The impact of participation in music on learning mathematics

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I hereby declare that, except where explicit attribution is made, the work presented in this these is entirely my own.

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Abstract

Music psychologists have established that some forms of musical activity improve intellectual performance, spatial–temporal reasoning and other skills advantageous for learning (Hallam, 2015; Rauscher, 2000; Schellenberg, 2004; Costa-Giomi, 1999, and Graziano, 1999). The research reported here explored the potential of active music making for developing students' spatial-temporal skills and the role this played in improving their progression in mathematics.

The study had an experimental design in which a group of 178 children aged 4-6 participated in a music programme containing a variety of musical, predominantly rhythmical, activities. Taking account of the earlier research which suggested that generalist primary teachers are not confident in delivering music lessons and that they feel inadequately prepared during their teacher training (Rogers et al., 2008, Hallam et al, 2009, OFSTED, 2009, Henley, 2011), the music programme created for the current study was aimed at non-specialist teachers. Based around popular nursery rhymes, the activities were easily accessible even for teachers who were not confident in singing in front of their class. The programme addressed the need for clearly specified progression and provided teachers with guidance about how to assess students' skills and their advancement. All activities were explicitly suited for Foundation Stage (FS) and KS1 pupils and were arranged to promote a range of competencies. To make it accessible for schools, the programme did not require any equipment, resources or staffing which would stretch schools' budgets. The programme lasted two years and throughout the intervention pupils' attainment in mathematics, spatial – temporal reasoning, and music was recorded. This included assessment of specific mathematical and musical skills. Parallel classes made up control groups. Attainment in all areas of measurement was compared between groups to examine the impact of music instruction on learning mathematics.

The findings demonstrated that the younger music groups achieved statistically significantly greater progression in mathematics over time than their peers from the control groups. This relationship was observed in the main study and in the combined groups. These results paralleled statistically significantly greater achievement in one or both spatial – temporal tests. The older groups also recorded statistically significant differences in outcomes in one or both spatial – temporal tests in all three periods of measurement. These scores were related to higher attainment in mathematics but this change as scores was not sizeable enough to reach statistical significance.

When results in specific mathematical skills were considered, only some of them were related to the musical training. The most basic mathematical skills like number recognition to 10, counting to 10 and to 20 were not impacted on by participation in music lessons. Skills

related to geometry, 2D and 3D shapes, attributes of shapes, and symmetry patterns, were closely related with the music programme. This was the result of the impact of the music instruction on spatial-temporal abilities. The strong relationship between musical training and arithmetic skills, for example, addition and subtraction, using number line, and problem solving was an unexpected finding. However, as these tasks require mathematical skills related to spatial abilities like number sense and strategy choice, the enhancement of spatial-temporal skills through participation in the rhythmic instruction is likely to have influenced these higher levels of mathematical attainment.

The results of the current study cast light on how musical, spatial-temporal, and mathematical skills are intertwined and explored how the music programme might be useful in learning in specific areas of mathematics whilst feeding into the overall mathematical development. These findings provide theoretical and pedagogical knowledge to inform teaching practice. The inexpensive and easy to deliver music programme could enable teachers, who lack confidence in teaching music, to engage their early years and Yr1 pupils in musical activities which would also support the development of mathematical skills.

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Chapter 1: Rationale

1.1 Introduction

The room was sunny and spacious. The ceiling so high up that the girl imagined that what she could see was a piece of sky of her own. In that much air, the sunbeam and the sound travelled slowly before it reached the girl and the woman sitting by the table. Warm autumnal light and the beauty of Chopin's music circled gently around them. The girl looked up and asked: "Could you tell me about those 'times' again?" How does one explain multiplication to a 4-year old? The woman reached out for a basket full of shiny conkers and some empty jars and the girl smiled. She liked it when her gran put the music on and explained the magic of numbers.

With such recollections of my first mathematics lessons, music and mathematics felt almost inseparable. But this connection was not obvious to most people. When I listed music and maths as my favourite subjects, people reacted in one of two ways. Rarely, they would give a knowing nod, of course these two work well together. 'Not quite so', a little voice kept saying politely in my head, 'how about many of my friends who were very good in music and really bad in mathematics?' Quizzical looks on the faces of the vast majority of others did not require further interpretation. Geek or what?

