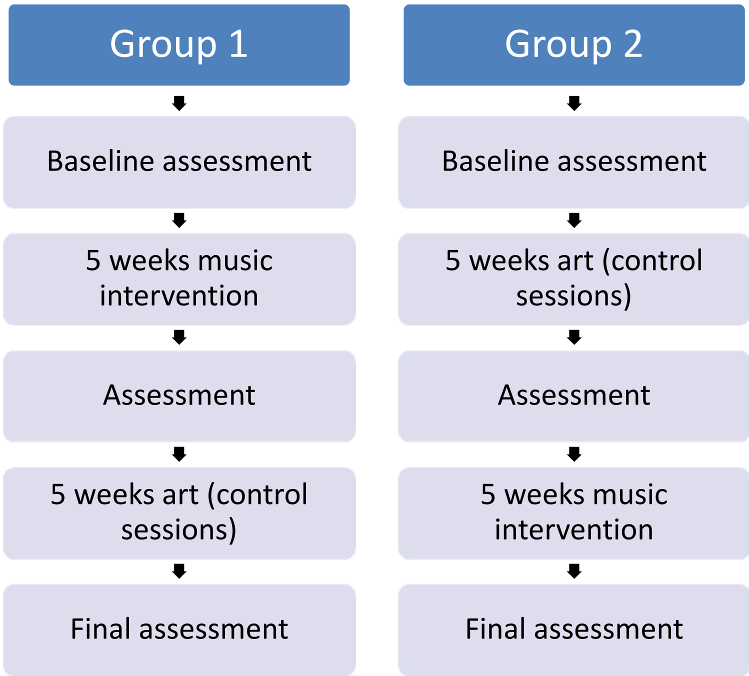
### 6.1.3 Method for the intervention

Before the intervention began several weeks were spent working alongside teachers and learning support assistants in the children's schools, getting to know the children and supporting them in class. This was essential to the smooth running of the intervention programme as it was necessary for me to be familiar with each child's mode of communication and ability threshold. Denmark & Atkinson, (2015) note that a crucial factor to consider when assessing deaf populations is that they are heterogenious, and they therefore emphasise the importance of knowing the*"full developmental history of an individual prior to assessment or inclusion in a research sample" (Denmark & Atkinson, 2015, pp.354).* Within the same school and same class, deaf children's language ability varied greatly and it took time to build a relationship with some of the children, particularly those who were shy when communicating with a new adult. Being able to communicate using SSE, BSL and spoken English, according to each child's preference was essential to the smooth running of the intervention and by getting to know the children before the commencement of the study, the author was able to start the intervention having already established what would appropriately challenge or potentially de-motivate each child. When considering potential future applications of the intervention, it is likely that the person delivering the intervention would be very familiar with the children (i.e. their class Teacher or Teaching Assistant), therefore familiarity with the children prior to carrying out the intervention contributes to the ecological validity of the study.

The children completed a total of 10 hours of intervention and 10 hours of the art control class. These were broken down into two one hour sessions carried out twice a week over a ten week period. For the first five weeks a group of children would participate in the EF intervention whilst the other group carried out the art (control) sessions. After five weeks, the children completed the EF and language assessments again, before switching topics and completing another 5 weeks of the intervention or control. The study was then concluded by the final round of assessments, subsequently followed by 6 week follow-up testing[3]. The schedule of testing and activities is shown in figure 6.1.3-1.

[3] Although many of the children underwent follow-up testing, not all of the children were available for this phase of data collection. The children who were assessed in the follow-up stage were not motivated or as engaged with the tasks as it was the fourth time they had undergone testing. It was not felt that the collected data were representative of their abilities, therefore these data will not be discussed further.

Figure 6.1.3-1. Program timetable for the study for schools A and C




All of the intervention and control sessions, across all three schools, were carried out at the same time of day. It was not feasible to take the children out of class in the morning time, as across all primary schools, this is the time when the core curriculum subjects are taught. The preferred time for all schools was during the afternoon sessions immediately after the children had had their lunch. The intervention and art sessions were scheduled in the children's timetables at a fixed time and became part of their school week for a term and a half.

As far as was possible, the same adults were involved in each of the sessions (both music and art) and they were briefed on the activities prior to the start of the session. All sessions lasted 1 hour each. An intervention journal was kept in order to monitor each session and note any deviations from the set lesson plan.

### 6.1.4 Practical Considerations

Schools are chaotic, busy places. With ever changing curriculum demands, Teachers are tasked with finding a way to accommodate an increasing number of extra curricula activities and 'initiatives' into an already jam-packed timetable. For example, during the time this intervention was carried out, nationwide concern about children's poor dental health had led to proposals for children up to the age of 11 to brush their teeth under supervision at school every day. Brushing one's teeth takes two minutes, but ensuring 25-30 children brush their teeth properly takes substantially more time and was not a prospect relished by most Teachers. Deaf children tend to have particularly busy timetables, as the majority of them meet with Speech and Language Therapists, Audiologists, Deaf mentors/teachers for deaf studies or signing classes and attend extra literacy booster classes in addition to their regular school timetable. Due to these demands on time, flexibility is essential when carrying out class based interventions. In preparation for this study scheduled times for the intervention and control sessions were negotiated with class teachers and included in the children's timetables. However, on some occasions it was necessary to change the time (or on two occasions, the day) of the sessions in order to ensure that all of the children could attend. There were 2 unavoidable occasions where a child missed taking part in the intervention due to visits to new schools and SATs revision classes. Including pre and post intervention and control testing, the 16 children who participated in the study committed to 24 hours of contact time, the equivalent to nearly four full school days.

All research and testing involving human participants is subject to a host of uncontrollable factors such as fatigue, participants being distracted or emotionally distressed depending on what has happened during their day prior to their participation in the study. These factors are particularly relevant in studies involving children, and, in this study, children who struggle to express themselves due to language delay or other developmental conditions can succumb to frustration and fatigue more easily. Occasions where children were not fully engaged in the intervention or art sessions (although this was a rare occurrence) were noted in the intervention journal.

For some participants, there were additional issues with testing. Due to low language ability or additional learning difficulties, some of the assessments proved too difficult for a minority of the students. Whilst all of the assessment tests were non-verbal where possible, (except for the narrative skills test) the issue of effectively communicating sometimes complicated task instructions still remained. This is another reason why it was important to build a relationship with the children prior to testing and the intervention.

The following sections will describe the EF and language profiles of the deaf children who participated in the study. It will then go on to provide detailed results of their performance on EF tasks following both the music-based EF Intervention and art control conditions. Additionally, data from ‘low ability’ and ‘high ability’ groups of children will be considered separately, in order to investigate the effect of the intervention on children with contrasting EF and language profiles.

### 6.1.5 Ability Grouping

As previously discussed, the children were split into groups according to ‘ability’ rather than by age or school class. The ‘higher ability’ group consisted of children whose communication skills were better than some of their deaf peers, and were of an educational level on a par to their hearing peers. The ‘lower ability’ group had apparent communication difficulties (e.g. poor sign language skills, poor total communication skills or additional educational needs), and received one to one support during mainstream school classes. Intervention and control classes were therefore tailored more easily to the needs of each group of children. Children were assigned to groups after consultation with their class teachers.

Children who were in the ‘higher ability’ group, received the intervention training first, followed by the control sessions. The ‘lower ability’ group took part in the control sessions first, and then completed the intervention sessions. This arrangement allowed the author to increase their familiarity with the communication needs and capabilities of the ‘lower ability’ group during the control sessions, when less sophisticated language was required in order to instruct and demonstrate activities. Although the author had spent two weeks at each school prior to the start of the study in order to build rapport and familiarity with all of the children, transitioning from the role of one-to-one teaching assistant to leading hour-long sessions, working with all of the children simultaneously was challenging. Therefore, starting the ‘lower ability’ group with the control sessions gave the author a better indication of the appropriate differentiation needed for the intervention sessions, and established the author’s new role as ‘teacher’ (as opposed to ‘visitor’) with the children.

The non-random allocation of participants to groups in this way is a limitation to the study design (see discussion in chapter 7 section 7.4), however, designation of children into ability groups was necessary in this instance due to variation in baseline EF ability between the children and the need for differentiation of activities for some of them. As stated, challenging a child to progress in an activity whilst maintaining their attention and avoiding loss of motivation (and therefore their disengagement with the tasks) is a core consideration in designing an effective EF training programme**.**

Of the sixteen children who took part in the study, seven were in placed in the ‘lower ability’ group and nine in the ‘higher’ ability group. Throughout this chapter, children who were in the ‘lower ability’ group are included in tables and graphs as participants 1-7, and the ‘higher ability’ group are children 8-16.

## 6.2 Children’s EF Profiles

This section will provide an overview of each child’s baseline EF profile, as determined by the results of the BRIEF questionnaire. Additionally, this section will provide details of their language experience, family background and their scores on a one-word picture vocabulary test, and test of narrative skills. The relationship between their language and EF profiles will be examined.

### EF Profiles

Table 6.2-1 below gives detail of each child’s non-verbal IQ t-score and their baseline score for each component of the BRIEF questionnaire, as rated by their parents. T-scores were calculated for each of the EF components, with a higher t-score indicating an area of potential difficulty for the child. T-scores have a mean score of 50 and a standard deviation of 10, and areas of poor performance (a t-score of 65 or higher) are shaded in grey.

Two composite index scores are also included to give an overall indication of the particular EFs children may be displaying difficulties with. The ‘Behavioural Regulation Index’ is a composite of the Inhibit, Shift and Emotional Control scores, and the ‘Metacognition Index’ was calculated from the sum of the Initiate, Working

Memory, Plan/Organise, Organisation of Materials and Monitor scores. Examination of each of these indexes enables the identification of specific areas of concern or potential EF dysfunction. The Global Executive Composite (GEC) incorporates all of the scales of the BRIEF and is used as a summary measure. Table 6.1-1 below shows those children with potential EF difficulties shaded in grey. The children's matrices T-scores, measuring their non-verbal IQ are also included. Low non-verbal IQ scores are indicated in blue.

Table 6.2-1. Children's Non-verbal IQ and EF Scores from the BRIEF Questionnaire

| Participant number | Ability Group | Matrices | Inhibit | Shift | Emotional Control | Initiate | Working Memory | Plan/Organise | Organisation of materials | Monitor | Behavioural Regulation Index | Metacognition Index | Global Executive Composite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lower | 25 | 89 | 80 | 73 | 78 | 74 | 75 | 63 | 78 | 85 | 77 | 81 |
| 2 | Lower | 28 | 82 | 88 | 65 | 53 | 65 | 67 | 39 | 75 | 81 | 63 | 72 |
| 3 | Lower | 24 | 82 | 84 | 67 | 72 | 76 | 84 | 64 | 78 | 81 | 81 | 83 |
| 4 | Lower | 31 | 50 | 50 | 40 | 78 | 77 | 57 | 37 | 67 | 46 | 65 | 54 |
| 5 | Lower | 23 | 69 | 67 | 67 | 59 | 60 | 33 | 42 | 72 | 70 | 53 | 60 |
| 6 | Lower | 32 | 45 | 50 | 36 | 52 | 77 | 65 | 40 | 64 | 42 | 62 | 55 |
| 7 | Lower | 60 | 42 | 64 | 56 | 47 | 49 | 33 | 36 | 40 | 53 | 39 | 44 |
| 8 | Higher | 41 | 46 | 47 | 54 | 69 | 52 | 56 | 49 | 47 | 49 | 55 | 53 |
| 9 | Higher | 61 | 40 | 41 | 40 | 43 | 44 | 38 | 34 | 41 | 39 | 38 | 38 |
| 10 | Higher | 54 | 44 | 40 | 43 | 35 | 36 | 35 | 33 | 31 | 41 | 31 | 34 |
| 11 | Higher | 42 | 40 | 39 | 38 | 40 | 55 | 47 | 34 | 41 | 37 | 43 | 40 |
| 12 | Higher | 66 | 46 | 43 | 43 | 35 | 38 | 37 | 33 | 37 | 43 | 33 | 36 |
| 13 | Higher | 45 | 37 | 47 | 36 | 44 | 43 | 50 | 36 | 37 | 37 | 41 | 39 |
| 14 | Higher | 45 | 48 | 41 | 36 | 55 | 52 | 51 | 32 | 54 | 41 | 48 | 45 |
| 15 | Higher | 71 | 47 | 43 | 35 | 39 | 45 | 50 | 33 | 38 | 40 | 41 | 40 |
| 16 | Higher | 42 | 47 | 53 | 45 | 46 | 41 | 53 | 34 | 49 | 48 | 45 | 46 |

### 6.3 EF Assessments Data Analysis

Data analysis began only once all of the data for the study had been collected, in order to reduce any potential experimenter effects, such as scoring bias. The changes in children's performance on the task at different testing time points were calculated from pre and post-music intervention test scores and pre and post-art control test scores. Comparisons were then made between these two gain scores, using a 2 (music intervention/ art control) x 2 (higher/lower ability group) mixed factorial ANOVA. Graphs of individual children's scores are provided, along with graphs showing the performance of each ability group over the three assessment time-points, revealing which groups of children saw improvements (for each specific EF) during post-intervention testing compared with post-control.

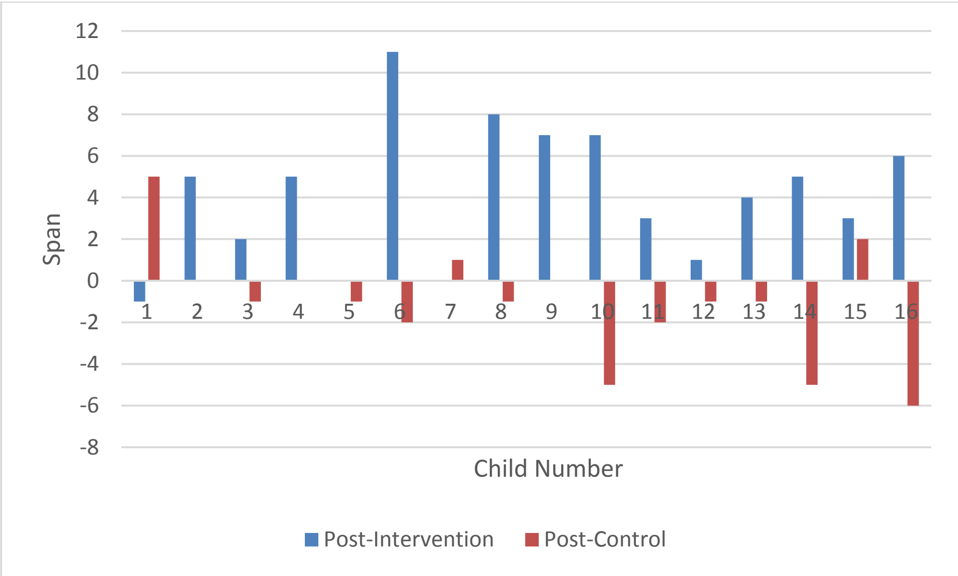
<u>Intervention's Impact on Assessments of Visuospatial and Working Memory</u>

#### 6.3.1 Visuospatial Span Task (Wechsler & Naglieri, 2006)

<u>Individual Performance</u>

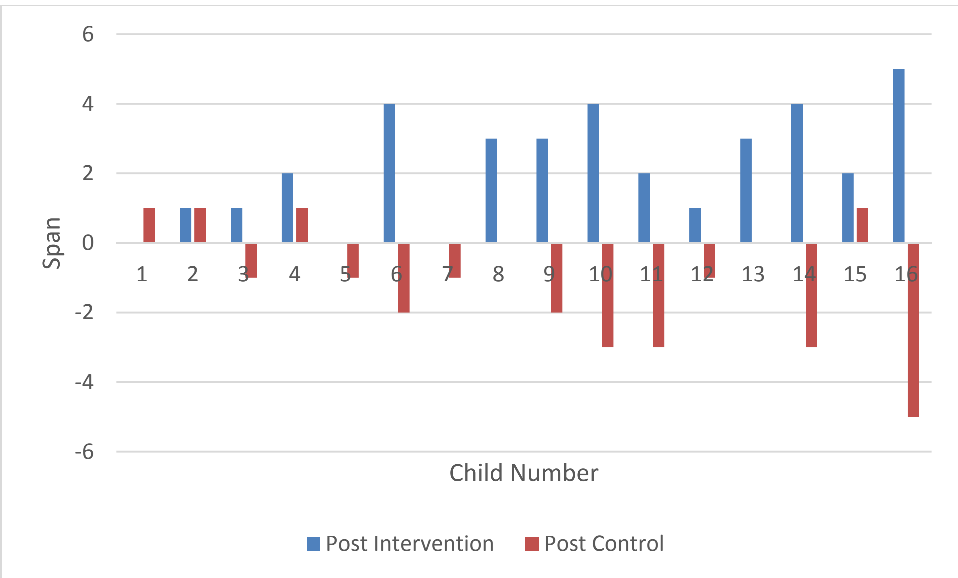
This task required children to copy the tester in tapping blocks in an increasing spatial sequence. The task had two parts, the first requiring the child to reproduce the same sequence as the tester; and the second part requiring them to reproduce the sequence in the reverse order. All children completed the visuospatial span task at baseline, post-intervention and post-control times. Differences in the children's forwards and backwards spans across times were calculated and are presented in graph 6.3.1-1 below. An absence of a data bar (e.g. the post-control span of participants 5 and 9), indicate no change in the child's achieved span between pre and post control testing.

Graph 6.3.1-1 Differences in visuospatial span scores pre and post intervention and control conditions

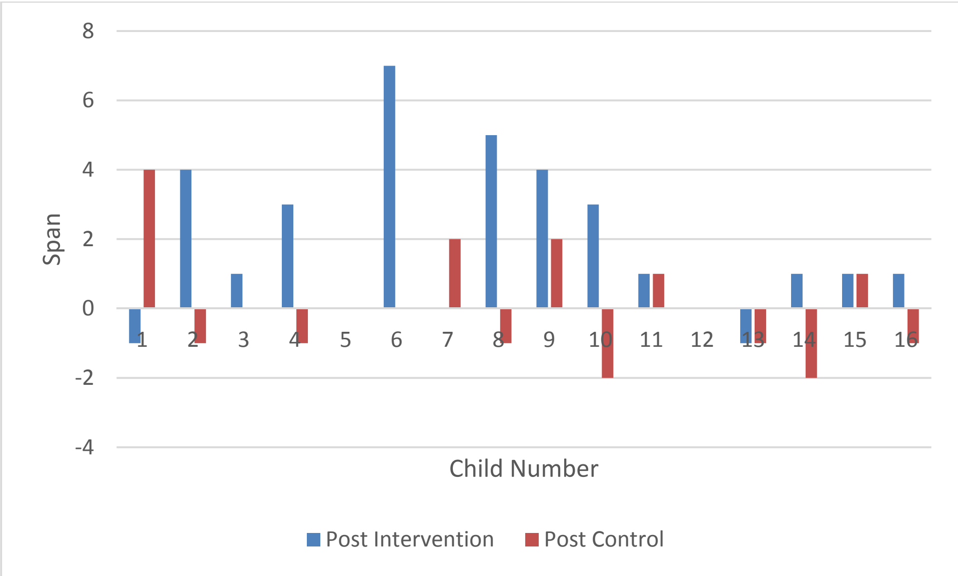



The scores were then broken down into forwards and backwards span scores, as shown in graphs 6.3.1-2 and 6.3.1-3 below. Once again, the graphs show the difference between scores pre and post intervention and control conditions.

Graph 6.3.1-2 Differences in visuospatial span forwards scores pre and post intervention and control conditions



Graph 6.3.1-3. Differences in visuospatial span backwards scores pre and post intervention and control conditions

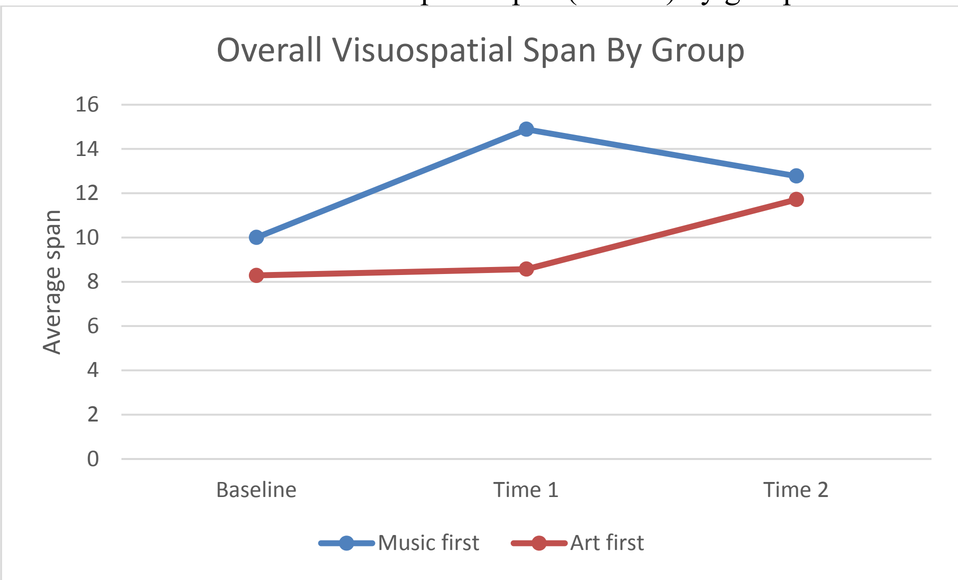



<u>Group Performance</u>

Graph 6.3.1-4 shows that the higher ability groups (who completed the music intervention first) showed an improvement in overall task performance, however this is not maintained as their average overall span drops at time 2, after they have completed the control condition.

The lower ability group show a clear effect of the intervention in graph 6.3.1-4. Their average span at time 1 (after completing the control sessions) is similar to their baseline span. However, after completion of the EF intervention at time 2, the overall span shows improvement.

Graph 6.3.1-4. Performance on visuospatial span (overall) by group

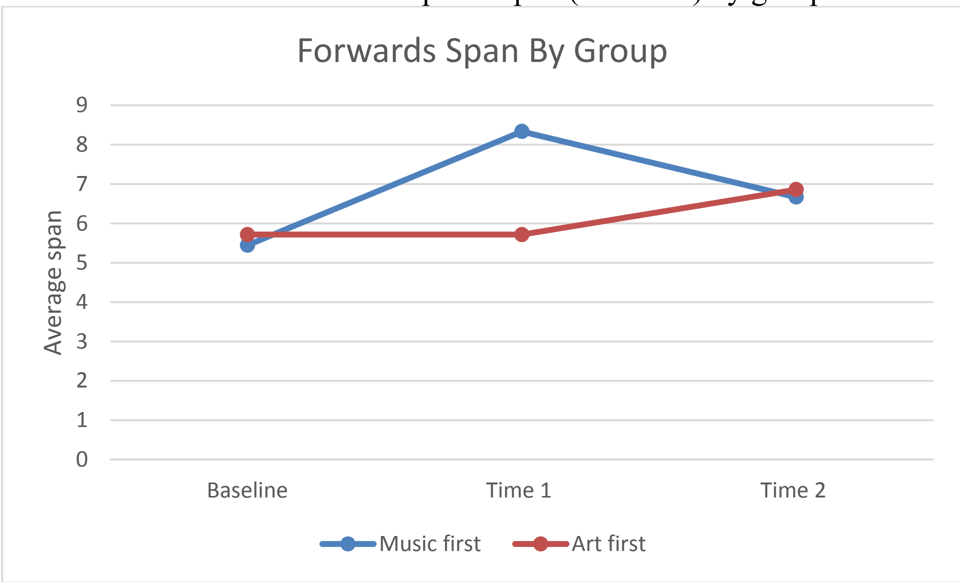



A 2(Intervention condition: Music or Art) x 2 (Ability group: high or low) mixed ANOVA was used to analyse the data. There was a significant main effect of intervention condition ($F_{(1,14)}$=15.714, p<.001, partial $\eta^2$=.53), and no significant interaction between treatment condition and ability group ($F_{(1,14)}$=2.776, p=.118). There was no significant effect of ability group ($F_{(1,14)}$=.173, p=.684).

Table 6.3.1-1 Mean and Standard deviations for Overall Visuospatial Change Scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post Music Intervention Overall Visuospatial | High | 4.89 | 2.315 | 9 |
| | Low | 3.14 | 4.220 | 7 |
| | Total | 4.13 | 3.284 | 16 |
| Post Art Control Overall Visuospatial | High | -2.11 | 2.667 | 9 |
| | Low | .29 | 2.289 | 7 |
| | Total | -1.06 | 2.720 | 16 |

Graph 6.3.1-5. Performance on visuospatial span (forwards) by group



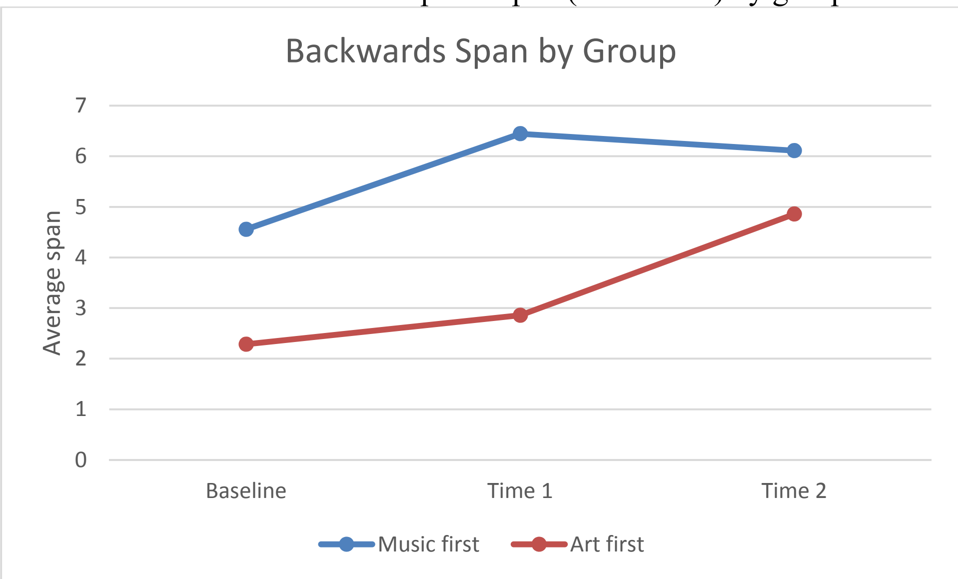

Graph 6.3.1-5 shows the performance of the higher and lower ability groups in the forwards condition of the visuospatial span task. In this condition, both groups have a similar average span at baseline testing. At time 1, the group who completed the art control sessions first (the lower ability group), maintained a similar score. However, the group who completed the music intervention (the higher ability group) show an improvement to their average span score. At time 2, the lower ability group show an improvement to their average span score after completing the music intervention, whilst the higher ability group show a fall in average span after completing the art control sessions, suggesting that the effects of the music intervention were not maintained.

A 2x2 mixed factorial ANOVA revealed a significant main effect of intervention condition ($F_{(1,14)}=22.288$, $p<.001$, partial $\eta^2=.61$) and a significant interaction between treatment condition and ability group ($F_{(1,14)}=6.490$, $p=.023$, partial $\eta^2=.32$). There was no significant main effect of ability group ($F_{(1,14)}=.227$, $p=.64$).

Table 6.3.1-2 Means and standard deviations for forwards span change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post Music Intervention Forwards scores | High | 3.00 | 1.225 | 9 |
| | Low | 1.14 | 1.464 | 7 |
| | Total | 2.19 | 1.601 | 16 |
| Post Art Control forwards Score | High | -1.78 | 1.922 | 9 |
| | Low | -.29 | 1.254 | 7 |
| | Total | -1.13 | 1.784 | 16 |

Graph 6.3.1-6. Performance on visuospatial span (backwards) by group




Graph 6.3.1-6 shows the performance of the higher and lower ability groups in the backwards span condition of the visuospatial span task. In this condition, a difference between the two groups can be seen at baseline, with the lower ability group having a lower average backwards span. At time 1, the group who completed the music intervention first (the higher ability group) showed an improvement of +2 in their backwards span score. The group of children who completed the art control sessions first (the lower ability group) showed little improvement to their average score. At time 2, the lower ability group show a post-intervention improvement of +2 to their average backwards span score, while the higher ability group show a slight drop in their post-control score.

A 2x2 mixed factorial ANOVA revealed a main effect of intervention condition which was approaching significance ($F_{(1,14)}$=4.387, p=.06, partial $\eta^2$=.24), and there was no significant interaction between treatment condition and ability group ($F_{(1,14)}$=.122, p=.732). There was no significant main effect of ability group ($F_{(1,14)}$=1.060, p=.321).

Table 6.3.1-3 Means and standard deviations for backwards span change scores

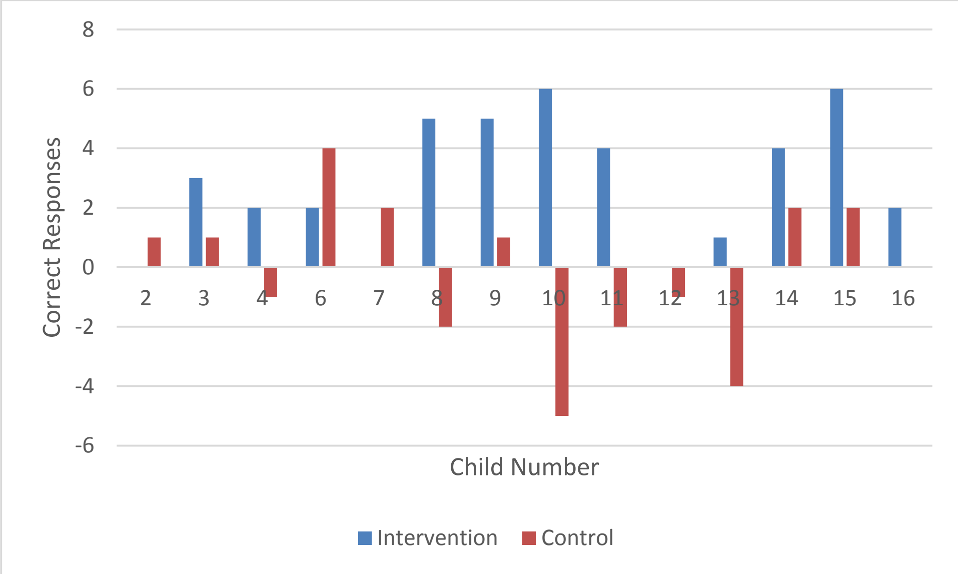
| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post Intervention Backwards scores | High | 1.67 | 1.936 | 9 |
| | Low | 2.00 | 2.828 | 7 |
| | Total | 1.81 | 2.287 | 16 |
| Post Control Backwards Score | High | -.33 | 1.414 | 9 |
| | Low | .57 | 1.813 | 7 |
| | Total | .06 | 1.611 | 16 |

### 6.3.2 The Odd One Out Task (Henry, 2001)

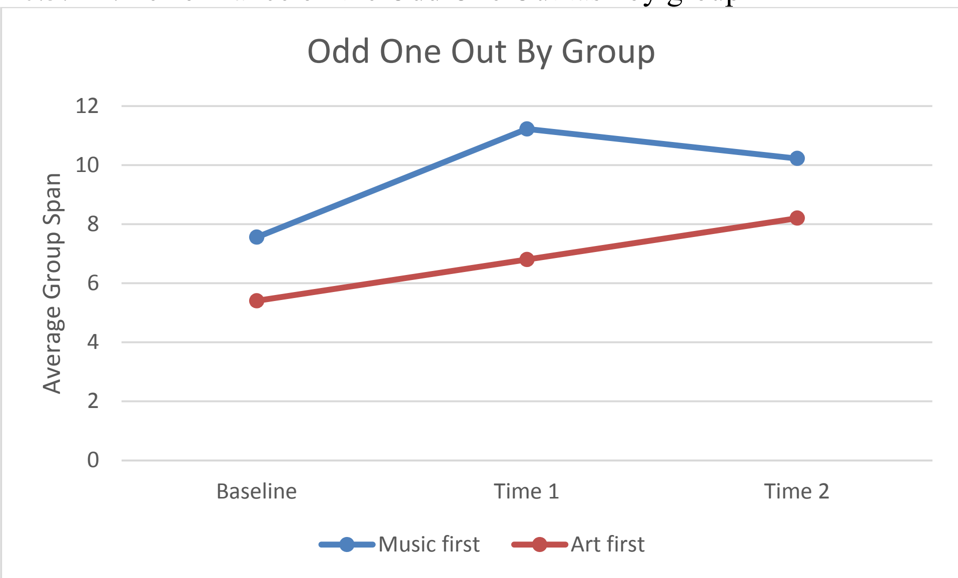
The 'Odd One Out' task was a measure of EF-loaded working memory which required children to make a judgement to identify one item out of three as the 'odd one out' and additionally remember its spatial location. Two children (numbers 1 and 5) did not understand the instructions for this test and had to be excluded from the data analysis. Therefore for this test N=14.

Children's scores on this task are the number of trials they answer correctly. The children completed the task during baseline, post-intervention and post-control testing sessions, and the differences in their scores across testing times are shown in graph 6.3.2-1 below. As shown in graph 6.3.2-1, all children either improved their score or achieved the same score (e.g. children numbers 1, 7 and 13) after completing the EF intervention.

Graph 6.3.2-1. Differences in Odd One Out task scores pre and post intervention and control conditions




Graph 6.3.2-2. Performance on the Odd One Out task by group




Graph 6.3.2-2. shows the performance of the higher and lower ability groups on the Odd One Out task. The difference between groups can be seen in their differing average baseline scores. At time 1, the higher ability group (who completed the music intervention first) show a post-intervention improvement to their average working memory score. However, this improvement appears not to be maintained at time 2, where their post-control score falls slightly. The lower ability group (who completed the art control sessions first), appear to show a linear improvement to their average score over time, showing an improvement to their average score at time 1 (post-

control) and time 2 (post-intervention). These results suggest that the music intervention may have had an impact on the performance of ‘higher ability’ children on this task, but no comparative effect is seen for the ‘lower ability’ group.

A 2x2 mixed factorial ANOVA found revealed a significant main effect of intervention condition ($F_{(1,12)}$=8.571, p=.013, partial $\eta^2$=.41) and a significant interaction between intervention condition and ability group ($F_{(1,12)}$=8.571, p=.013, partial $\eta^2$=.41). These results indicated that the EF intervention had a positive effect on EF loaded-working memory skills for the higher ability group, but not for the lower ability group.

Table 6.3.2 Means and standard deviations for Odd One Out change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post music intervention Odd One Out score | High | 3.67 | 2.179 | 9 |
| | Low | 1.40 | 1.342 | 5 |
| | Total | 2.86 | 2.179 | 14 |
| Post art control Odd One Out score | High | -1.00 | 2.500 | 9 |
| | Low | 1.40 | 1.817 | 5 |
| | Total | -.14 | 2.507 | 14 |

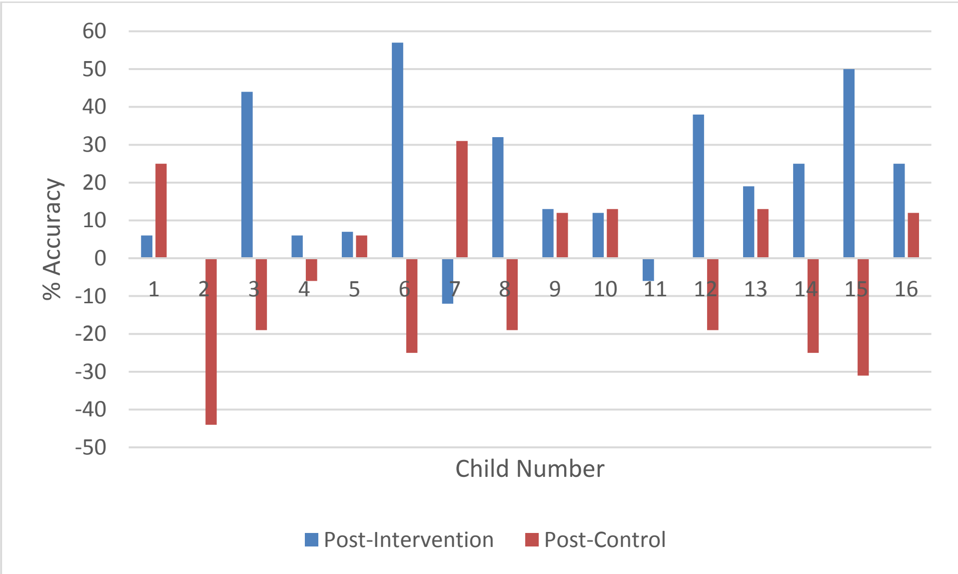
Impact on Inhibition

### 6.3.3 The Sun Apple Task

The ‘Sun Apple’ task provided a measure of inhibition as it required the children to respond quickly and accurately to whether a picture of an apple or sun was displayed on the computer screen. Performance on incongruent trials (where the picture was displayed on the opposite side of the computer screen to its corresponding response key) represents the child’s inhibitory response score. All of the children understood and completed the Sun Apple task at baseline, post-intervention and post-control testing sessions. The data were trimmed and trials where children were too late to respond (i.e. responses timed-out after 900 ms) were removed. Correct responses on EF-loaded incongruent trials were then reported as percentages.

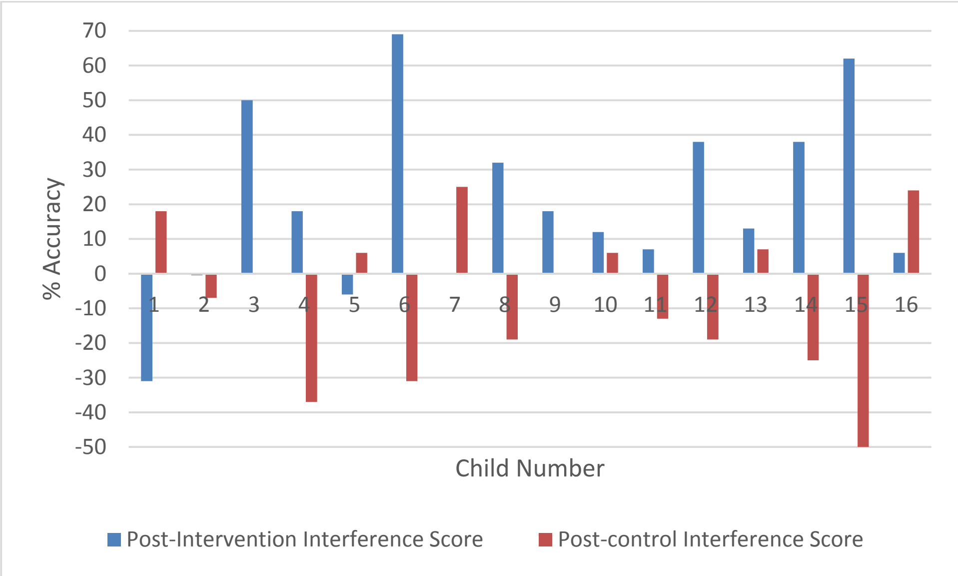
Graph 6.3.3-1 below shows the change in children's performance on the EF-loaded incongruent trials across testing sessions. An absence of data for some participants (e.g. children numbers 1 and 7) represents no change in percentage accuracy performance across testing sessions.

Graph 6.3.3-1. Differences in Sun Apple incongruent scores in pre and post intervention and control conditions

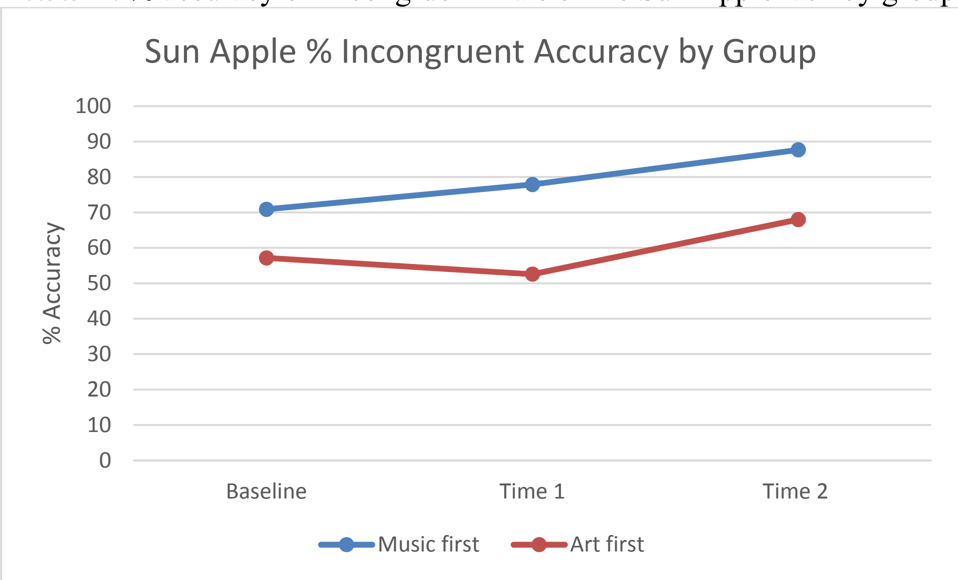



An interference score was calculated by subtracting the children's number of accurate congruent trials from accurate incongruent trials. Interference scores are commonly used in stroop tests and other inhibitory tasks as an accurate measure of a person's inhibition, based on their baseline accuracy on congruent trials. Graph 6.3.3-2 shows the change in the children's interference scores across testing sessions. The absence of any data (e.g. for post-control testing of child number 3) represents no change in the child's performance.

Graph 6.3.3-2. Differences in Sun Apple interference scores in pre and post intervention and control conditions




Graph 6.3.3-4. % accuracy on incongruent trials of the Sun Apple task by group




Graph 6.3.3-4 shows the performance of higher and lower ability groups for average % accuracy on executive-loaded incongruent trials of the Sun Apple task. The graph shows that the children in the higher ability group (who completed the music intervention first, and whose post-intervention scores are given at time 1), improve linearly across time, showing improvements to their score at post-intervention (time 1) and post-control (time 2). However, the lower ability group show a greater

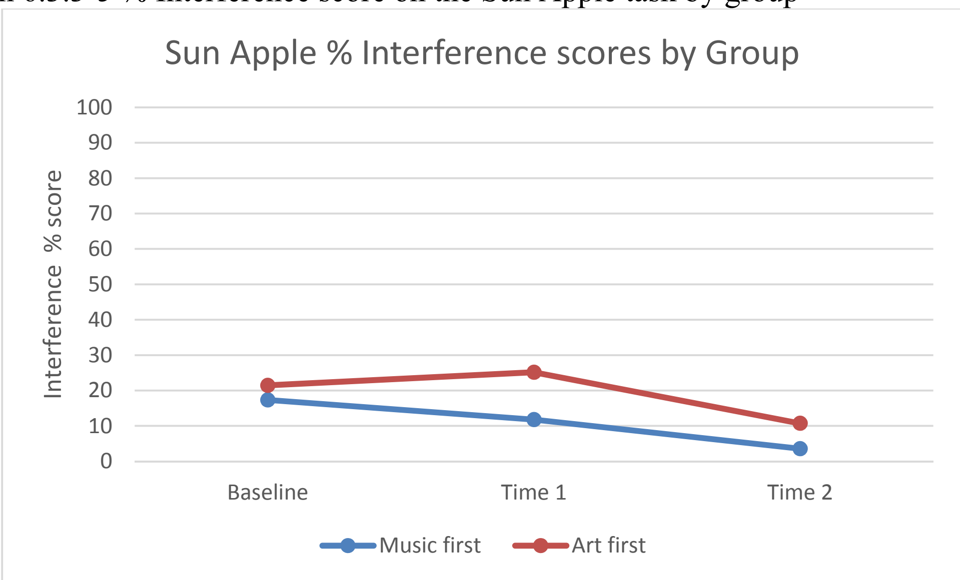
improvement to their post-intervention average % accuracy at time 2, indicating that the intervention had more of an effect to the performance of this group.