Tunes and patterns, rhythms and lengths, beats and numbers, music and mathematics – a relationship observed for centuries, is just as perplexing today, as it was to Ancient Greek philosophers. Although we know more than ever about the brain, in particular learning and music perception, the connection remains unclear. Is it related to brain structure or brain function? Is it malleable as neural plasticity would suggest? Is the relationship causal? Could educating in music have wider implications for learning in mathematics? The aim of the research reported here was to try to begin to address some of these questions through a rigorously undertaken intervention study.

1.2 Theoretical framework

Since the late 1990s academic evidence has emerged that music instruction might positively influence the development of spatial-temporal skills in children (Rauscher et al., 1997; Rauscher, 1999b; Shaw, 2000; Hetland, 2000a; Rauscher and Zupan, 2000; Rauscher, 2003). Spatial-temporal reasoning, as opposed to language-analytic thinking, is one of the two complementary ways we reason (Shaw, 2000). This skill involves the ability to manipulate and understand complex shapes, often without the presence of the physical objects. Through this mental imagery, the individual develops and evaluates patterns which change in space and time. Spatial recognition including matching and copying visual objects provides the basis for more complex spatial-temporal tasks. Spatial-temporal reasoning allows individuals to visualise problems and potential solutions leading to conceptual understanding, especially in the related areas of mathematics and science. This type of reasoning is closely related with symmetry, transformations and relations/proportions and as such can be particularly useful in learning proportional mathematics and fractions which are otherwise difficult to teach using language-analytic methods (Shaw, 2000). It seems plausible that the development of spatial-temporal thinking would also positively affect geometrical skills in students. A key question then is whether any other mathematical abilities are susceptible to this influence. Is the relationship between spatial-temporal reasoning and music the only facilitator of the music-maths connection? Can learning music have an impact on learning mathematics in more general terms? What would be the necessary conditions for such influence in terms of musical activities, age of pupils, time span etc.?

Some of these questions have been addressed by research in the psychology of music. More detailed description of these issues is presented in the literature review in Chapter 2. For the purpose of creating a research proposal it was crucial to understand and draw on previous research. The musical activity that has emerged as the most beneficial in developing spatial-temporal reasoning is rhythmic instruction (Hetland, 2000a; Rauscher and Le Mieux 2003; Rauscher and Hinton 2004). Children in the early years of primary school seem to be most susceptible to such enhancement (Graziano et al. 1999; Rauscher and Zupan 2000; Rauscher 2002, Rauscher and La Mieux 2003; Schellenberg 2004; Costa-Giomi, 2004, Costa-Giomi, 2013). Not many studies have considered the optimal length of intervention required to have an impact and the extent to which the impact is sustainable. Research by Rauscher and Zupan (2002) showed improvement in spatial-temporal skills which continued throughout a four-year long programme, whilst Rauscher (2000) pointed to the need for a two-year long programme to achieve lasting change.

Explanations for the relationship between music and spatial-temporal reasoning were sought in relation to the literature from neuroscience. As our understanding of the functioning of the brain is currently incomplete theoretical approaches were drawn on. Two main theories inform the explanation of the relationship between musical and spatial reasoning activities. Theories related to connectivity propose that the processing of music and spatial tasks is the result of an overlap in brain functions (Fiske, 1996). The near transfer theory suggests that music and spatial- temporal reasoning share some processes and the development of one leads to the development of the other (Schellenberg, 2004; Rauscher, 2011).

Neuroscientific research into brain structures has confirmed that the areas of the brain where spatial reasoning occurs are more pronounced in adult musicians and that processing of music and spatial-temporal tasks activates similar neural structures. In particular, two studies in which musicians achieved better results than the controls on a line orientation test (Sluming, 2002) and were better in finding the middle of a line (Patston, 2006) are of great importance in looking for potential overlap between music and mathematics. Skills used in these two tasks may also be related with the ability to manipulate the mental number line. Taking account of the importance of the concept of mental number line for the development of mathematical thinking, it is possible that learning music enhances this mechanism (Siegler and Booth, 2005; Ramani and Siegler, 2008).