A 2x2 mixed factorial ANOVA revealed a significant main effect of intervention condition ($F_{(1,14)}$=6.262, p=.025, partial $\eta^2$=.31) and no significant interaction between intervention condition and ability group ($F_{(1,14)}$=.174, p=.638). The main effect of ability group was not significant ($F_{(1,14)}$=.513, p=.486).

Table 6.3.3-1 Means and standard deviations for Sun Apple incongruent change scores.

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Sun Apple post-music intervention incongruent accuracy | High | 23.111 | 16.2822 | 9 |
| | Low | 15.429 | 25.1121 | 7 |
| | Total | 19.750 | 20.2270 | 16 |
| Sun Apple post-art control incongruent accuracy | High | -4.889 | 18.4353 | 9 |
| | Low | -4.571 | 27.1837 | 7 |
| | Total | -4.750 | 21.8373 | 16 |

Graph 6.3.3-5 % Interference score on the Sun Apple task by group



Graph 6.3.3-5 shows the average % interference scores for the higher and lower ability groups on the Sun Apple task. In this instance, a lower score is an indication of better performance. As with their performance on the incongruent trials, the higher ability group show a steady improvement over time, whilst the lower ability group show a greater improvement in their score at post-intervention testing (time 2).

A 2x2 mixed factorial ANOVA revealed a significant main effect of intervention condition ($F_{(1,14)}$=6.006, p=.028, partial $\eta^2$=.30) and no significant interaction between intervention condition and ability group ($F_{(1,14)}$=.859, p=.370). The main effect of ability group was not significant ($F_{(1,14)}$=.501, p=.491).

Table 6.3.3-2 Means and Standard Deviations for Sun Apple Interference change scores.

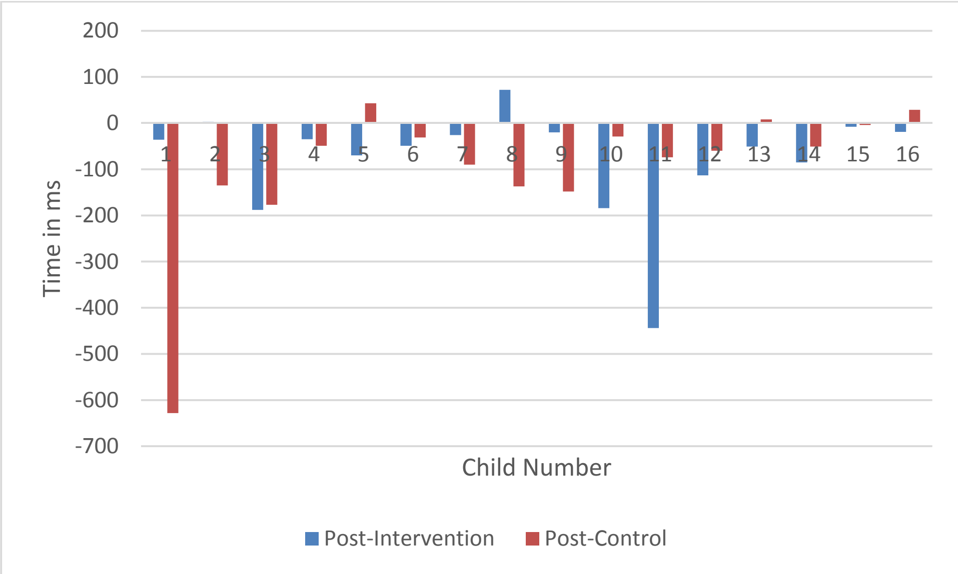
| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Sun Apple Post-Music Intervention Interference | High | -23.67 | 20.211 | 9 |
| | Low | -11.43 | 20.703 | 7 |
| | Total | -18.31 | 20.703 | 16 |
| Sun Apple Post- Art Control Interference | High | 9.89 | 21.786 | 9 |
| | Low | 3.71 | 23.336 | 7 |
| | Total | 7.19 | 21.931 | 16 |

Intervention's impact on planning and flexibility

### 6.3.4 The Tower of London Task (Shallice, 1982)

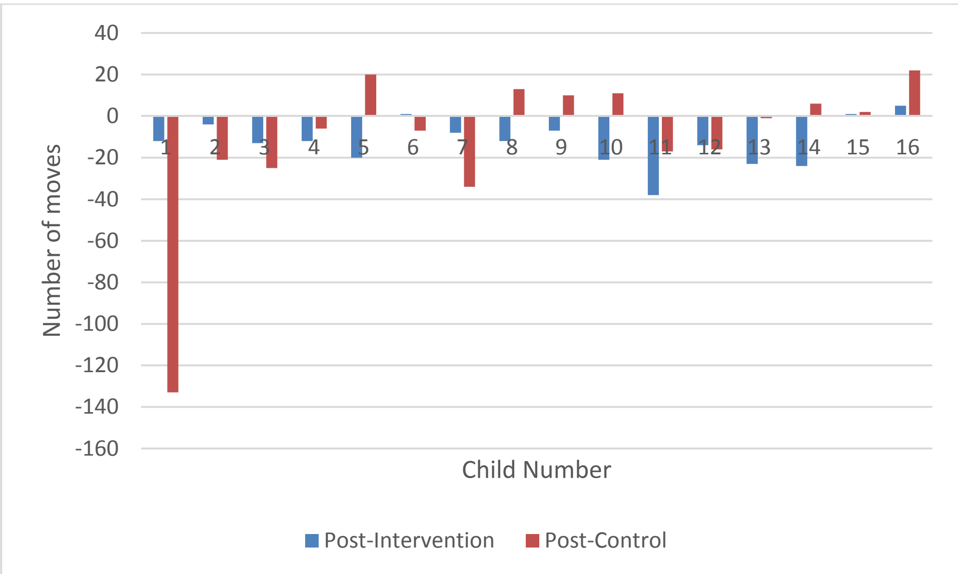
In the computerised Tower Of London task, children had to move coloured disks one at a time in order to create the same arrangement of disks as shown by the computer. There were 8 trials for this task. Children were scored according to the time taken to complete the task and the number of moves they made – fewer moves being indicative of more efficient planning ability. Graph 6.3.4-1 below shows the change in children's performance time across the testing sessions.

Graph 6.3.4-1. Differences in Tower of London time scores in pre and post intervention and control conditions




Graph 6.3.4-2 below shows the difference in the number of moves children took across testing sessions.

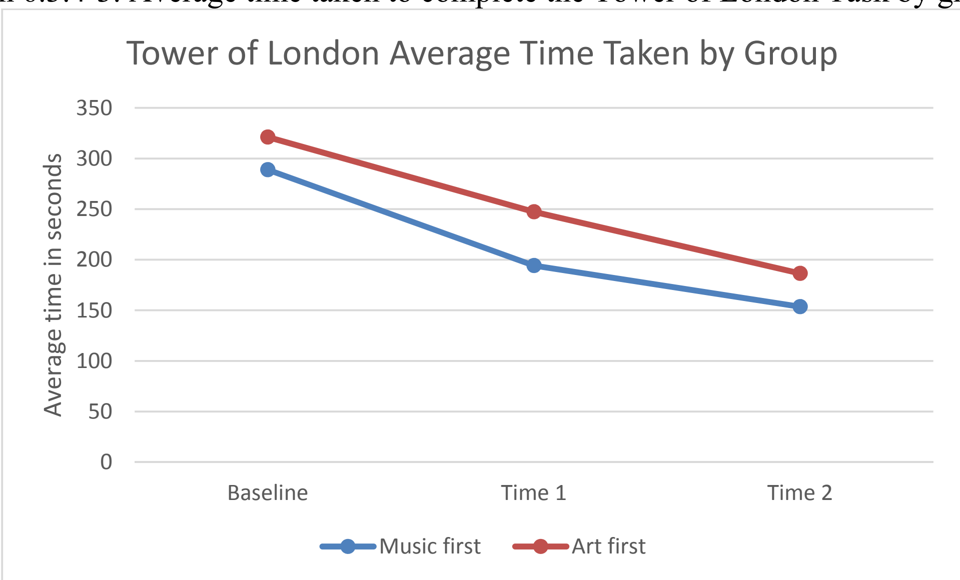
Graph 6.3.4-2. Differences in the number of moves taken to complete the Tower of London task across pre and post intervention and control conditions




It is clear when looking at graphs 6.3.4-1 and 6.3.4-2 that child number 1's post-control performance on this task appears extreme. This is reflected in the standard deviation for the post-control scores and could be considered to be an outlier. This child struggled to understand the aim of the task during the baseline assessment, however she was very motivated and determined to complete the task. She subsequently took part in the control sessions and when it came to taking the test again, post-control, she had grasped the aim of the task and her performance was more in line with that of the other children. Therefore the difference between her baseline and post-control score appears extreme. It can be noted that her third assessment on this task (post-intervention) is more in keeping with the performance of other children on the task. As the baseline performance of child number 1 appears to be an outlier, her scores were removed from subsequent analysis comparing the performance between the higher and lower ability groups.

Graph 6.3.4-3 below shows the average time in seconds taken by the higher and lower ability groups to complete the Tower of London task. The graph shows a clear difference between the average times of both groups at baseline. The higher ability group (who completed the music intervention first), show a sharp improvement to post-intervention task completion time at time 1, and continue to improve on the task at post-control (time 2). The lower ability group show a steady improvement in performance at post-control (time 1) and post-intervention (time 2) testing.

Graph 6.3.4-3. Average time taken to complete the Tower of London Task by group

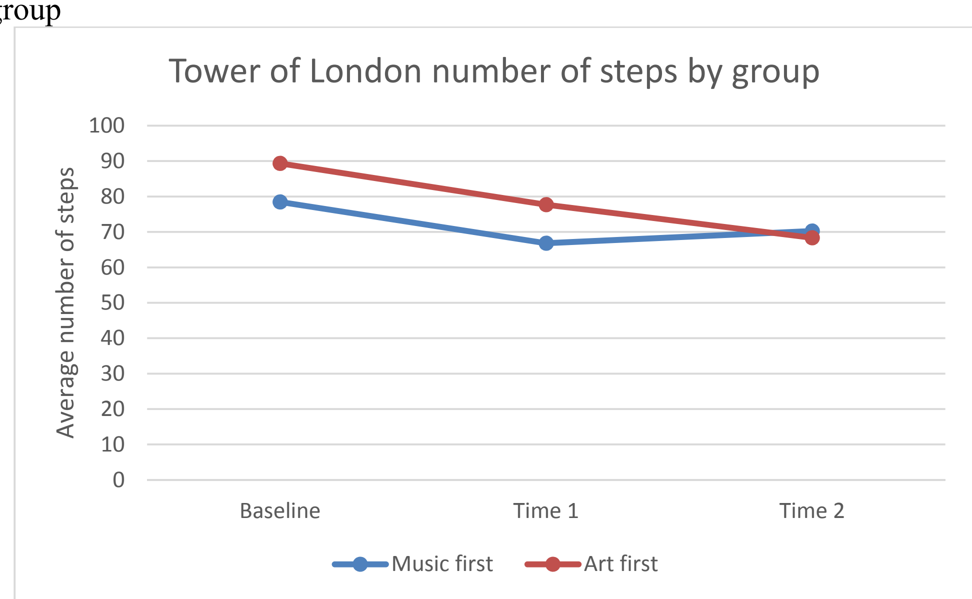


A 2x2 mixed factorial ANOVA found no significant main effect of intervention condition ($F_{(1,13)}$=.175, p=.683) and there was no significant interaction between intervention condition and ability group ($F_{(1,13)}$=.571, p=.463). The main effect of ability group was not significant ($F_{(1,13)}$=.026, p=.873).

Table 6.3.4-1 Means and Standard Deviations for Tower of London Time change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post Music Intervention TOL Time | High | -94.67 | 149.558 | 9 |
| | Low | -60.83 | 66.859 | 6 |
| | Total | -81.13 | 121.129 | 15 |
| Post Art Control TOL Time | High | -51.78 | 61.220 | 9 |
| | Low | -73.17 | 78.415 | 6 |
| | Total | -60.33 | 66.749 | 15 |

Graph 6.3.4-4. Average number of steps taken to complete the Tower of London task by group




Graph 6.3.4-4 shows the average number of steps taken by each group to complete the Tower of London task across time. It is clear that, at baseline, the higher ability group (who completed the music intervention first) used around an average of 10 fewer steps to complete the task than the lower ability group. The higher ability group showed an improvement in post-intervention performance at time 1, with little change to their

post-control score at time 2. The lower ability group showed a steady improvement in their performance from baseline to post-control testing (time 1) and post-intervention testing (time 2). It is notable that, at time 2, the lower ability group have comparable performance to the higher ability group in terms of number of steps taken to complete the task.

A 2x2 mixed factorial ANOVA found no significant main effect of intervention condition ($F_{(1,13)}$=2.826, p=.117), and a significant interaction between intervention condition and ability group ($F_{(1,13)}$=5.311, p=.038, partial $\eta^2$=.29). The main effect of ability group was not significant ($F_{(1,13)}$=.800, p=.387).

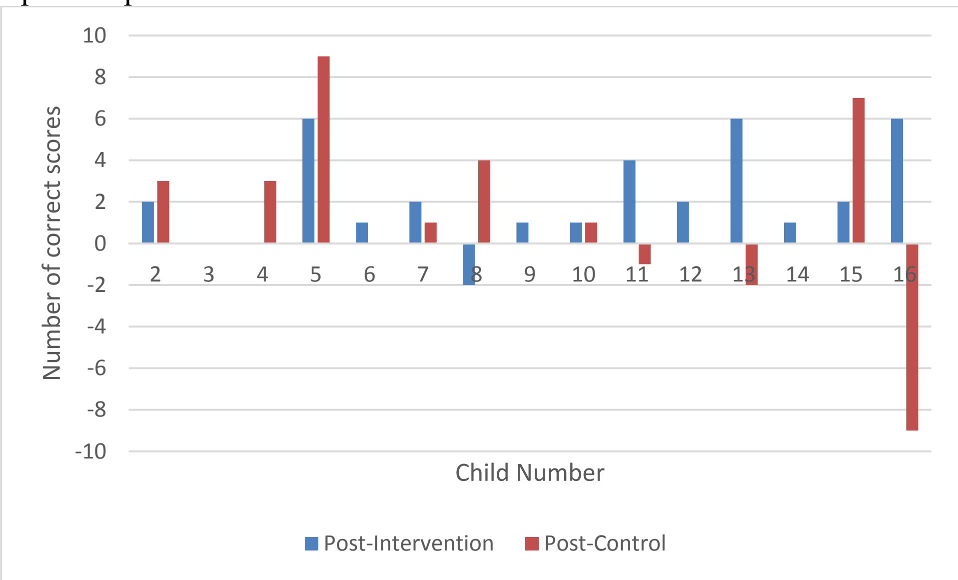
Table 6.3.4-2 Means and Standard Deviations for Tower of London number of moves change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post Music Intervention TOL Moves | High | -14.78 | 13.414 | 9 |
| | Low | -9.33 | 7.367 | 6 |
| | Total | -12.60 | 11.394 | 15 |
| Post Art Control TOL Moves | High | 3.33 | 13.038 | 9 |
| | Low | -12.17 | 19.073 | 6 |
| | Total | -2.87 | 16.995 | 15 |

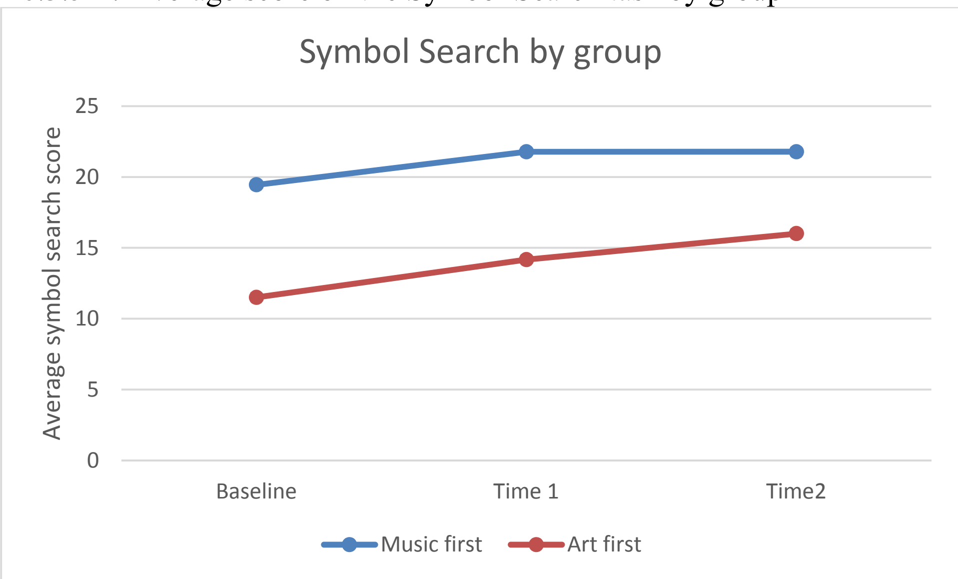
### 6.3.5 Symbol Search (WISC-III; Wechsler, 1991)

The Symbol Search task was a measure of processing speed whereby children were asked to identify whether one of two symbols were present in an array. Children's scores on this task were the number of correct trials they completed in two minutes. Child number 1 did not complete this task as she was unable to understand the instructions. Therefore for this test N=15. Graph 6.3.5-1 shows the difference between children's scores before and after completing the EF intervention and control sessions.

Graph 6.3.5-1. Differences in children's performance on the Symbol Search task across pre and post intervention and control conditions.




Graph 6.3.5-2. Average score on the Symbol Search task by group




Graph 6.3.5-2 shows the performance of the higher and lower ability groups on the Symbol Search task. A clear difference in average score between groups can be seen from baseline testing. The higher ability group (who completed the music intervention first) show an improvement in post-intervention score (at time 1), which is maintained at post-control testing (time 2). The lower ability group show a gradual improvement in score on this test from baseline to post-control testing (at time 1) and post-

intervention testing (at time 2). While both groups improved across the time periods, the difference between the higher and lower ability groups at had narrowed by time 2.

A 2x2 mixed factorial ANOVA revealed no significant main effect of intervention condition ($F_{(1,13)}$=.302, p=.592) and no significant interaction was found between intervention condition and ability group ($F_{(1,13)}$=1.345, p=.267). The main effect of ability group was not significant ($F_{(1,13)}$=.966, p=.344).

Table 6.3.5 Means and Standard Deviations for Symbol Search change scores.

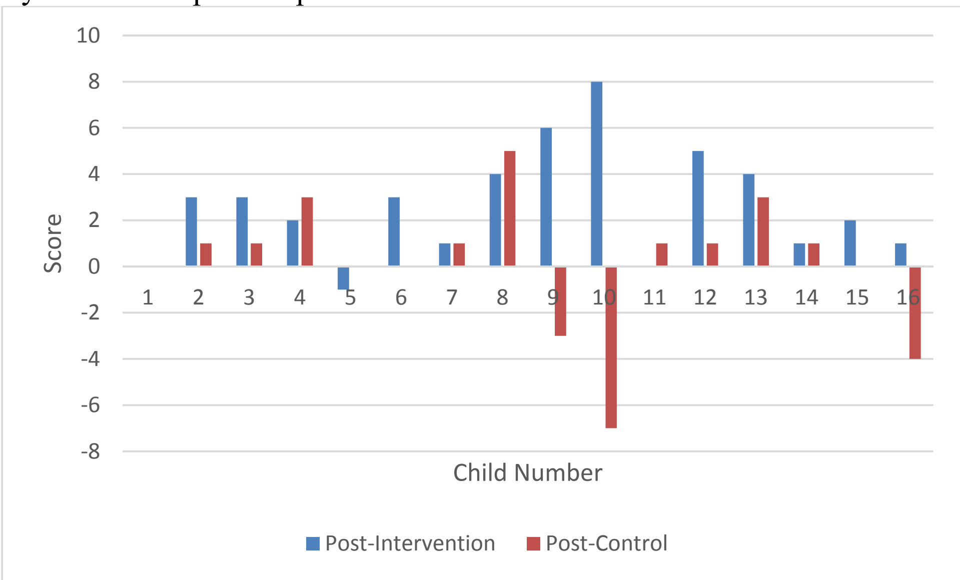
| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post Music Intervention Symbol Search | High | 2.33 | 2.598 | 9 |
| | Low | 1.83 | 2.229 | 6 |
| | Total | 2.13 | 2.386 | 15 |
| Post Art Control Symbol Search | High | .00 | 4.359 | 9 |
| | Low | 2.67 | 3.386 | 6 |
| | Total | 1.07 | 4.096 | 15 |

### 6.3.6 Design Fluency

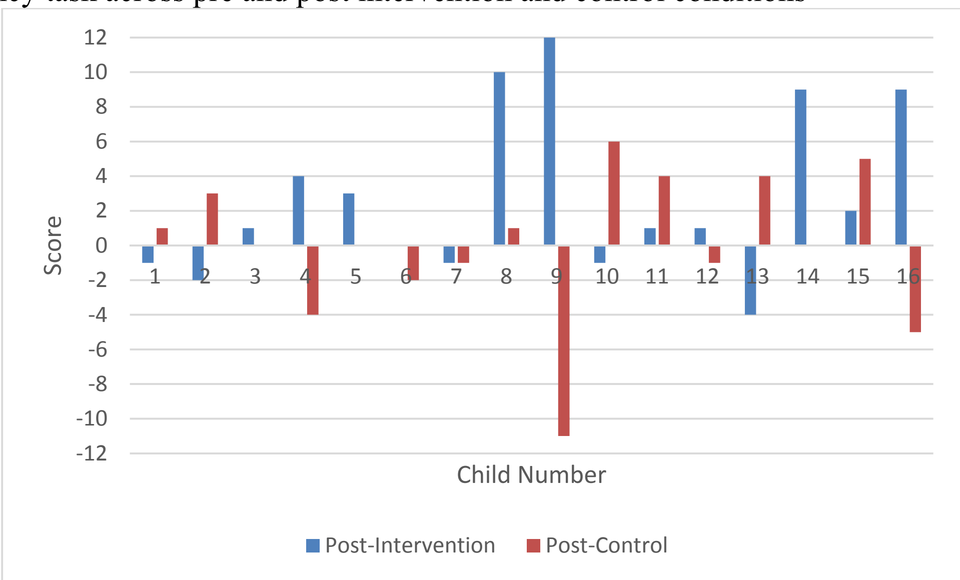
For this pencil and paper task, children were required to create unique designs by joining dots together. The task had two parts. In the first, the children were presented with dots arranged in a structured array, and in the second the dots were arranged in a random array. All children completed the design fluency task before and after the intervention and control conditions. Their score on each section of the task consisted of the number of accurately drawn and unique designs they could produce in one minute.

Graphs 6.3.6-1 and 6.3.6-2 show the change in children's performance on the task after taking part in the intervention and control sessions. Absence of a data bar indicates no change a child's performance on the task after taking part in the sessions.

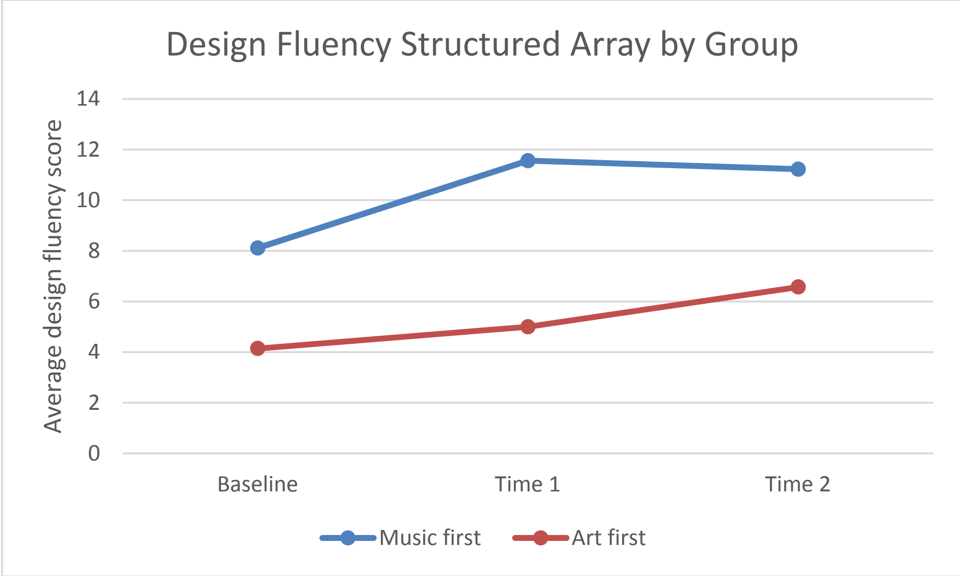
Graph 6.3.6-1. Differences in children's performance on the structured Design Fluency task across pre and post intervention and control conditions




Graph 6.3.6-2. Differences in children's performance on the random array Design Fluency task across pre and post intervention and control conditions



Graph 6.3.6-3. Average score on Design Fluency task (structured array) by group



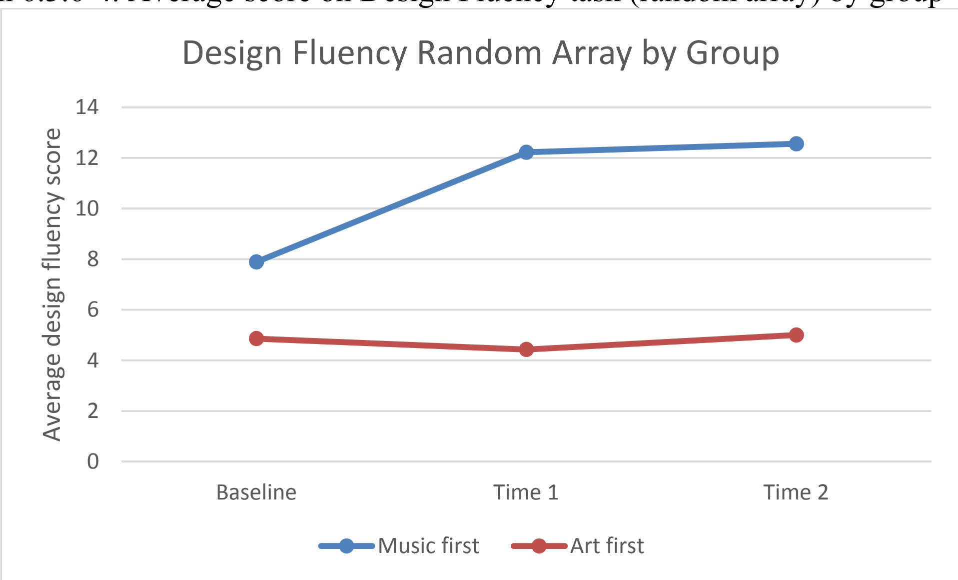

Graph 6.3.6-3 shows the average score of the higher and lower ability groups in the structured array condition of the design fluency task. The higher ability group (who took part in the music intervention first) showed a clear effect of the intervention, with a sharp increase in performance at post-intervention testing (at time 1). Their performance remains stable after completion of the control condition (at time 2). The graph suggests that the lower ability group show a weaker effect of the intervention condition, with a slightly larger improvement in scores between time 1 and time 2 (post-intervention testing), than baseline and time 1 (post-control testing).

A 2x2 mixed factorial ANOVA revealed a significant main effect of intervention condition ($F_{(1,14)}$=4.616, p=.050, partial $\eta^2$=.25) and there was no significant interaction between intervention condition and ability group ($F_{(1,14)}$=2.147, p=.169). The main effect of ability group was not significant ($F_{(1,14)}$=.188, p=.671).

Table 6.3.6-1 Means and Standard Deviations for Design Fluency Structured array change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Design Fluency Post-music Intervention structured array | High | 3.44 | 2.651 | 9 |
| | Low | 1.57 | 1.618 | 7 |
| | Total | 2.62 | 2.391 | 16 |
| Design Fluency Post-art control structured array | High | -.33 | 3.708 | 9 |
| | Low | .86 | 1.069 | 7 |
| | Total | .19 | 2.857 | 16 |

Graph 6.3.6-4. Average score on Design Fluency task (random array) by group




Graph 6.3.6-4 shows the average design fluency scores for the higher and lower ability groups in the random array condition. In this condition, the lower ability group (who completed the art control sessions first), show a stable performance across all time points, and do not make any significant improvement at post-control (time 1) or post-

intervention (time 2) testing. However, the graph indicates a strong effect of the intervention on the higher ability group who show a large increase in score at post-intervention testing (time 1) and their average score remains stable at post-control testing (time 2).

A 2x2 mixed factorial ANOVA revealed no significant main effect of intervention condition ($F_{(1,14)}$=1.409, p=.255) and no significant interaction between intervention condition and ability group ($F_{(1,14)}$=.507, p=.488). There was a significant main effect of ability group ($F_{(1,14)}$=8.009, p=.013, partial $\eta^2$=.36). These results indicate that the higher ability group's score improved over time while the lower ability group showed no improvement on this task (as illustrated in graph 6.3.6-4).

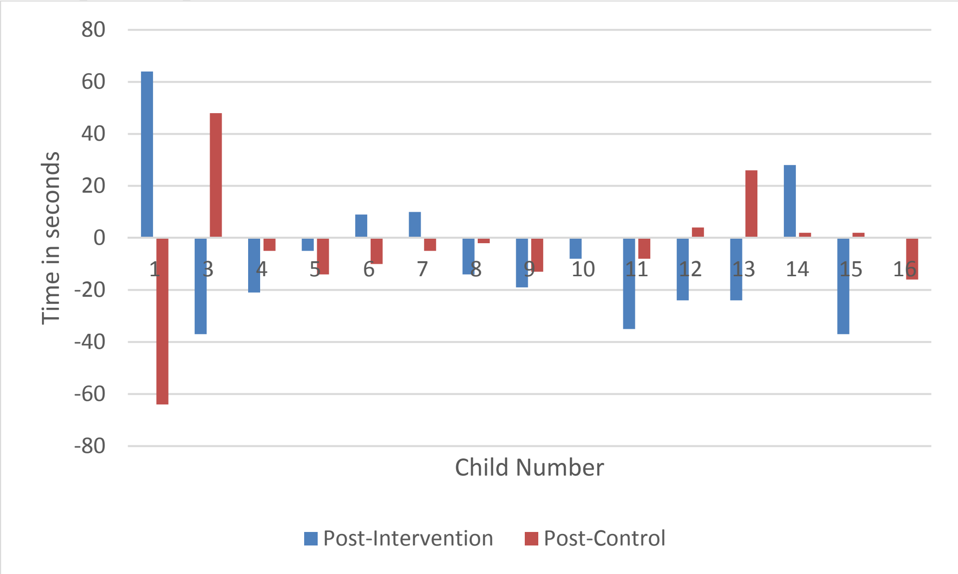
Table 6.3.6-2 Means and Standard Deviations for Design Fluency random array change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Design Fluency Post-music intervention Random array | High | 4.33 | 5.701 | 9 |
| | Low | .57 | 2.225 | 7 |
| | Total | 2.69 | 4.799 | 16 |
| Design Fluency Post-art control Random array | High | .33 | 5.477 | 9 |
| | Low | -.43 | 2.225 | 7 |
| | Total | .00 | 4.258 | 16 |

### 6.3.7 Colour Trails

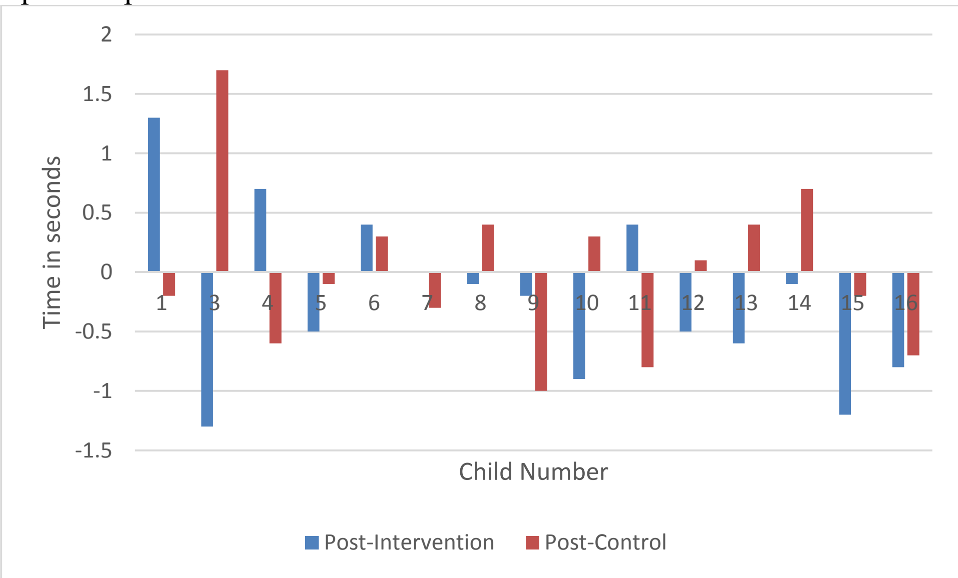
The Colour Trails task was administered as a measure of cognitive flexibility. It was a pencil and paper task consisting of two parts. The first part (Colour Trails 1) was a straightforward 'join the dots' exercise, where children had to join dots in the correct order labelled one to fifteen. Their score on this (control) task was the time taken in seconds to complete the task. The second part (Colour Trails 2) required children to join numbered dots, but additionally to alternate between pink and yellow colours. This required cognitive flexibility and inhibition skills. As with the first task, children's scores consisted of the time in seconds taken to complete the task. Any errors of number or colour made by the children were also noted. For this task, child number 2 did not complete the testing, so for this task N=15. Graph 6.3.7-2 shows the time difference in children's performance on the EF loaded Colour Trails 2 task before and after completing the EF intervention and control sessions.

Graph 6.3.7-2. Differences in children's time performance on the Colour Trails 2 task across pre and post intervention and control conditions

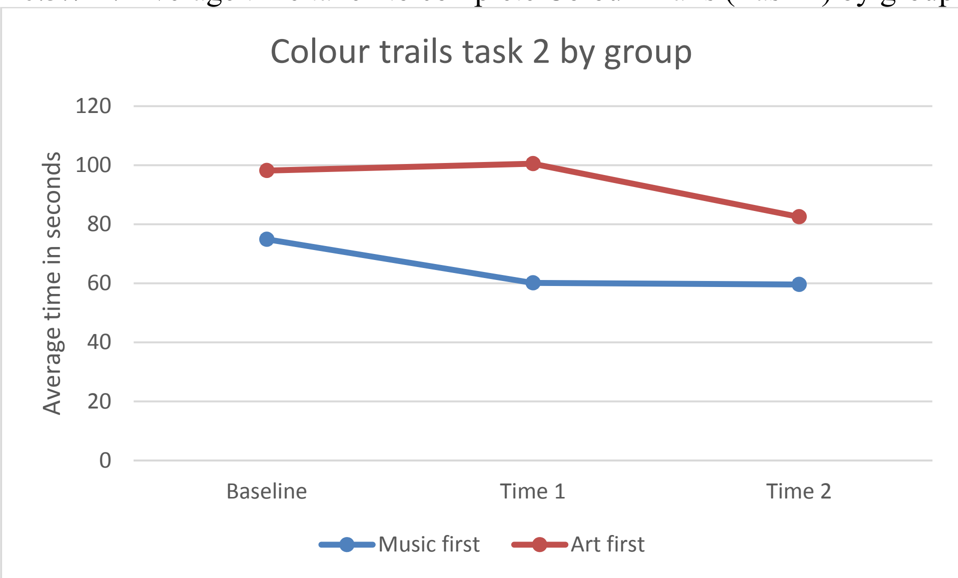



Interference scores were calculated for this test according to the test instructions, by subtracting the time taken on the second task from the time taken on the first, and dividing the result from the initial baseline time. The difference between children's interference scores before and after completing the EF intervention and control sessions are shown in graph 6.3.7-3 below.

Graph 6.3.7-3. Differences in children's interference scores on the Colour Trails task across pre and post intervention and control conditions




Graph 6.3.7-4. Average time taken to complete Colour Trails (Task 2) by group




Graph 6.3.7-4 shows the average time taken in seconds for higher and lower ability groups to complete the EF-loaded second part of the Colour Trails task. In this condition, an effect of the intervention can be seen in both groups. The higher ability group (who completed the music intervention first) show a faster average time during post-intervention testing (at time1), which remains stable at post-control testing (at time 2). Likewise, the lower ability group (who completed the art control sessions first)

showed no change in performance at post-control testing (at time 1), but showed a faster average time at post-intervention testing (at time 2).

A 2x2 mixed factorial ANOVA revealed no significant main effect of intervention condition ($F_{(1,13)}$=.011, p=.919) and there was no significant interaction between intervention condition and ability group ($F_{(1,13)}$=1.097, p=.314). There was no significant main effect of ability group ($F_{(1,13)}$=1.021, p=.331).

Table 6.3.7-1 Means and Standard Deviations for Colour Trails part 2 change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post- music Intervention CT2 Time | High | -14.78 | 19.955 | 9 |
| | Low | 3.33 | 34.772 | 6 |
| | Total | -7.53 | 27.271 | 15 |
| Post-art Control CT2 Time | High | -.56 | 12.197 | 9 |
| | Low | -8.33 | 35.579 | 6 |
| | Total | -3.67 | 23.509 | 15 |

For interference scores, a further 2x3 mixed factorial ANOVA found no significant main effect of intervention condition ($F_{(1,13)}$=.376, p=.552) and there was no significant interaction between intervention condition and ability group ($F_{(1,13)}$=.258, p=.621). The main effect of ability group was approaching significance ($F_{(1,13)}$=4.399, p=.055).

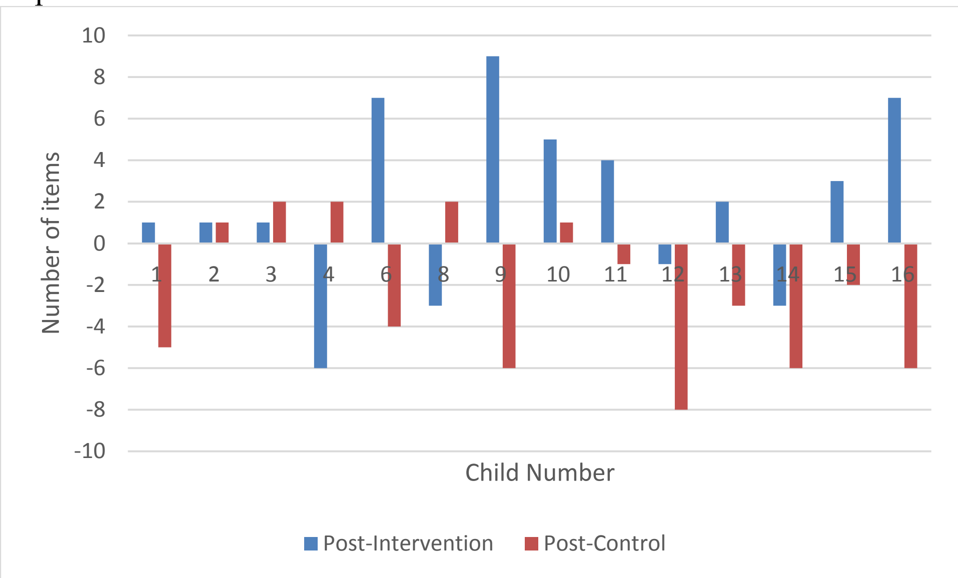
Table 6.3.7-2 Means and Standard Deviations for Colour Trails Interference change scores

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Post-music Intervention Interference change scores | High | -.444 | .4927 | 9 |
| | Low | .100 | .9187 | 6 |
| | Total | -.227 | .7186 | 15 |
| Post-art Control Interference change scores | High | -.089 | .6133 | 9 |
| | Low | .133 | .8214 | 6 |
| | Total | .000 | .6845 | 15 |

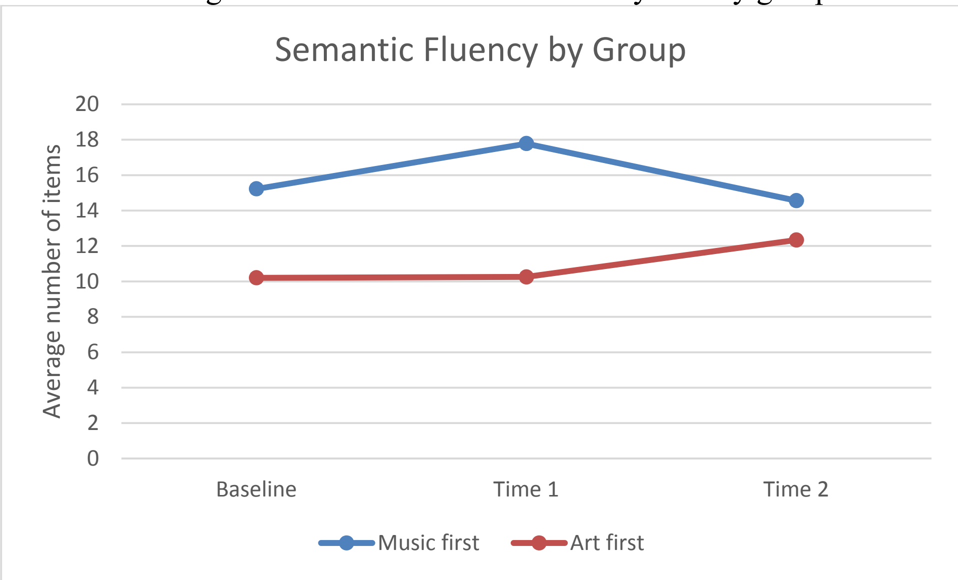
### 6.3.8 Semantic Fluency

A semantic fluency task was administered as a measure of verbal fluency. Children were given one minute to name as many animals as they could, and were able to give their responses in either BSL or spoken English. Due to language difficulties, two children (participants 5 and 7) were unable to complete this task. Therefore, for this test N=14. Children's scores on this test were the number of correct unique animal names produced in one minute. Incorrect category responses (e.g. food items) and repetitions were noted and discounted. Graph 6.3.8-1 shows the difference between children's scores on this task before and after completing the intervention and control sessions.

Graph 6.3.8-1. Differences in children's scores on the Semantic Fluency task across pre and post intervention and control conditions



Graph 6.3.8-2. Average scores on the Semantic Fluency task by group




Graph 6.3.8-2 shows the average number of items children produced on the semantic fluency task, in both the higher and lower ability groups. The higher ability group (who completed the music intervention first), show an increase in performance at post-intervention testing (time 1), however this performance is not maintained and they achieve a lower average score at post-control testing (time 2). There appears to be an effect of intervention for the lower ability group, who show no change in performance between baseline testing and post-control testing (time1), and an improvement in performance during post-intervention testing (time 2).

A 2x2 mixed factorial ANOVA found the main effect of intervention condition approaching significance ($F_{(1,12)}$=4.404, p=.061, partial $\eta^2$=.27). There was no significant interaction between intervention condition and ability group ($F_{(1,12)}$=1.412, p=2.58). The main effect of ability group was not significant ($F_{(1,12)}$=.063, p=.813).

Table 6.3.8 Means and Standard Deviations for Semantic Fluency change scores.

| | Ability Group | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Semantic Fluency Post-music Intervention | High | 2.56 | 4.246 | 9 |
| | Low | .80 | 4.604 | 5 |
| | Total | 1.93 | 4.287 | 14 |
| Semantic Fluency Post-art Control | High | -3.22 | 3.492 | 9 |
| | Low | -.80 | 3.421 | 5 |
| | Total | -2.36 | 3.543 | 14 |

### 6.3.9 Feedback from Teachers and Children

At the end of the study, the children were invited to give feedback on the intervention and say what they enjoyed or didn't like. All of the children said that they enjoyed the intervention and several expressed disappointment that it had finished. The most popular activities reported by the children were 'Sevens', 'Don't clap this one back' and 'the Naughty Orchestra'. No children reported disliking any of the activities, but two said that the 'Follow the Leader' game was their "least favourite".

Class teachers also provided their views and feedback on the intervention, often commenting that the children were extremely motivated to take part. For example, when an intervention session had to be re-scheduled due to a school trip, three of the children were concerned that they wouldn't get to do their music class that week, and wanted reassurance that they wouldn't miss out. One teacher said that when preparing end of year school reports, she asked children what their favourite subjects were so that that information could be included in their report. One child who had taken part in the study insisted on writing about the intervention as her favourite class. A child at a different school who had limited language was asked during parent's evening what her favourite class was and she spontaneously started demonstrating one of the clapping games to her parents. The teacher recognised her clapping patterns and explained to her parents that this was part of the intervention.

Teachers and teaching assistants also provided general feedback on some of the tasks. A teaching assistant mentioned that they body orchestra game was a familiar format to the children (finding matching pairs of cards), and they had previously played similar games to this on a computer. However, she commented that playing games like this in a group with their peers provided a more enriching experience than playing against a computer, as it required interactive social skills such as turn-taking, playing fairly, using strategy and learning how to be a gracious loser or a gracious winner. These experiences also support the development of EF, promoting skills not tested in the current study (but reported in the BRIEF), such as emotional regulation, co-operation and theory of mind. When considering the value that certain interventions can offer, it should be noted that experiences such as these cannot be practiced or developed in the same way through computerised tasks; a reason expressed by some teachers for their preference for more 'traditional' class-based games.

The author observed several opportunities throughout the intervention for teaching 'mindfulness-style' techniques, involving awareness of oneself and others around you. For example, when playing the clapping game 'Sevens', in a round, some children closed their eyes or instinctively looked away from each other in order to avoid being distracted. However, this resulted in them getting out of time and sync with each other. Once they were reminded to look at each other, and use the down beat to keep together if they lost their place, they saw that their performance improved. Paying attention to others, as well as to yourself and your own role, is an important element of musicianship and group playing, and was an observable skill that the children began to acquire over the course of the intervention.

## 6.4 Discussion of Study 2

A summary of the results of the intervention study are shown in table 6.4-1. Cells highlighted in grey indicate areas of EF in which the children showed improvement post-intervention in comparison to the post-control condition. Analysis of the data suggests that the intervention had a positive effect on children's visuospatial working memory, executive-loaded working memory, inhibitory skills, verbal and non-verbal fluency. There appeared to be no significant impact on children's planning skills, attention/speed of processing skills or cognitive flexibility.

Table 6.4-1 Summary of Results of the EF Intervention Study

| Assessment Test | Related EF | Significant Effect of Intervention Found? |
|---|---|---|
| Visuospatial Span Overall Score | Visuospatial working memory | YES |
| Visuospatial Span Forwards Score | Visuospatial working memory | YES |
| Visuospatial Span Backwards Score | Visuospatial working memory | YES |
| Odd One Out | Executive-loaded working memory | YES |
| Sun Apple Overall Score | Inhibition | Approaching significance |
| Sun Apple Incongruent Score | Inhibition | YES |
| Sun Apple Interference Score | Inhibition | YES |
| Tower Of London - Time taken | Planning | NO |
| Tower Of London - Number of Moves | Planning | NO |
| Symbol Search | Attention/Processing speed | NO |
| Design Fluency Overall Score | Non-verbal Fluency | YES |
| Design Fluency - Structured | Non-verbal Fluency | YES |
| Design Fluency - Random | Non-verbal Fluency | NO |
| Colour Trails Task2 | Cognitive Flexibility | NO |
| Colour Trails Interference score | Cognitive Flexibility | NO |
| Semantic Fluency | Verbal fluency | YES |

When considering the data according to ability group (as summarised in table 6.4-2), each group appeared to show an impact of the intervention for particular tasks. Both groups showed a post-intervention improvement on the visuospatial working memory task and the verbal fluency task, showing a quadratic trend.

Table 6.4-2 Impact of the intervention on individual EFs by ability group

| Assessment Test | Related EF | Lower ability | Higher ability |
|---|---|---|---|
| Visuospatial Span Overall Score | Visuospatial working memory | YES | YES |
| Visuospatial Span Forwards Score | Visuospatial working memory | YES | NO |
| Visuospatial Span Backwards Score | Visuospatial working memory | YES | YES |
| Odd One Out | Executive-loaded working memory | NO | YES |
| Sun Apple Congruent Score | Inhibition | NO | NO |
| Sun Apple Incongruent Score | Inhibition | YES | NO |
| Sun Apple Interference Score | Inhibition | YES | NO |
| Tower Of London - Time taken | Planning | NO | NO |
| Tower Of London - Number of Moves | Planning | NO | NO |
| Symbol Search | Attention/Processing speed | NO | NO |
| Design Fluency - Structured | Non-verbal Fluency | NO | YES |
| Design Fluency - Random | Non-verbal Fluency | NO | YES |
| Colour trails task 1 | Cognitive Flexibility | NO | NO |
| Colour trails task2 | Cognitive Flexibility | NO | NO |
| Semantic Fluency | Verbal fluency | YES | YES |

However, for the executive-loaded working memory task, ‘the odd one out’, the higher ability group showed an effect of the intervention, while the lower ability group’s improvement on the task appeared linear over time. The converse was true for the inhibition test, ‘the Sun Apple task’ where the lower ability group showed an effect of the intervention, while the higher group’s improvement on the task showed steady linear improvement over time. Additionally, observing the pattern of performance of the two ability groups over time on the design fluency task, the higher ability group showed an effect of the intervention with a quadratic trend, while the lower ability group showed a steady linear improvement. These patterns are interesting as they potentially point to differences in thresholds and ceilings for the improvement of different EF skills. For example, visuospatial memory was improved in both higher and lower ability groups post-intervention, however only the higher ability group appeared to benefit from training when it came to the more complex EF-loaded memory task. While there may be several explanations for this finding, it suggests that a certain level of working memory capacity needs to be achieved before an intervention will become effective beyond what could be considered a practice effect. The dissociation between the performances of the two ability groups on these tasks will be discussed further in chapter 7.

This study has demonstrated that EF skills are trainable in young deaf children who are considered to have several risk factors for poor EF development (such as delayed access to language or additional learning difficulties) and also in deaf children whose EF skills are considered to be within the average range. Developed from a combination of evidence from successful EF interventions and advice from teachers and musicians working with deaf children, the current music-based intervention has shown an effect of EF training within a relatively short amount of time. The following chapter will discuss the findings from this study, along with the study of adult musicians (Chapter 3) and will describe the theoretical implications and potential practical applications of the findings.

# Chapter 7 GENERAL DISCUSSION

This chapter will provide an overview and synthesis of the findings from the two experimental studies and questionnaire described in this thesis. Study 1 was an examination of EF with adult deaf and hearing musicians. Data collected in Study 2 included a questionnaire which examined the familiarity of teachers and other professionals with existing EF interventions, and the results of a music-based EF intervention for deaf children. Following this overview, there will be a discussion of how these findings link with existing theoretical models of EF and plasticity. Finally, some possible limitations of the studies will be addressed and suggestions made for future directions in this research area.

## 7.1 Study 1. Adult musician study

This study compared the EF abilities of adult hearing and deaf musicians with those of non-musicians. In previous research on the typical hearing population, music experience was found to lead to greater EF skills although the direction of this effect is not yet clear (Bialystok & DePape, 2009). The results of the current study supported previous findings that, in general, musicians show greater EF skill when compared to non-musicians, particularly in working memory and inhibition. The present study was the first to examine the performance of deaf musicians on EF tasks, providing a novel perspective from which to consider the potential underlying causes of EF benefits of musicianship, specifically whether these are driven by improved acuity of auditory temporal processing (Pisoni & Cleary, 2003), or by improvement to more domain-general abilities. There was a similar pattern of performance on EF tasks for both hearing and deaf musicians, which suggests that musical training influences EF even in individuals born deaf. These findings point away from the auditory aspects of music as being more influential on EF and highlight the cognitive aspects of this activity. This leads to the possibility that music classes could potentially be used in the future as a way to improve certain EF skills in deaf children which has been investigated in the past with hearing populations (e.g. Moreno, et al., 2011). Music training can go beyond immediate instrumental playing and singing skills towards improving EF abilities more broadly. However, this possibility can only be investigated systematically through training studies. Therefore, the findings from study 1 provided a strong motivation for investigating the potential impact of a music-based training intervention on deaf children's EF skills in study 2. If music as an activity practiced regularly can lead to higher EF abilities in both deaf and hearing adults, it is possible a systematic training study utilising music will lead to similar benefits in a group of children.

In analysing the results from study 1 in more detail, the primary finding from this study was that there was a significant difference between the performance of musicians and non-musicians (regardless of hearing status) on several EF tasks. Results of the data analysis indicated that the key areas where musicianship produced most cognitive benefits are inhibitory control and spatial working memory. Musicians achieved significantly greater accuracy scores on the flanker task than non-musicians, with a large effect size (d=1.45) for the difference in performance on the EF-loaded incongruent trials. This pattern was also found for the Simon task, supporting the hypothesis made in the outset of the thesis that musicians would show superior performance on these tasks in comparison to the non-musician groups.

Previous studies (e.g. Bialystok, 2009) also found enhanced performance for musicians on tests the flanker task (and another conflict task that is similar to the Simon task, but using auditory stimuli) in comparison to monolingual English speaking non-musicians. However, in Bialystok's (2009) study the enhancement was manifested in the faster reaction time of musicians on incongruent trials. This was not replicated in the present study, which did not find musicianship to produce a significant advantage to participants' reaction time, but instead it appeared to improve accuracy in incongruent conditions. In terms of the EF ability, accurately dealing with incongruence is an important element, possibly more so than speed of reactions.

Study 1 of the thesis also found a significant difference between the visuospatial memory abilities of musicians and non-musicians, with musicians having larger overall visuospatial working memory spans, particularly in the forwards span condition. This finding replicates that of other studies (e.g. Analya, Pisoni & Kronenberger, 2016) which report enhanced visuospatial memory in trained musicians. Analya et al. (2016) suggest that these differences may be due to underlying cognitive differences e.g. in working memory driven by experience of formal musical training involving visuospatial and sensory-motor systems, not limited to auditory processing. Music requires much rehearsal and storage of information, often during intense on-line tasks such as monitoring performance while planning the next piece of music to play. Analya et al's. (2016) hypothesis is supported by the second finding of the current study (regarding differences found between the four participant groups) as enhanced visuospatial spans were also found within the group of deaf musicians. This is an important finding. As suggested in the literature review on EF and deafness research it has been hypothesised that deafness itself can lead to EF deficits. Analya et al. (2016) themselves postulate that deficits which have previously been found in the visuospatial sequencing skills of deaf children with cochlear implants (e.g. Conway, et al., 2011) may be due to early auditory deprivation, preventing the processing of temporal and sequential information. Therefore, several sets of authors have argued that deafness is a 'risk factor' for the development of EF and in particular visuospatial working memory. The findings from the current study instead suggest that early and long-term musical experience in deaf individuals may provide the same cognitive benefits found in hearing musicians with regards to visuospatial span, as both the deaf and hearing musician groups achieved a significantly higher score on this task than non-musicians. Thus the underlying cognitive training given by music based activities rather than the auditory aspects of music can lead to enhanced EF in deaf people. This implies that while deafness might disturb the typical development of EF it is not a complete barrier to these individuals developing good EFs. Thus the experience of deafness on EF can be gradient. Musicianship, therefore, may be considered to be a 'protective factor' for EF development in the deaf population as well as the hearing.

In this sense there are several factors that influence an individual's EF development. In environmental terms, as is revealed in the literature review, these may be experiences of being a balanced bilingual or involved in EF enriching activities at school. Additionally, Marshall et al. (2015) found that language experience (and not deafness per se) had a strong impact on deaf children's visuospatial working memory skills using the Corsi blocks and Odd one Out tasks, whereby Deaf children who were native BSL users performed comparably to their hearing peers. Having early successful communication and acquiring language within the typical period of development has an impact on EF skills in later childhood. Marshall et al (2015) posited it was either the experience of communication and interaction that led to children evolving EF skills as communication scaffolding as well as language being a useful tool for the representation and manipulation of information during the EF testing itself. The vast majority of deaf children do not experience early language and communication experiences such as these. Late exposure to language may also be considered a 'risk factor' for EF development (as described in section 2.7), indeed many studies have found poorer development of EF in deaf children from hearing families. However evidence that early language and extensive musical experiences in deaf individuals can alter this poor EF performance. As such, these 'protective factors' could be used as ways of training EF development.

As well as working memory, analysis of data in study 1 from the four participant groups also found that deaf musicians follow the same pattern of improved performance as hearing musicians for tasks requiring inhibitory control. This finding suggests that gains in inhibitory skills of musicians are apparent even in deaf individuals and again points away from an enhancement of auditory processing skills and more towards specific practice of cognitive control found in music practice. The third finding from study 1 related to tasks where no significant differences were found between the groups of musicians and non-musicians. Analysis of data from the Number Stroop task (which was another measure of inhibition) found that deaf non-musicians performed more poorly, while no differences were found between the other groups. While this may be a surprising finding, (given the significant differences found between the two musician and non-musician groups for the other inhibition measures: Flanker and Simon tasks), this may be due to the complexity of the Number Stroop task. Responses to the Simon and Flanker tasks consisted of a choice between two options (red/blue or left/right), whilst the participants simultaneously inhibited distracting stimulus information (i.e. stimulus location or the direction of surrounding items). However, the Number Stroop task was a more complex measure of inhibition, with participants needing to respond with one of three stimulus options (whether there were one, two or three stimuli present on the computer screen), with a greater variety of distracting stimulus information (i.e. whether the stimuli were numbers or letters and, if numbers, whether they corresponded to the quantity present on the screen or not). Therefore, this task could be considered to be more cognitively complex, placing a higher load on inhibitory responses. The pattern of results from the three computerised inhibition tasks suggests that musicians (whether hearing or deaf) show an enhanced ability to perform tasks requiring inhibitory skill, up to a certain level. For more complex tasks, this advantage disappears. In addition, the deaf non-musicians' poorer performance may also be indicative of the task's higher level of complexity, and that other underlying factors may have played a role. However, as there was no significant difference between the nonverbal IQ of the participant groups, nor their reaction response times on the task, these particular factors can be discounted.

Although there was no significant difference on the Wisconsin Card Sorting task between musicians and non-musicians , it is interesting that disparity between the performance of the two groups of musicians was found. The hearing musicians made significantly fewer perseverative errors than the deaf musicians, which can be interpreted as indicating better cognitive flexibility. The hearing musicians also outperformed both deaf musicians and deaf non-musicians in terms of overall percentage accuracy. This finding is interesting as while EF can be improved despite deafness in some domains it may be that the full impacts of musicianship on the full range of EF required for cognitive flexibility, is in fact somewhat dependent on auditory processing. Thus deafness in some way may lead to differences across certain aspects of EF compared with typically hearing individuals. In this sense even deaf musicians performed more poorly on this task than hearing non-musicians. However, no significant differences were found between the hearing musicians and hearing non-musicians on this task. Just the experience of being hearing rather than deaf, without music training might lead to better cognitive flexibility. Of course this finding needs more replication to be considered fully but it does emphasise the variability across different EFs and their potential for change brought about by environmental influences. This point is reiterated in the discussion of the findings from study 2.

Whilst interesting comparisons have been made between EF performance of the four participant groups, care needs to be taken when considering the data from this study. Findings are based on data from a relatively small sample of participants, due to the rarity and availability of deaf musicians trained to a high musical standard.

However, other studies have also based findings on relatively small sample sizes (e.g. Rauscher, et al., 1997; Skoe & Kraus, 2012). While generalised claims about deaf musicians' EF skills cannot be made with such a sample size, it can be argued that the current study provides a strong indicator that music experience does improve EF regardless of hearing status. Further research in this area is required and will add to the present debate about the influence of music and other environmental factors on EF skills. As well as sample sizes, another limitation of the study is the variability of the background and auditory experiences of the participants. Whilst a lot of care was taken to ensure that participant groups were matched for age, NVIQ and number of years of music tuition, some unavoidable variation within the deaf musician group remained. For example, whilst all of the participants were hearing aid users, the conditions under which they used their hearing aids varied. Participant DM05 for example wears digital hearing aids on an everyday basis, but chooses to remove them when playing music. Conversely, participant DM06 does not usually wear hearing aids, but wears one on his right ear when performing. This is an illustration of the variation in the use of residual hearing between the participants. It is therefore possible to argue that musicianship in deaf individuals involves some training of residual auditory skills, and therefore the case of auditory temporal processing mediating the improvements seen in EF skills cannot be completely discounted. However, as the majority of deaf musicians in this study were profoundly deaf from birth, it is unlikely that residual auditory processing skills alone have contributed to their gains in EF, but rather the combination of a variety of sensory-motor skills resulting from intensive and repeated practice of musical skills over many years.

## 7.2 Questionnaire

Prior to the design phase of study 2, a questionnaire was sent to teachers of the deaf and other professionals working with deaf children (such as teaching assistants and speech and language therapists) to gather information about the extent to which currently available EF interventions are utilized in schools, and the circumstances under which they are applied. The findings of that questionnaire were interesting as they revealed a lot about the kinds of cognitive training deaf children are exposed to in UK schools. Results from the questionnaire indicated that whole-school, curriculum-based EF interventions were seldom used in their entirety, but teachers were likely to ‘cherry-pick’ particular activities that they find the most effective. Another finding from questionnaire responses was the lack of familiarity respondents had with computerised EF training. Whilst computerised interventions are likely to become a more common feature in classrooms in the future, the findings from this study suggest class-based interventions are currently more widely preferred by teachers, with computerised training games being used less formally, less frequently, and are sometimes used to reward children for good work or behaviour. Findings from the questionnaire study, including feedback from respondents on the type of EF training they use, informed and influenced the design of the music-based EF intervention which has been the main focus of this thesis.

### 7.3 Study 2: The Music-based EF Intervention Study

Because deaf musicians were found to have enhanced EF skills (as fits the literature on factors influencing EF skills in general), and respondents from the questionnaire study suggested schools would be responsive to a curriculum based EF intervention it was decided to run such a study with deaf children. The aim of the intervention study was to investigate which areas (if any) of EF may be improved in primary school aged deaf children, using a music-based EF intervention and begin to answer the following questions which will be discussed in this section:

1. Does the intervention have a positive effect on deaf children’s EF skills?

2. Which children benefit the most? (i.e. children with poorer EF at the outset, or higher ability children? Is there a pattern to EF improvement?)

3. Are some areas of EF more ‘trainable’ than others?

The results of the study revealed an improvement in the children’s working memory and inhibitory skills following completion of 10 hours (over 5 weeks) of the intervention, in comparison to their performance on the same tasks after 10 hours of art sessions which acted as an active control condition. Significant improvements were also found in some children’s post-intervention design fluency and semantic fluency scores which were used as measures of flexibility, planning and fluency respectively. This is the first study to find that EF can be improved in deaf children through a music-based intervention; a finding which is strengthened by the inclusion of an active control condition. Again, the finding that EF is sensitive to environmental enrichment supports the idea that auditory deprivation is not a complete barrier to EF development.

While there is evidence from the data that the intervention had a positive impact on the children's working memory skills, these effects were not maintained once the intervention ended. The performance of some children on this task appears to drop during testing following completion of the control sessions. This is an unusual finding, but may be indicative of the need to maintain EF interventions in this group so as to achieve sustained results. There is currently no consensus on how long or short in duration an intervention needs to be before positive impacts on EF are found and maintained (as described in section 2.8). Individual variability in EF and other factors (such as children's willingness to undergo lengthy testing procedures for a third time) may also play a role in the observation of this result.

The second question the study addressed concerned which children benefited the most. When the data were analysed in terms of 'lower' and 'higher' ability groups, it became clear that improvements on some of the EF tasks were specific to children in particular ability groups. For example, the post-intervention improvement seen in inhibitory skills in the incongruent condition of the Sun Apple task was seen more strongly in the lower ability group, but not the higher ability group. Conversely, while no improvement was seen in either the structured or random conditions of the design fluency task for the lower ability group, the graphs in section 6.3.6 show a pattern on improvement in the higher ability group post-intervention (at time1), which remains stable at post-control testing (at time 2). The patterns of improvement that have emerged from the data raise questions about the nature of particular EFs and calls into question the previous finding that those with poor EF skill are the ones most likely to benefit across the board from interventions (e.g. Diamond, 2012). The current study suggests rather that EFs are differentially sensitive to environmental influence and the children's current starting point in development. Again more research with larger groups is needed to verify this finding.

Considering results from study 2 (and those of study 1), working memory and inhibition emerge as the two key EFs that appear to be most affected by music training. This finding addresses the third question originally posed at the start of study 2, which considers whether some EFs are more 'trainable' than others. The literature review in chapter 2 of this thesis discussed the heterogeneous definitions of EF and the variety of theoretical models put forward to describe the relationship between them. Findings from this study support Miyake's model (Miyake, 2000) as there were clear differences in the magnitude of impact the intervention had on different EFs, suggesting that they can be considered unitary to some extent. However, other models (e.g. Barkley, 1997), which emphasise the importance of inhibition in particular as being the key cognitive component underlying more metacognitive features of EF, such as planning, organising and initiating tasks, are also supported by findings from the intervention study. Results from this study indicate that children in the 'lower ability' group saw the most significant improvement to their inhibitory skills post-intervention in comparison to post-control performance. This can be considered relevant in the context of models of EF such as Barkley's (1997) model, which single out inhibition as the key precursor to other EF skills. Indeed, the authors of the BRIEF (Gioia et al., 2000) considered the distinction between particular EFs in the design of their scale. Gioia et al. divided the BRIEF rating scale into a 'Behavioural Regulation Index' – rating inhibition, flexibility and capacity for emotional control, and a 'Metacognitive Index' – concerned with children's capability in efficiently and systematically problem solving. As with Barkley's model, Gioia et al. point out that inhibition is likely to underpin the other metacognitive aspects of EF. If a child has poor inhibitory and self-regulatory skills, they are less likely to be "appropriately inhibited, flexible and under emotional control for efficient, systematic and organized problem solving to take place" (Gioia et al., 2000, p21). This pattern was seen in the EF profiles of the 'lower ability' group in the current intervention study, where children with poor behavioural regulation index scores also scored poorly on the metacognition index. A possible explanation for the differing effects of the intervention on ability groups in study 2 may therefore be that baseline EF abilities dictate which areas of EF are more likely to be influenced by an EF intervention, according to a loose hierarchical system.

If inhibition and self-regulation are considered to be core EF skills, it is perhaps not surprising that children in the 'lower ability' group who showed initial marked poor performance in inhibition in their BRIEF scores, would show the most improvement in inhibitory skill after a period of training. The 'higher ability' group, who had no reported problems with self-regulation prior to the commencement of the study, also showed improvement, but this was a steady linear improvement over time and more likely to be a practice effect. In this instance, it appears that the children who had poor inhibitory skills at baseline benefitted most from the intervention. Conversely, the significant improvement in design fluency scores at post-intervention compared to post-control, appears to be driven by improvements in the 'higher ability' group. This task involves continual self-monitoring and working memory, as children are required to create unique designs without replicating previous patterns in accordance with the rules of the task (connect at least two dots, use only straight lines, make sure you don't miss the dots etc.).

The effect of the intervention on the 'higher ability' group can be seen clearly in graph 6.3.6-3, and, although post-intervention improvements in the random array condition were not found to be significant, graph 6.3.6-4 shows a clear difference in performance between the two ability groups, with the 'lower ability' group maintaining similar performance at post-control and post-intervention testing, while the 'higher ability' group appear to have responded to the intervention with improved scores at post-intervention testing. It is possible that, as this task required more complex metacognitive EFs, the 'lower ability' group in this sense would not have had a sufficient level of core inhibitory and self-regulatory skills needed to see an improvement in non-verbal fluency tasks. In other words, until a particular developmental level of inhibitory skill is achieved, training on metacognitive EFs may not be effective.

Thus on core EF tasks, those children with low EF ability at the outset make most progress as a result of training. But with more complex EF tasks, children with outset levels of EF that are higher are able to benefit from training more than children with poorer EFs. This possibility is supported by the results of the working memory tests used in study 2. Both high and low ability groups showed a significant improvement in visuospatial working memory ability at post-intervention testing in comparison to post-control testing. However, in the Odd one Out task – a measure of more complex, executive-loaded working memory – the ‘higher ability’ group appear to show the greatest effect of the intervention, while the ‘lower ability’ group show a linear improvement over time (see figure 6.3.2-2). This distinction in the pattern of results between the two working memory tests may be another example of the limited effect training of complex EFs may have for some children with low EF skills on particular tasks. In this study, it appears to be the children who are considered to have EF skills within the normal range, that show improvements in more complex EF tasks post-training. Conversely, they do not show a training effect for skills for which they do not have particular difficulties with (for example, inhibition). However, it is the ‘lower ability’ group who show post-intervention improvements in core EFs (inhibition and working memory), which they initially struggle with. Little effect of the intervention is seen for the ‘lower ability’ group on tests involving more complex EF, indicating that poor performance on core EF skills limits the ability to train and progress more metacognitive EF skills. This issue will be discussed further in the concluding section, 7.4.

When comparing the results from study 1 and study 2, working memory and inhibition stand out as two areas of EF with a clear potential to be improved through musical training. These two cognitive elements may be more straightforward to train than other EFs such as planning or cognitive flexibility. However, patterns within the data from both studies suggest that, within working memory and inhibition, complexity of tasks and level of proficiency play a role in determining whether a training effect is seen. This means EF training is complex. For example, adult deaf and hearing musician’s superior performance to non-musicians on two tasks requiring inhibition disappears when they are given a more complex inhibition task; and deaf children in the ‘lower ability’ group saw improvements to their visuospatial working memory post-intervention, but not on a task which was more cognitively complex and demanding such as the Odd One Out task. In the case of study 2, children’s preference for activities that required inhibition and working memory may have also played a role in determining which EF tasks saw a significant improvement in performance. These may also have been activities that children were more likely to play independently, outside of the study at home and in the playground, therefore increasing the amount of practice they received for those EF skills.

These findings demonstrate the importance of considering individual needs, strengths, weaknesses and abilities when implementing EF interventions and training. The widely-held belief that it is those with poorer EF skills who will benefit most across the board from EF training (e.g. Diamond, 2011) needs to be nuanced in light of the findings of the current studies. Children with different baseline EF abilities show post-intervention improvements in different areas of EF in line with their own strengths and limitations.

### 7.4 Limitations and future directions

In their review of EF assessment instruments, Chan et al. (2008) raise important issues relating to the validity of tests used to identify specific areas of EF difficulty, and the subsequent interventions selected to address them. One of the key issues with EF assessments, which is also relevant to the current set of studies, is the limitation imposed by the necessary test-retest methodology of assessment. As Chan et al. (2008) point out, EFs, by definition, deal with novel situations. In the current study, the linear improvements made by children on some of the tasks over time represent expected practice effects as a function of increased familiarity with the tasks.

Another methodological issue, common to studies which measure EF skills also needs to be taken into account with the present work. This is that, as the study includes school-age children (as opposed to infants), tasks used to assess EFs need to be sufficiently challenging in order to avoid ceiling effects. Therefore, issues of task ‘impurity’ arise, as more complex tasks are likely to require the co-ordinated use of multiple EFs (Miyake et al., 2000). For example, the Tower of London task, used as a measure of planning in this study, most likely involves a number of EFs in practice, and has been described in previous studies as a measure of inhibition, planning or working memory (e.g. Berg & Byrd, 2002; Huizinga et al., 2006; Welsh, Satterlee-Carmell & Stine, 1999). This is a further illustration of the continuing theoretical debate about the extent to which individual EFs can be dissociated from each other in practice, as addressed by Miyake's 2000 theoretical framework of "unity and diversity" of EFs.

In future replications of the intervention study, some improvements to the design would be to include additional baseline assessment sessions (two or more) in order to establish a more stable baseline measure of the children's EF. For example, the baseline performance of child number 1 on the Tower of London task was particularly poor, as it took her a longer than average amount of time to understand the aim of the task. Her subsequent attempts at the task were more in-line with that of the other children. Repeated testing at baseline is a commonly used research method for intervention studies (Robson, 2002); however it would not have been suitable for the current study due to the relatively short length of the intervention (in comparison to longitudinal studies of a year or more).

In the current studies, it was important to minimise the impact of over-testing and aforementioned practice effects, particularly as there were numerous assessments for the children to complete in study 2. Therefore, taking multiple baseline measures in a study of this length would not have been preferable. A longitudinal study with longer duration would allow for stable baseline EF measures to be collected, as well as the potential for increasing the number of hours that children are involved in the intervention activities. Effects of the intervention on children's EF skills were not maintained in the current study. However, whilst 10 hours of training was a sufficient amount to reveal an improvement in working memory and inhibitory skills, it may be that a longer duration of training is required in order to maintain those effects. The findings from studies of long-term musicians (including the study of hearing and deaf musicians presented in this thesis), suggest that continual and repetitive musical practice is more likely to produce longer lasting effects to EF.

An additional limitation to the study (previously discussed in chapter 6, section 6.1.5) was the non-random allocation of children into groups, in favour of the necessary allocation of children into ability group. While this may be seen as a weakness to the study design, it enabled the investigation of the impact of the intervention and control sessions on children with differing baseline EF and language abilities. Not excluding children who had additional needs was, however, a strength to the study as these are potentially the type of children who are most likely to require an intervention for EF skills and would be targeted by teachers. It is therefore important that they are included in studies investigating the impact of interventions.

As discussed in chapter 5 section 5.2.1, the intervention in study 2 has been described throughout this thesis as "music-based" as the format for delivery of the training was through a music class. The children were introduced to musical notation and were allowed to explore different instruments. Nonetheless, it should be acknowledged that many of the activities in the intervention focused on rhythm. The current intervention study did not introduce pitch or tone discrimination into the research, as it was decided that this would be an additional variable that is not relevant to the focus or scope of the current research question. Labelling the intervention "rhythm-based" instead of "music-based" was resisted as this would be exclusionary to the other musicianship skills that the children were learning. However, pitch discrimination and the impact of improved auditory acuity on spoken language skills have been the focus of previous research (e.g. Biedlman, Hutka, & Moreno, 2013) and is an equally important component of music as rhythm. Future research in the area of deafness, music and EF could expand on the current intervention to include activities involving pitch, and examining its potential impact on deaf children's EF and language skills. One of the main strengths of the intervention is that, whilst it was designed specifically for deaf children, it is suitable for both deaf and hearing children to use without any further differentiation being needed. This would be of particular benefit to mainstream schools where deaf and hearing children are educated together, but, on some occasions, audition based music lessons may be a particular challenge for deaf children to follow or fully participate in.

Both studies reported in this thesis involved relatively small groups due to the availability of a unique population (study 1), and practical issues in terms of teaching time and delivery (study 2). However, there are an increasing number of opportunities for deaf people to take part in music, with organisations such as 'Music and the Deaf' offering workshops and training to teachers in order to include the deaf children in their music classes in meaningful ways; and signing choirs (such as the 'Kaos' signing choir who performed at the opening ceremony of the 2012 London Olympics) making the presence of deaf musicians more visible and commonplace. As more deaf children are encouraged to become involved in music in the future, further longitudinal studies involving larger groups of deaf children will be possible with the potential to build on the work reported here. One of the key implications of the findings of study 2 for practitioners is the discovery of no training effect for EF skills that were well-established at baseline. This finding supports the argument for tailored, individualised training in order to target particular EF difficulties that some children may have. The ability to identify areas of EF deficit in deaf children and target these areas with specific interventions is a viable aim for the future direction of this research. The development of the music-based intervention tool (in conjunction with other agencies such as Music and the Deaf) to expand the number of sessions and replicate the study with a larger number of children will be the next step in continuing research in this area.

Research into the beneficial effect of music training on EF, language, general intelligence, and emotional intelligence is still in its infancy and is producing varied, important and interesting results. This thesis adds to the conversation by including an important minority group and enabling an alternative perspective to be taken on what music can offer children developmentally and socially. However, the positive influence of musicianship on cognition should be considered as an additional benefit, rather than a primary reason to engage in musical activities. Music is worth teaching for its own sake because it is unique, inventive, and provides all children and adults with a creative avenue of communication and expression.

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# APPENDIX

## I. Musical Background Questionnaire

Personal Details

Name: .................................................... Email.........................................................................................

Date of birth: ………………….. Male ☐ Female ☐

Right-handed ☐ Left-handed ☐ Ambidextrous ☐

Hearing-impairment/deafness

Are you deaf/hearing impaired? YES ☐ NO ☐

(If No, go to the section “Musical Background”)

a) Please indicate the level of deafness*
Right ear: MILD ☐ MODERATE ☐ SEVERE ☐ PROFOUND ☐
Left ear: MILD ☐ MODERATE ☐ SEVERE ☐ PROFOUND ☐

(* *Descriptions used by the RNID*)

b) How old were you (in years) when you started to lose your hearing?

Right ear: 0-9 ☐ 10-19 ☐ 20-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ 70-79 ☐

Left ear: 0-9 ☐ 10-19 ☐ 20-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ 70-79 ☐

c) Do you use a hearing-aid? Right ear: YES ☐ NO ☐
Left ear: YES ☐ NO ☐

d) Do you currently experience tinnitus? YES ☐ NO ☐

e) Do you have a cochlear implant? YES ☐ NO ☐

Musical Background

Can you play a musical instrument and/or have sung in a choir or vocal group? YES ☐ NO ☐

If Yes,

a) What type of hearing aid do you wear when playing and/or singing?

Right ear: DIGITAL ☐ ANALOGUE ☐ NONE ☐

Left ear: DIGITAL ☐ ANALOGUE ☐ NONE ☐

b) What instrument(s) do you play and what age did you start to play?

Instrument………………………….Age Started…………Number of years playing……….Grade Proficiency? (1-8+)………

Instrument………………………….Age Started…………Number of years playing……….Grade Proficiency? (1-8+)………

Instrument………………………….Age Started…………Number of years playing……….Grade Proficiency? (1-8+)………

Instrument………………………….Age Started…………Number of years playing……….Grade Proficiency? (1-8+)……...

Instrument………………………….Age Started…………Number of years playing……….Grade Proficiency? (1-8+)……..

c) How long have you played and/or sung? (in years) ……............................................

d) Do you currently play and/or sing regularly (i.e. daily or weekly)? YES ☐ NO☐

e) Are you a professional musician**? YES ☐ NO ☐
(** *Definition: One who earns money from music-making*)

f) Do you have any qualifications in music? YES ☐ NO ☐

If yes, what is your highest qualification in music?

(E.g. ABRSM exam, degree/diploma) ………………………………………………………………………………

g) Can you read music? YES ☐ NO ☐

h) Do you have absolute pitch (sometimes called 'perfect pitch')? YES ☐ NO ☐

i) Do you have relative pitch? YES ☐ NO ☐

<u>Language Background</u>

What is your first (native) language? ……………………………………………………………………

If you speak/sign any other languages, please list them below, along with your level of fluency:

………… ☐ Basic /school level ☐ Intermediate/conversational ☐Advanced/fluent

………… ☐ Basic /school level ☐ Intermediate/conversational ☐Advanced/fluent

………… ☐ Basic /school level ☐ Intermediate/conversational ☐Advanced/fluent

………… ☐ Basic /school level ☐ Intermediate/conversational ☐Advanced/fluent

………… ☐ Basic /school level ☐ Intermediate/conversational ☐Advanced/fluent

## II. Adult Study Information Sheet

# Information Sheet
# Confidential

**Study name:** *The development of executive function abilities in deaf individuals across the lifespan*

Thank you very much for your interest in our research. Before you decide whether you would like to participate or not, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

This study is part of a larger project looking at the development of executive function abilities in deaf individuals across the lifespan. Executive function refers to skills such as planning and organisation, working memory, selective attention, inhibiting behaviours and switching attention. Previous studies have found that people who have had musical training (both singing and instrumental) show advantages in some of these areas, compared to those who have not had any music training. The outcome of this project is to determine whether this is also true of deaf individuals, which would help us to learn more about the underlying cognitive links between executive functions, music and language.

<u>What will you be asked to do?</u>

You will be given a short questionnaire to find out some general background information about you i.e. age, when you became deaf, cause of deafness, what aids you use, what communication methods you use etc. You will also be given a “Music Background Questionnaire” which focuses on your music experience i.e. what instruments you play, how long you have studied music etc. Next, you will be given 4 short computerised tasks presented on a laptop. The tasks will be given with sufficient breaks in between. This will be followed by 4 other non-computerised tasks. Altogether, the tasks and questionnaires should take no more than 1 hour to complete.

There are no risks associated with your participation in this study. You do not have to take part in this study if you do not want to. If you decide that you are happy to take part, you may withdraw at any time without having to give a reason and without penalty. All proposals for research using human subjects are reviewed by an ethics committee before they can proceed. This proposal was approved by the UCL Research Ethics Committee.

The questionnaires and tasks will take 45mins to 1 hour to complete. Following your participation in the study, we will provide you with further information regarding the specifics of the study, and you may contact the researcher (Kathryn Mason, see contact details below) if you desire more information.
If you agree to participate in this study, please complete the participant consent forms attached.

## III. Adult Study Participant Consent Form

## Consent Form
## Confidential

**Study name:** *The development of executive function abilities in deaf individuals across the lifespan*

Thank you for your interest in taking part in this research. Before you agree to take part, the person organising the research must explain the project to you.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

**To be completed by participant:**

1. Have you read the Participant Information Sheet?
   YES NO

2. If requested was the project been explained to you in BSL?
   YES NO N/A

3. Have you had the opportunity to ask questions and discuss the study?
   YES NO

4. Have you received satisfactory answers to all your questions?
   YES NO

5. Have you received enough information about the study?
   YES NO
   From whom? Dr/Mr/Mrs/Ms/Professor……………………….

6. Do you understand that you are free to withdraw yourself from this study at any time without giving a reason for withdrawing and without penalty? YES NO

7. Do you agree with the publication of the results of this study in an appropriate outlet/s?
   YES NO

8. Do you agree to have your signed responses video-recorded?
   YES NO N/A

9. Do you agree to take part in this study?
   YES NO

**Comments or concerns during the study**

If you have any comments or concerns you should discuss these with the Principal Researcher. If you wish to go further and complain about any aspect of the way you have been approached or treated during the course of the study, you should email the Chair of the UCL Research Ethics Committee (ethics@ucl.ac.uk) or send a letter to: The Graduate School, North Cloisters, Wilkins Building, UCL, Gower Street, London WC1E 6BT who will take the complaint forward as necessary.

Signed: …………………………………………………………… Date: ……………………….

Participant Name (Please print)……………………………………………………………….

All the data collected in this study will be managed in compliance with the Data Protection Act (1998).

## IV. Questionnaire for Teachers of the Deaf and Other Professionals Working with Deaf Children: Knowledge and Experience of Executive Function Interventions

*Lists all the questions in the survey and displays all the comments made to these questions, if applicable.*

**Question 1** Name (Optional)

**Question 2**: Contact email address

**Question 3**: Please indicate your profession

**Question 5**: What type of school do you work at?

**Question 6**: Which modes of communication are used in your school?

**Question 7**: How many deaf children attend the school?

**Question 8**: What age range of children do you teach/work with?

**Question 9**: Have you ever been trained in or used any of the following curriculum additions?

**Question 10**: If you are familiar with any of the above, please provide a brief overview of your experience.

**Question 11**: Have you ever used any of the following computer programmes with Children at school?

**Question 12**: If you are familiar with any of the above computer programmes, please provide a brief overview

**Question 13**: Please note down any examples of skills taught in your school which help to boost executive function skills.

**Question 14**: On average, how many music lessons per week do children have at your school?

**Question 15**: How many hours per week do children in your school spend taking part in exercise program?

**Question 16**: Would you be interested in taking part in training aimed at improving deaf children's cognitive skills?

## V. Questionnaire Responses

**Stored responses:** 134

**Number of completed responses:** 76

Question 10
If you are familiar with any of the above, please provide a brief overview of your experience (e.g. do you find them valuable or not, how often you do you implement them?)
Text input

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I did Mind Gym a while back with hearing pupils - it was quite good fun, but I am not sure that pupils made measurable progress with it.

Used some brain gym exercises when I was mainstream teacher. They did seem to help the children settle. Have also seen Activate (brain gym type thing) used in some schools and this again seemed to help them settle.

Brain Gym Have used. Useful to focus children and provide time to move then calm. Very put off by claims such as that if you massage your earlobes it will give you inspiration etc. Find this aspect complete rubbish which undermines some good aspects.

PATHS is useful for those unable to manage their frustrations. Brain Gym is used frequently in Maths.

I Rarely use them now.

Trained many years ago, not used consistently within. School now

I find Mind Mapping a most useful tool both personally and as a means of developing children's thinking, recording and memory skills.

I have in the past used Fastforward for improving the processing skills of pupils suffering from Auditory Processing Disorder and Auditory Neuropathy, with positive results. When I taught in mainstream school I used Brain Gym and found that Reading Levels jumped as the pupils used the hook up exercises before beginning their silent reading tasks, it also improved balance skills enormously. I am a Mindfulness Awareness Practitioner and often use this with my older deaf pupils when they are stressing about exams and course work deadlines. Varied results, but a calming effect!

Brain gym is used daily as a whole school for morning exercises. PATHS, I haven't used this in practice since the training many years ago.

I received training from RNID in 1997 when a deputy head in a school for the deaf. We used this in the curriculum. Success varied according to consistency of use, the age group it was applied to. Over time the fundamental principles of PATHS are replicated or adapted for use in Circle Time and promoting self esteem and emotional literacy.

PATHS for a useful program which I used with a Deaf Instructor in the deaf unit. I only used it once because now the deaf children are in mainstream for a lot of the day. I I used Brain Gym in Greenwich when I had my own group of deaf children. It was used in the mainstream school as a whole and was a useful strategy and fun to do as well.

Any curriculum additions are determined by the teacher of the class I'm working within.

Read about Brain Gym, used some of the ideas as wake up ready to learn exercises.

I know Brain Gym but have never used it

Memory and learning programme somewhat useful though aimed at slightly older age range.

Have used Brain Gym to good effect in the past but my current role does not allow for this.

I'm aware f Brain Gym and the benefits/concept behind it but have never been trained to deliver it.

yes very useful

I know from experience how much thinking skills are affected by deafness, I see it every day.

Aware of Montessori - but not aware of how valuable it is

Brain Gym is used in mainstream

Brain gym is used in mainstream

Used when I was a mainstream teacher, but due to the short times I have in each school I have not used them in this post.

I found PATHs useful with small groups of younger children and implement similar activities.

No longer use either of the above, but have done so in the past.

None used

Used Brain Gym when a primary school teacher - only in post as teacher of the deaf for 2 months and have not applied it in my work yet

I have heard of Brain Gym and read about Montessori. I haven't heard of MAPS specifically or heard much about
Mindfulness for children but I have taken part in two Mindfulness courses and read books about Mindfulness for myself

I used Brain Gym in a primary setting where I previously worked. It was a whole school initiative and we would do short exercises with the children every day. Ii was hard to monitor if the programme was being effective for the deaf students. It was easy to do and the children thought it was fun. At Frank Barnes I only looked at the Thinking skills materials they used but did not deliver any lessons.

I used before with Maps, it is all depend every individual pupils where i could meet their needs to access the curriculum

Many other strategies are used as a designer and DT teacher but terminology and branding of the strategies change as different groups claim them as their own. they are all useful as starting points in design and especially in revision or categorisation to aid memory exercises.

I have heard of some of them - PATHS, Brain Gym and Montessori. But I am not familiar enough with them to use them.

I'm not familiar with any of the above

Rarely used

We use Paths with year 1 upwards regularly. We value it very highly and teach it once a week but use the path emotions boxes regularly.

The mind maps which we use are essential when exams are approaching. They provide our pupils with a visual method of revising, which has proven very successful

Trained in brain gym but not used often in my teaching due to visiting work

Brief training session on Brain Gym and psychology - Haven't had enough development to embed as much as I would like to in my lessons

PATHS has proved useful but it's very difficult to do something like this when you're only in a school for an hour at a time.

PATHS- I have used an adapted version in Primary (yr5/6) and with hearing SEN children yr 7. Worked better with Yr 5/6 as they were willing to share personal experiences which helped to think of strategies.

Question 12

If you are familiar with any of the above computer programmes, please provide a brief overview of your experience (e.g. do you find them valuable or not, how often you do you implement them?)

I myself have trialled Luminosity, but as all systems, this is a good, but very expensive tool.

I have used Lumosity on my own iPhone. The problem with using any of these programs is when to have the time with such a full curriculum and the pressures of Ofsted etc.

Not a clue.

n/a

Weekly with some pupils

Used as a fun starter activity or at the end of a lesson as a reward

Used as a fun starter or a reward at the end of a tutorial session

Brain training was good to help develop memory skills with pupils

None used

Not applicable

n/a

No

I'm not familiar with any of the above

Question 13
Please note down any examples of skills taught in your school which help to boost executive function/thinking skills. For example, visual timetables, use of timers for planning, goal setting etc.

Visual aids for vocab using packages such as communication in print goal setting timers role reverse 'student as teacher' thinking hats etc

Use task sheets with some pupils to encourage them to work independently through a task.

visual timetables / egg timers / time out cards / positive tick sheets

Target Setting, Tick charts to organise work, revision time tables, Visual timetables, writing frames,time limits

The children are encouraged to think out tasks and problems themselves, but no specific programme. Visual skills are always promoted to help independence and build confidence.

We use visual timetables and occasionally timed planning activities.

visual timetables, visual notes/information

visual timetables including Now and Next boards

For older children, I use colour codes and mapping sheets for revision, or when planning for assignments. A dictaphone comes in really handy for taping lessons for years 10 and 11 and upwards - a USB dictaphone can be slotted into the computer and the pupil can then fast forward, rewind and pause the lesson content. I find the ipad really brilliant for all ages - some of the apps are really good, without costing very much and often free!

Visual timetables/ sand timers/ visual symbolised and signed targets for children. Children are explicitly told what they have done well / praise and prompt.

We capacity build in settings and train staff in the use of visual resources like those and for younger children we use visual home school books/PSPs.

Visual timetables, timers, goal setting, visual reward linked to cause and effect

The school uses 'Assessment for Learning' and 'Assessment of Learning' to involve the children in taking responsibility for their own learning, understanding their own targets and knowing what outcomes they are expected to achieve. Visual timetables are always used with the younger children and in special schools.

Small toy to 'display' the skill / task / theme which also signifies one exercise has ended and another begins. This has picture and word. Picture /word clues to pre-teach which are gradually removed. Involvement in target setting.

Visual timetables, timers, reward charts, visual books to determine what’s going to happen now ,next and later. PECS

Target setting used extensively at various levels - subject specific, generic, pastoral, language and speech specific where needed. Revision planning collaboratively with students. Breaking tasks into smaller steps.

Visual timetables, target setting with pupils, sharing learning intentions and success criteria. A lot of work is 1:1 so lot of discussion and children explaining their thinking

Visual cues

visual timetables, individual targets, prompts, Winnie the pooh characteristics of learning, activities in SLT and ToD sessions to help auditory and visual memory, providing learning (acoustic environment in which they can use and apply these skills,

all classrooms have visual timetables, we use sand timers to give definite end times for different activities, children all have individual targets written on the wall, reviewed regularly and changed when achieved.

visual timetables at school and home - encourage to use visual methods in all teaching

Visual timetable/listening website/picture cards/books etc

Visual timetables are used in class. Visual posters and reminders are around the room to support independent thinking and learning. Thinking skills & problem solving activities are incorporated into the curriculum. ipad apps are used for problem solving thinking skills games. Thinking skills activity sheets are used as a morning starter activity

Visual timetables,

Visual timetables, IEP targets

I am not in a school but advise schools to use visual timetables, and visuals for maths a and mind mapping skills

We do auditory memory and working memory work, linked to the curriculum.

Mind maps such as emind, ipads

30 minute Listening skills session once a week; Ling sounds; deaf awareness training with a section briefly on deaf children's' cognitive ability.

Visual timetables

Many schools use visual timetables, and in our planning we set smart targets, other skills taught depend on the level of need etc of the individual pupil

Visual timetables, PECS, timers, target setting, Points system, competitions, Plan-it cubes BSL Assessments - Expressive & Receptive.

Timers for planning, target setting, mind mapping, study support

Timers for planning, target setting, mind mapping, study support

Visual timetables, timers, signed recipes

Included through the range of schools visual timetables timers TEACCH tables

Use of mind maps Semantic mapping grids Target setting

Visual timetables Widget symbols/sign graphics to support communication

None to my knowledge

Visual timetables. timers, goal setting, aids to memory - visualization, mind mapping etc., memory games/training, auditory memory games, barrier games etc

Visual time table memory games/stories speech and language

Visual Timetables. We try to develop language skills in at least one language to a level commensurate with cognitive ability. Many of our children enter the school with very low language skills in both BSL and English. That situation must be very bad for Executive Function. Our Deaf Studies Teacher does one to one work with children whose BSL skills are very low - We call this Sign Therapy. We work with the Deaf Child and Family Service to sort out emotional and mental health issues which could otherwise affect Executive Function. Some pupils go horse-riding for he disabled which seems to improve coordination, confidence, mood, concentration. We sometimes provide one to one Teaching Assistant support. Through English as an Additional Language and Modern Foreign Language teaching techniques, we try to support the pupils to understand their bilingual situation and to be able to separate their use of BSL and English. The Deaf Studies curriculum supports development and understanding of identity. We teach some Neurolinguistic Programming strategies for retaining spelling that we were taught on a training day. I can't think of any other specific thinking/memory programmes we use. Many of our pupils don't have the fundamentals of language, identity and emotional well-being when they arrive so we set about repairing those.

We regularly use Mind mapping to help develop thinking skills between concepts learnt in lessons.

visual smart board as part of visual plus use BSL

all the above that you have listed but so many we do it automatically

Some visual timetables. Some self evaluation of tasks using traffic lights

Visual timetables, visual supports for organisation, e.g. remembering equipment / packing school bag, use of timers for activities, some aspects of TEACCH approach to help with planning and organisation. Language-based thinking skills, e.g. programmes to develop verbal reasoning and verbal problem solving skills ('Language for Thinking', use of Blanks levels / Blooms taxonomy, 'Talkabout' social skills programme, Black Sheep Press 'Pragmatics' and 'Talking about...' activities).

visual time tables, planners, learning targets

curriculum target setting with pupils, planners, visual timetables,

everything within the classroom is visual, labelled and differentiated according to the needs of each individual pupil

School planner/timetables Personal Learning Plan leaning intentions at beginning of lesson, evaluating at end

Visual timetables, timers,

Visual time tables targets are set in each subject pupils regularly review their progress they know their levels for each subject

Visual timetables, pecs, NDCS memory programme

Visual timetables are in place but not referred to as often as I would like. Timers used for SEN/additional difficulties although other children may benefit

Visual timetables, use of timers, setting targets with individuals.

Our pupils need minimum support in Executive thinking skills. Most are straight deaf

In the Resourced Unit we aim to use lesson starters as a regular opportunity to develop thinking skills. Formal resources used include: - Memory Booster programme (Lucid). - Brain Thinks (Independent Thinking Ltd.) but we also aim to challenge and develop thinking skills incidentally. The whole school has had training on independent thinking skills / cognitive development: we use Habits of Mind.

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# Improving Deaf Children's Concentration, Control, Thinking and Memory Skills

ESRC DEAFNESS COGNITION AND LANGUAGE RESEARCH CENTRE

## VI. Information Sheet for Parents

Dear Parents,

My name is Katie and I am a PhD student and Researcher at University College London. I have worked with deaf children for 8 years, both teaching and designing language tests for them. I am interested in finding new ways of supporting deaf children's learning and language skills.

In January 2015 I will be working with the deaf children at XXXX for 10 weeks in a study aiming to help improve their attention, memory and decision making skills.

### What is the study about?

During their time at primary school, children go through many changes in their ability to control their thinking, concentrate and make decisions. Psychologists call this set of skills ***'Executive Functions'***. There has been quite a lot of research looking at the importance of executive function skills to children's development and success at school, but there has been very little research looking at these skills in deaf children. My study is trying to find ways of improving deaf children's executive function skills and will also look at the link between language skill and executive function.

### What will my child be doing?

I have designed a programme of lessons with activities to help boost deaf children's executive function skills. The children will be taking part in a 1hr class twice a week for 5 weeks consisting of fun music based games and activities designed to target their executive function skills. They will also take part in an art class for 5 weeks which will act as a control condition for the study.

## What will happen when the study has finished?

At the end of the study I will be able to give the school a report of your child's executive function skills (i.e. Their scores on memory, reasoning and decision making tasks) and how these have changed over time. Their data will be kept secure at the university, and their name will not appear on any

## How can I get more information?

If you would like more information about the study, please email me at Kathryn.mason.12@ucl.ac.uk I will also be available after school on **Tuesdays and Wednesdays** if you would like to meet me and I can answer any questions you may have then. If you are happy for your child to take part in the study, please complete the consent forms attached.

Yours sincerely,

**Kathryn Mason,**
PhD Student, University College London

**UCL DCAL RESEARCH CENTRE**

**VII. Parental Consent Form**

# Parental Consent Form
# Confidential

**Study name: The development of executive function abilities in deaf individuals across the lifespan**

**To be completed by parents and/or carers:**

1. Have you read the Parent Information Sheet attached? YES NO

(If requested was the project explained to you in BSL?) YES NO

2. Have you had the opportunity to ask questions about the study? YES NO

3. Have you received enough information about the study From Katie Mason? YES NO

4. Do you understand that you are free to withdraw your child from this study at any time without giving a reason for withdrawing and without penalty? YES NO

5. Do you agree with the publication of the results of this study in an appropriate outlet/s? (e.g. Research journals) YES NO

6. Do you agree to have your child's signed responses video-recorded? YES NO

7. Do you agree for your child to take part in this study? YES NO

**Comments or concerns during the study**

If you have any comments or concerns you should discuss these with the Principal Researcher. If you wish to go further and complain about any aspect of the way you have been approached or treated during the course of the study, you should email the Chair of the UCL Research Ethics Committee (ethics@ucl.ac.uk) or send a letter to: The Graduate School, North Cloisters, Wilkins Building, UCL, Gower Street, London WC1E 6BT who will take the complaint forward as necessary.

Signed: ……………………………………………………………… Date: ……………………….
Parent/carer name (Please print)…………………………………………………………………
Child's name..........................................................................................................................

All the data collected in this study will be managed in compliance with the Data Protection Act (1998).

## VIII. Video Consent form

# VIDEO CONSENT FORM
# Confidential

**Study name:** *The development of executive function abilities in deaf individuals across the lifespan*

Your child will be filmed for this research. Your child's name will not be used. The video will be labelled with a number.

1. I agree for my child to be filmed and for the video to be watched by research staff only
   YES NO

We would also like to ask your permission for the other uses of still images or video clips. These will not be confidential as people may recognise your child. You do not have to say YES. If you say NO, no one will ask you why. If you say NO, we will respect your wishes.

| | | |
|---|---|---|
| 2. Presentations at university research conferences | YES | NO |
| 3. Research reports in university publications | YES | NO |

Please note any concerns about these uses or restrictions to their agreement on the back of this paper.

Signed: ………………………………………………………………… Date: ……………………….

Parent/carer name (Please print)……………………………………………………………………

Child's name.........................................................................................................................

Kathryn Mason PhD Student
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E·S·R·C
ECONOMIC & SOCIAL RESEARCH COUNCIL

## IX. Music-based EF Intervention Lesson Plan

# A Music-based Intervention to Improve Deaf Children's Executive Function Skills

Kathryn Mason

The Deafness Cognition and Language Research Centre, UCL

Kathryn.mason.12@ucl.ac.uk

# *Overview of Activities*

Successful interventions for executive functions require a lot of repetition and practice of skills. For that reason, many of the activities in this programme are repeated over the course of the 10 sessions.

It is anticipated that some of the children may find particular activities harder than others, therefore each activity has the potential for differentiation according to ability. Even though the lesson plans should be followed, some flexibility must be given to account for individual differences between the children, and the teacher needs to make sure that each child is able to grasp and complete the activity before moving on to a more challenging version. However, it is equally important that the children are continuously challenged by the programme, and are encouraged to keep attempting tasks that they may find difficult, with adults demonstrating and scaffolding techniques when appropriate.

Motivation is also an important factor and some of the games include a competitive element (such as 'don't clap this one back', where the motivation is for the class to collectively beat the teacher over the course of the 10 sessions).

If children appear too frustrated or bored with any of the activities, the activity can be swapped to another on the programme that they prefer. This is working on the basis that motivation and interest will be more beneficial, as all of the activities are designed to incorporate the training of similar areas of EF. Any deviations from the set programme need to be noted.

Two games will be used to open and close every session:

1. **<u>"Pass the Rhythm game"</u>** – will be at the start of every session. Sat in a circle, the teacher claps out a rhythm and passes it on to the next student in the circle until it has passed all the way around the circle. Continue playing and increasing the difficulty of the rhythm until there is only one child left – the winner!

2. **<u>"Don't clap this one back"</u>** – every session ends with a game of don't clap this one back, standing up in a circle. The teacher claps a range of rhythms, no more than 4 beats long, using hands, body, and the floor and the children copy the rhythms. However if the teacher claps the rhythm 'Don't clap this one back' – (♩♩♩♩♩) they don't clap it back. Every time someone claps the rhythm when they aren't supposed to, the teacher gets a point. If no one claps when it's 'don't clap this one back' the children get a point. Who will win at the end of the term, children or the teacher? This provides motivation for the children to play the game and pay attention.

## *Resource List for activities*

| | |
|---|---|
| *Drums – ideally one each* | *Tray and cloth for memory game* |
| *Baton /special conductor's hat* | |
| *Shakers,* | *musical items for memory game* |
| *Clappers/woodblock* | |

| | |
|---|---|
| *Follow the Leader* | *Children have to copy whatever the 'leader' does while the leader changes their actions frequently. One child who is not taking part has to guess who the leader is. Therefore transitions need to be subtle and participating children need to pay attention and adapt to the new action quickly! All take turns as the leader and the guesser. Requires planning from the leader and monitoring/attention/ inhibition from the participants.* |
| *The Body Orchestra* | *Attending to different timbres and textures. The game requires working memory as children need to remember which action accompanies which animal and instrument. This session introduces composition which requires planning skills* |
| | *Children need to attend to the changing instructions of the conductor. The Naughty orchestra requires inhibition and* |

| | |
|---|---|
| *The Naughty/Good Orchestra* | *working memory skills, as children are required to do the opposite of what they are instructed to do. The conductor can give directions in quick succession to increase the difficulty of the game.* |
| *Making our own Music* | *Introducing children to basic musical notation enables them to create simple rhythms for others to play. This requires planning and working memory. These sessions can be easily differentiated.* |
| *The memory game* | *A working memory game requiring children to recall as many items as they can from a tray containing 20 music-related items.* |
| *Switch!* | *A rhythmic version of the N-Back, this game requires working memory, monitoring and attention.* |
| *The Rhythm Machine* | *Different simple rhythms played by each child require inhibition and selective attention skills. Children are encourage to attend to their own playing, and then the group as a while whist maintaining their rhythm. This requires monitoring and flexibility.* |

## Week 1 Session 1 – Drums and Rhythms

| **Executive Function Focus**<br>Working memory, attention and switching | |
|---|---|
| **VOCABULARY**<br>Conductor<br>Rhythm<br>Baton | **RESOURCES**<br>Drums – ideally one each<br>Baton /special conductor's hat<br>Powerpoint |

**INTRODUCTION**
Introductions (Introduce self and what we will be doing 2 lessons every week)

"Hello/welcome" song
Short video of different drums and where they come from (Japan, Africa, Orchestral)

**ACTIVITY**

GAME 1 – Copying. First demonstrate different rhythms to the children. Can include clapping.
Go around each person having a turn to play a rhythm for 30 seconds. All others watch carefully and copy (Adults assist if any children struggle). This is where the game "pass the rhythm" can be introduced. Explain the rules to the children and play a simple version of the game.

Game 2 – "Follow the Leader". One child leaves the room. A leader is chosen to play a rhythm and will change it occasionally. Can be played without drums and just clapping and stamping feet (depending if there are enough drums to go around). Child enters the room and has to work out who the 'leader' is.

Game 3 – The Conductor.

Demonstrate conducting – use signs to reinforce concepts faster, slower, louder, quieter. Practice these on the drums

Children take turns being the conductor. When the conductor points to you, you play your drum and pay attention to their requests …. Faster, quieter, louder etc. Conductor can point to individual players or to everyone.

**PLENARY**
Short overview of what we did today.
"Goodbye" song/ Introduce "Don't clap this one back" game
Tidying up.

**EVALUATION/NOTES ON THE SESSION**

## Week 1 Session 2 – Body Orchestra

| **Executive Function Focus**<br><br>Working memory, switching. | |
|---|---|
| **VOCABULARY**<br>Texture<br>Timbre | **RESOURCES**<br>Shakers,<br>One drum,<br>Clappers/woodblock<br>2-3 laminated sets of "body orchestra" cards<br>Powerpoint |

**INTRODUCTION**

"Hello/welcome" song. Pass the rhythm game
Introduce today's topic – Body orchestra
Focus on different timbre and texture of instruments.

**ACTIVITY**

Activity 1 – Using powerpoint and allowing the children to handle the instruments, talk about different textures the instruments make. Use "body orchestra" flash cards in the powerpoint.

Activity 2 – Once the link between the instrument, animal, and body movement have been established, children can take turns being the 'conductor', The conductor hands out animal cards to the other students and arranges how they like, in a line. They will then conduct the body orchestra!

When it is the turn of the next conductor, different cards will be handed to the children and they have to remember the body action that corresponds with it.

Activity 3 – In groups, play the memory card game using the "body orchestra" cards. When a child picks up a pair, they have to produce the corresponding action.

**PLENARY**

Overview of what we did today
"Goodbye" song/ Don't clap this one back
Tidy up

**EVALUATION/NOTES ON THE SESSION**

## Week 2 ~ Session 3 – Making Our Own Music

| **Executive Function Focus**<br><br>Planning, attention, flexibility | |
|---|---|
| **VOCABULARY**<br>**Rhythm**<br>**Tempo** | **RESOURCES**<br>Four Chairs<br>Simple percussion (tambourines/shakers)<br>Blue and red coloured sheets of paper |

**INTRODUCTION**
Hello song. Pass the Rhythm game
What are we doing today? – Composing our own music (focus on rhythm and tempo)
**ACTIVITY**
Game 1 – "Quick and slow" introduce children to simple and basic concepts of notation and time value of notes.

Use colour codes for value of notes. Red for crotchet, blue for a quaver. Practice clapping examples of 4/4 lines of music. Make sure the children understand each bar needs to add up to 4 whole notes.

Create a visual 'natation tree'. "Tea, Coffee"

Game 2 – composing your piece.
Working in pairs, children use coloured paper to compose their own rhythms. After 10 mins, come back to circle and present their compositions…. Everyone claps/uses percussion to play the rhythms.

Game 3 – People composition!
Four chairs at the font and six volunteers. Demonstrate how to compose using people. If sat on chair normally = crotchet, if sat to the side = half a crotchet (quaver) note. Ie. Two people sat back to back followed by one sat normally can be clapped as – *quick quick slow.*

Children take turns to physically move people into position to create their own rhythm. Everyone plays the rhythm. Can re-introduce the concept of loud and quiet from last session to make it more interesting, e.g. if standing = loud, if seated = quiet.

**PLENARY**
Come back to the circle
Overview of what we did today
Goodbye song/ Don't clap this one back game
Tidy up

**EVALUATION/NOTES ON THE SESSION**

## Week 2 ~ Session 4 The Memory Game and Naughty Orchestra

| | |
|---|---|
| **Executive Function Focus**<br>Working memory, inhibition and attention | |
| **VOCABULARY**<br><br>Vocabulary linked to percussion instruments and musical items depending on what is sourced. | **RESOURCES**<br>20 music related items/percussion.<br>Tray<br>Cloth to cover all the items<br>Paper and pencils<br>Small prize (or prizes in case of a draw)<br>Baton / special conductor's hat |

**INTRODUCTION**
Hello/welcome song. Pass the rhythm game
Introduce today's topic – learning about new instruments

**ACTIVITY**
Activity 1 – Memory game. Being with the tray of items covered with the cloth. Children sit in a semi-circle around the tray. Produce each time one at a time, giving its name and how it is played/works then return it underneath the cloth before removing the next one. Explain the memory game to the children. Remove the cloth and give them 1min to memorise as many items as they can. After 2 mins, cover the items again and encourage the children to write down as many items as they can remember – there is a small prize for whoever can remember the most. Adults can support those children needing help writing/spelling and items can be signed.

Activity 2 – Explore the instruments. Children have 10mins to play with the instruments and see how many different ways they can use them. Instruments are passed around. Children do not need to remain seated for this part.

Activitiy 3 – The "Naughty Orchestra". Using the items from under the cloth and building on the "orchestra" game from a previous session. All the children choose an instrument and play the Orchestra game. After 3 children have had a go as conductor, the rules will change. This time the children have to do the OPPOSITE of what the conductor requests – session leader to model as the "naughty orchestra" player first. After a few children have had a go conducting, the naughty orchestra, alternate between the "good" and "naughty" orchestra.

**PLENARY**
Overview of what we did today
Goodbye song/ don't clap this one back game
Tidy up

**EVALUATION/NOTES ON THE SESSION**

## Week 3 ~ Session 5 – Switch!

| | |
|---|---|
| **Executive Function Focus**<br><br>Working memory, attention, inhibition | |
| **VOCABULARY**<br>Switch | **RESOURCES**<br>Drums<br>Shakers,<br>Clappers/woodblock<br>2-3 laminated sets of "body orchestra" cards<br>Powerpoint |

**INTRODUCTION**

Hello song/ pass the rhythm game

**ACTIVITY**

Activity 1 – Switch!! Begin with a game of "follow the leader" to remind children of the rules. After a couple of rounds, introduce the harder "switch" element. Children continue the rhythm while the leader changes their beat. When the leader says "switch!" (visual cue) the children have to copy the previous beat whilst the leader performs a new one. Keep the rhythms simple. Musical version of the N-Back. (When this activity is repeated in later sessions, difficulty can be increased by having to remember 2-back or 3-back rhythms)

Activity 2 – Body orchestra. Re-visit the game where children take turns assigning the cards and conducting the orchestra. When the children successfully remember all of the movement/animals/instruments, introduce some more cards to the pack.

They can then split into pairs and use the cards to play the memory card game.

**PLENARY**

Overview of what we did today
Goodbye song / don't clap this one back game
Tidy up

**EVALUATION/NOTES ON SESSION**

## Week 3 ~ Session 6 – Making Our Own Music

| **Executive Function Focus**<br><br>Planning, attention, flexibility | |
|---|---|
| **VOCABULARY**<br>Rhythm<br>Tempo | **RESOURCES**<br>Four Chairs<br>Simple percussion (tambourines/shakers)<br>Blue, red , yellow and green coloured sheets of paper<br>Drums if available |

**INTRODUCTION**

**ACTIVITY**
Game 1 – Revisit "Quick and slow" introduce children to simple and basic concepts of notation and time value of notes.

Use colour codes for value of notes. Red for crotchet, blue for a quaver. Practice clapping examples of 4/4 lines of music. Make sure the children understand each bar needs to add up to 4 whole notes.
***Providing the children mastered this in the last session, introduce semi quavers and minims on yellow and green paper. Those who find it harder, stick with crotchets and quavers. This time, the notation can be written on the back of the paper.***

Create a visual 'natation tree'. – "Tea, Coffee"

Game 2 – composing your piece.
Working in pairs, children use coloured paper to compose their own rhythms. After 10 mins, come back to circle and present their compositions…. Everyone claps/uses percussion to play the rhythms.

Activity 3 – The Rhythm Machine.
Using simple rhythms that the children just created, one child starts by playing their rhythm over and over again on the floor. The person sitting to the left of the starter then adds their own rhythm to go along with the rhythms that are already going. Again, the rhythm has to repeat and can not change.
When everyone has added a rhythm, let the children listen for a few measures.
The first person will then stop doing their rhythm. Again pause for a second or two, and then the second person drops out.
It continues until the last person is the only rhythm. Encourage the children to attend to the changes in sound and how one part can make a HUGE difference.

**PLENARY**
Overview of what we did today

| |
|---|
| Goodbye song / don't clap this one back game<br>Tidy up |
| **EVALUATION/NOTES ON SESSION** |

# Week 4 ~ Session 7 – Naughty or Nice Orchestra

| **Executive Function Focus**<br>Working memory, inhibition and attention | |
|---|---|
| **VOCABULARY**<br>Vocabulary linked to percussion instruments and musical items depending on what is sourced. | **RESOURCES**<br>20 music related items/percussion.<br>Tray<br>Cloth to cover all the items<br>Paper and pencils<br>Small prize (or prizes in case of a draw)<br>Baton / conductor's special hat |

**INTRODUCTION**

Hello song/pass the rhythm game.
What are we doing today? – Memory Game and Naughty or Nice orchestra.

**ACTIVITY**

Activity 1 – The memory game. Repeat the memory game as in the previous session but introducing items one by one and covering them up with a cloth. This time, use 10 items that appeared in the previous session, and 10 new items. This time, there is an added bonus for the person who can remember the most items, and also which were on the tray before and which are new.

Activity 2 - The naughty orchestra. All the children choose an instrument from the tray and play the Orchestra game. After 3 children have had a go as conductor, play the naughty orchestra.
After a few children have had a go conducting, the naughty orchestra, alternate between the "good" and "naughty" orchestra – the child conducting can decide what they want the orchestra to be, good or naughty

**PLENARY**
Overview of what we did today
Goodbye song / don't clap this one back game
Tidy up

**EVALUATION/NOTES ON SESSION**

## <u>Week 4 ~ Session 8 – Switch!</u>

| **Executive Function Focus**<br><br>Working memory, attention, inhibition | |
|---|---|
| **VOCABULARY**<br>Switch<br>Crotchet<br>Quaver<br>Semi quaver<br>Minim | **RESOURCES**<br>Coloured sheets of paper<br>Notation posters/ rhythms<br>Examples of 4/4 bars for children to play using quavers, crotchets, minims and semiquavers |

**INTRODUCTION**
Hello song/ pass the rhythm game
What are we doing today? – Switch and making our own music

**ACTIVITY**
Activity 1 – Switch!! Begin with a game of "follow the leader" to remind children of the rules, but this time, nobody leaves the room. Only copying.
After a couple of rounds, introduce the harder "switch" element. Children continue the rhythm while the leader changes their beat. When the leader says "switch!" (visual cue) the children have to copy the previous beat whilst the leader performs a new one. Keep the rhythms simple. ***This time try introducing 2-back and (maximum) 3-back. Children can practice this in pairs, while the teacher goes around and individually plays "switch" with each child in order to see how each of them copes with the task.***

Activity 2 – Making our own music. Continue with exploring notation and beating different rhythms (preparation for next session, where simple syncopation is introduced). This activity needs to be differentiated according to the abilities of each child. More advanced can move on from coloured paper to simple notation.

Activity 3 – People composition! Children are given cards with simple rhythm notation on them. They then have to re-create the rhythm using people (as they did in session 3) and then clap the rhythm when they are done. All children to check whether they have got it right.

**PLENARY**
Overview of what we did today
Goodbye song / don't clap this one back game
Tidy up

**EVALUATION/NOTES ON SESSION**

## Week 5 ~ Session 9 – Rhythmic Patterns 1

| **Executive Function Focus**<br>Working memory, inhibition, attention, planning | |
|---|---|
| **VOCABULARY**<br>Metronome<br>Syncopation<br>Off-beat | **RESOURCES**<br>Drum for each child<br>Printed copies of simple rhythms<br>Printed copies of syncopated rythms<br>Metronome with flashing light<br>Posters with review of basic music note vales and examples of syncopated rhythms |

**INTRODUCTION**
Hello song/ pass a rhythm
What are we doing today – Rhythmic patterns and the rhythm machine

**ACTIVITY**
Activity 1 Children will be shown examples of syncopated rhythm. The teacher assigns three different groups their own rhythm patterns and different sounds. Student groups clap them individually and together as a class. Then groups rotate for experience, and finally come up with their own rhythms.

Procedure:

Teacher will review basic music note values with the class.
Teacher will assign the students to one of three groups.
Give each group a different pattern and/or sound as follows:
clap quarter notes, repeat
clap quarter note – two eighth notes – quarter note – two eighth notes, repeat
rub hands together for eight eighth notes, repeat
Lead each group in practice individually.
Set the metronome to a reasonable tempo. Explain how the metronome works, what the numbers/settings mean, and why it is used.
Have each group practice again, using the metronome.
Group performance time! Start the rhythm one group at a time.
After you think the class has accomplished that particular pattern, change the groups around so they get a chance to do every pattern.
Let the children make up their own patterns and tempos to express excitement, solitude, and sadness

Activity 2 - The Rhythm Machine.
Give each child a printed 4 beat rhythm with simple notation. On the drums, go around the circle and allow each child to beat their rhythm to check that they can do it. One child starts by playing their rhythm over and over again. The person sitting to the left of the starter then adds their own rhythm to go along with the rhythms that are already going. Again, the rhythm has to repeat and can not change.
When everyone has added a rhythm, let the children listen for a few measures.

| |
|---|
| The first person will then stop doing their rhythm. Again pause for a second or two, and then the second person drops out.<br>It continues until the last person is the only rhythm. Encourage the children to attend to the changes in sound and how one part can make a HUGE difference.<br><br>**PLENARY**<br>Overview of what we did today<br>Goodbye song / don't clap this one back game (try and make the scores close in the penultimate session!)<br>Tidy up |
| **EVALUATION/NOTES ON SESSION** |

## Week 5 ~ Session 10 – Rhythm Patterns 2

<table>
<tr><td rowspan="2">Executive Function Focus<br>Working memory, inhibition, attention, planning</td><td>LEARNING OUTCOMES</td></tr>
<tr><td>SUCCESS CRITERIA</td></tr>
<tr><td>VOCABULARY<br>Metronome<br>Syncopation<br>Off-beat</td><td>RESOURCES<br>Drum for each child<br>Printed copies of simple rhythms<br>Printed copies of syncopated rythms<br>Metronome with flashing light<br>Posters with review of basic music note vales and examples of syncopated rhythms<br>All percussion and instruments from previous sessions</td></tr>
<tr><td colspan="2">
INTRODUCTION<br><br>
Hello song/ Pass the rhythm<br>
What are we doing today? – last music session<br><br>
ACTIVITY<br><br>
Activity 1 – Continue with the more complicated rhythms from the previous session. Follow the same procedure, re-capping notation values and beating out the rhythms together first.<br><br>
Activity 2 – Children are allowed to select their favourite instrument from the previous sessions and explain what they like about it. What different sounds can they make with it? How is it different from other instruments? This can be followed by a game of Nice/naughty orchestra with the selected instruments.<br><br>
Activity 3 – Final game of follow the leader. (Time permitting)<br><br>
PLENARY<br><br>
Overview of what we did today<br><br>
Feedback from the children – did they enjoy the music sessions? Were they fun, easy, hard, boring?? What did they enjoy and what didn't they like?<br>
Goodbye song / don't clap this one back game – for the final time! Look at the score board who is going to win? Children or teacher?<br><br>
Tidy up
</td></tr>
<tr><td colspan="2">EVALUATION/NOTES ON SESSION</td></tr>
</table>

**X. Art Sessions Lesson Plans (Active Control Condition)**

# Art Sessions

# (Active Control Condition)


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## *Overview of Activities*

The activities detailed in the following lesson plans form the active control condition for a study investigating the effect on executive function skills of a music-based intervention for deaf children. The art activities described here are designed to have as little demand on children's executive function skills as possible. Therefore, children are to be presented with an example of the intended finished art work, prior to beginning the activities and they are guided by adults who help them complete the activities if necessary. As they receive support in the activities and they are designed to be as easy as possible for the children, no specific differentiated tasks have been devised.

The theme of the art activities is "Seasons of the year". There are 10 sessions – 8 of which cover the 4 seasons of the year (i.e., 2 sessions are spent on each season), one session where the children make a rainbow collage, and one session where they make a folder in which to keep all of the artwork they produce over the course of the study. If children appear too frustrated or bored with any of the activities, they can be given the option of colouring in pre-printed scenes based on the appropriate season. If children don't complete their activity in a particular session, they may complete it at the end of the next session if there is time.

## *Resource List for activities*

| | |
|---|---|
| Assortment of stickers | Seasonal themed pictures for colouring |
| PVA Glue | |
| Coloured tissue paper – variety of colours | Glitter paint – red/blue/silver |
| Black paper | A3 coloured paper |

# Week 1 Session 1 – Rainbows

**RESOURCES**

Coloured tissue paper
Coloured paint
Felt pens and colouring pencils
Coloured felt squares
Glitter paints
Scissors
Newspaper to cover work surfaces
White A3 paper
Coloured buttons
Rainbow print out and picture examples

**INTRODUCTION**

Introduce the topic to the children. Ask them about the seasons of the year – what are they? What kinds of colours are associated with each season? What season is it right now? Over the next 5 weeks we will be making art work related to the seasons of the year. Today we are starting with a fun activity… making rainbow collages.

**ACTIVITY**

Show the children example pictures of rainbow collages.
Give each child a piece of A3 white paper. They can choose to draw their rainbow free-hand or use the print out as a template.
Children have choice of using paint, colour pencils, glitter paint, felt, tissue paper and/or coloured buttons on their collage.

**PLENARY**

Short overview of what we did today, everyone shows their work.
Tidying up.

**EVALUATION/NOTES ON THE SESSION**

## Week 1 Session 2 – Making Folders for Art Work

**RESOURCES**

A3 Coloured card
Hole punch
Treasury tags
Colouring-in print outs
Seasons of the year cover page
Glue

**INTRODUCTION**

**Show the children an example of the folder they will make**

**ACTIVITY**

**Let them choose which colour paper they want to use for their folder – 2 pieces**
**Hole punch both pieces for the children and attach treasury tags**
**Children glue the cover page to the front and decorate the folders with their colouring pictures**

**PLENARY**

Overview of what we did today
Tidy up

**EVALUATION/NOTES ON THE SESSION**

## Week 2 ~ Session 3 – Winter (1) Snowflakes

**RESOURCES**

| | |
|---|---|
| Snowflake templates | Glue |
| Scissors | Paint brushes |
| Glitter paint | Newspaper to cover work surfaces |
| A4 paper | |

**INTRODUCTION**

What are we doing today? Introduce 'Winter' topic of the week. What colours do we associate with winter? Show the children the silver and blue glitter paints. Show them examples of paper cut-out snowflakes already made.

**ACTIVITY**

Give each of the children a template of the snowflakes. Show them how to fold the paper and cut out their own snowflakes. They can make their own if they wish.
Snowflakes are then stuck to A4 white paper and the children can decorate them with blue and silver glitter paints.

**PLENARY**

Overview of what we did today
Tidy up

**EVALUATION/NOTES ON THE SESSION**

## Week 2 ~ Session 4 – Winter (2) Penguins

**RESOURCES**

| | |
|---|---|
| Black Card | Scissors |
| White A3 paper | Glue |
| Orange Card | glitter paint |
| Stick on "Googly eyes" | |

**INTRODUCTION**
Introduce today's topic – second session of winter. Making penguins. Show the children an example of a pre-made penguin picture.

**ACTIVITY**
Children create the penguins by layering white paper on top of the black paper (shapes can be pre-cut for children who would have difficulty cutting out)
Children cut an orange triangle for the beak and add eyes to the penguins
The finished penguins are then mounted on white paper which can be decorated and painted with glitter/paint.

**PLENARY**
Overview of what we did today
Tidy up

**EVALUATION/NOTES ON THE SESSION**

## Week 3 ~ Session 5 – Spring (1) – Blossom Trees

**RESOURCES**

Light and dark pink, green and white tissue paper
Felt tip pens
Glue
Paint brushes
Colouring pencils
Print outs of tree trunk template

**INTRODUCTION**

Talk about springtime – what colours are associated with spring? etc. Show children an example of blossom tree art they are about to create.

**ACTIVITY**

Children can choose to use the print out of a tree trunk to begin their picture, or draw their own tree trunk using pencils and felt tip pens.
The children tear up pieces of the tissue paper and screw them up into a ball. These are then glued to the paper to represent the leaves and blossoms on the tree.

**PLENARY**

Overview of what we did today
Tidy up

**EVALUATION/NOTES ON SESSION**

## Week 3 ~ Session 6 – Spring 2 – Spring scene and collage

**RESOURCES**

Tissue paper in spring colours (yellow, pink, light green) A4 white paper
Paints – various colours Spring coloured buttons and feathers
Colouring pencils and felt tip pens
Scissors Spring scene print outs
Glue

**INTRODUCTION**

Show children the different spring scene print outs and allow them to choose 2 different ones.

**ACTIVITY**

Children can create a spring collage by cutting out the spring scenes and decorate using paint, colouring pencils and tissue paper, coloured buttons and feathers.

**PLENARY**

Overview of what we did today
Tidy up

**EVALUATION/NOTES ON SESSION**

## Week 4 ~ Session 7 – Summer (1) – Holiday colouring scenes

| | |
|---|---|
| | **RESOURCES**<br>Tissue paper in bright colours A4 white paper<br>Paints – various colours<br>Colouring pencils and felt tip pens<br>Scissors Holiday scene print outs (beach, park, fishing)<br>Glue |

**INTRODUCTION**
Show children the different summer scene print outs and allow them to choose 2 different ones.

**ACTIVITY**
Children can create a spring collage by cutting out the summer scenes and decorate using paint, colouring pencils and tissue paper,

**PLENARY**
Overview of what we did today
Tidy up

**EVALUATION/NOTES ON SESSION**

## Week 4 ~ Session 8 – Summer (2) – Butterfly symmetry

| | |
|---|---|
| | **RESOURCES**<br>**A4 white paper**<br>**Various coloured paints**<br>**Paintbrushes**<br>**Water pots** **Newspaper to cover work surfaces** |

**INTRODUCTION**
What are we doing today? Show children examples of painted butterfly symmetry pictures. Demonstrate how to make the butterfly by folding the paper in half and making a wing design on one side of. Fold the other half over and press firmly to produce a symmetrical wing on the other side. Fill in the butterfly body in the middle.

**ACTIVITY**
Give each child a piece of A4 white paper and help them when needed in completing the task. Children can make as many butterflies as they wish. Cut paper into smaller sections to produce various size butterflies. Cut them out once dry.

**PLENARY**
Overview of what we did today
Tidy up

**EVALUATION/NOTES ON SESSION**

## Week 5 ~ Session 9 – Autumn (1) – Hedgehogs

| |
|---|
| **RESOURCES**<br>**A4 white paper**<br>**Glue** **(optional: leaves collected from playground)**<br>**Scissors**<br>**Hedgehog print out** **Felt tip pens** |
| **INTRODUCTION**<br>What are we doing today – Introduce Autumn. What colours do we need etc. Show children a completed picture of hedgehog collage<br><br>**ACTIVITY**<br>Children each take a print out of the hedgehog outline to colour in and mount on a piece of paper. They then use leaves, colours pens and any other materials they choose to represent the hedgehog spikes. Then they decorate/colour in the background however they wish using appropriate autumnal colours.<br><br>**PLENARY**<br>Overview of what we did today<br>Tidy up |
| **EVALUATION/NOTES ON SESSION** |

## Week 5 ~ Session 10 – Autumn (2) – Squirrel/Autumn collage

**RESOURCES A4 white paper**
**Glue**
**Scissors**
**Squirrel print out**
**Brown/yellow/ grey feathers**
**Felt tip pens**

**INTRODUCTION**

What are we doing today? – last art lesson together. Children have the opportunity to finish off any uncompleted work and put everything in their folders to take home.

**ACTIVITY**

Children each take a print out of the squirrel outline to colour in and mount on a piece of paper. They then use feathers, colours pens and any other materials they choose to represent the squirrel's tail. Then they decorate/colour in the background however they wish using appropriate autumnal colours.

**PLENARY**

Overview of what we did today

Feedback from the children – did they enjoy the art sessions? Were they fun, easy, hard, boring?? What did they enjoy and what didn't they like?
Tidy up
Put all artwork into folders to take home to their parents

**EVALUATION/NOTES ON SESSION**