The study of the psychology of mathematics, and in particular mathematics cognition provides some explanations as to how spatial-temporal reasoning is used in mathematical thinking and what mechanisms underpin this connection. Academics emphasize the separation of the two early mathematical skills – number knowledge and number operation (Griffin, 2004) and link the latter with the formulation of mental number line which enables children to understand magnitudes, relations between them and arithmetic operations (Jordan et al., 2008; Gunderson, 2012). The spatial and imaginary character of this structure places it within the remit of spatial-temporal reasoning. Its development is fundamental for mathematical understanding and facilitates performance, especially in arithmetic (Ramani and Siegler, 2008; Booth and Siegler, 2008; Van Nes and Doorman, 2011; Gunderson et al., 2012).

Spatial skills have also been linked with spatial structuring which is a skill used in determining quantities, comparing and calculating them (Butterworth, 1999; Mulligan and Mitchelmore, 2009). Such operations, at an early stage of development, occur unitarily. This is time consuming and has the potential for making mistakes. With time, most children learn to organise objects to count them more efficiently. This skill is also employed later in understanding the concept of the decimal system. Furthermore, spatial awareness contributes to the development of patterning, while the temporal element of spatial-temporal reasoning might be used in structuring and strategy choice. A more in depth review of these concepts is presented in chapter 2.

The inter-disciplinary approach required for the research presented a significant challenge but was necessary. Each of the disciplines engaged with uses its own terminology, concepts and methodology so unequivocal comparisons were not always possible.

1.3 Developing the strategy

Once the aims of the proposed study were defined, the strategy for the project and methodology of the research had to be decided on to provide the best possible platform for the inquiry. An empirical study set in a primary school and using a music programme with the youngest children was considered the most appropriate approach. Many previous studies used musical instruction which was costly or involved the participation of professional musicians. The current research attempted to not only investigate the research problem but also to make it possible for it to be replicated in other educational settings. To achieve this, the music programme used in the intervention was created taking account of the most recent overviews of and recommendations for music education in primary schools (a detailed description of the programme is presented in chapter 3).

1.3.1 An overview of music education in primary schools in England

In his review of music education in England commissioned by the Department for Education, Henley (2011) proposed a number of recommendations to improve the quality and accessibility of music for all children. The report stated that music provision was inconsistent. There were many very active music centres and hubs which facilitated high quality instruction in schools, but there were also many areas which were not so well served and where teachers had little support in teaching music. Henley pointed out that there should be clearer progression routes in music education and that for children to achieve their best, they needed to gain an understanding from learning music in the classroom as an academic subject. In most primary schools, music is provided by non-specialist teachers. Unfortunately, they often lack confidence to teach the practical aspects of music. This lack of confidence is largely a result of an inadequate amount of time dedicated to music in most Initial Teacher Training courses (Hallam et al., 2009a, Hallam et al., 2009b). This could be tackled in the early stages of teachers' careers, either while still in teacher training or working as an NQT, but is often not addressed. Henley proposed that all primary schools should have access to a specialist music teacher and as a form of achieving this he suggested that secondary school teachers should be given time to work and share their experience with their feeder primary schools.

Prior to Henley's report, OFSTED compiled evidence of music teaching from analyses of inspections entitled Making More of Music: Improving the Quality of Teaching Music in Primary Schools (2009). Some of the findings of this report paralleled those of the Henley review. For example, the report stated that while there was some outstanding provision in many school, there was still a significant number of pupils who did not make as much musical progress as they could, especially in the older primary years (Year 5 and 6). As observed in inspections, the best teaching engaged all pupils and enabled them to develop musically through progressive curriculum with well-chosen and accumulative tasks. The report indicated the main weaknesses of current music education. These included the lack of emphasis on increasing the quality and depth of student's musical responses which were linked closely with ineffective assessment. There was also great inconsistency of musical experiences within and across key stages. In tackling these deficiencies OFSTED suggested that the quality of subject leadership was more important than whether classes were taught by music specialists. Teachers who considered themselves non-specialists were able to provide good quality teaching when they were effectively supported by a music subject leader. Another step to improving the quality of music teaching as proposed by the report was defining clear steps of progression at various stages of learning.

There has been and continues to be discussion about whether music in primary schools should be taught by teachers who are specialists in music or by generalist teachers (Mills 1989; Mills, 2005). Some have argued that specialist visiting music teachers should teach music. There were however some challenges to this view (Glover and Ward, 1993; Hennessy, 1994; Mills, 2005). Having knowledge of pedagogy of only one subject might mean that specialist peripatetic teachers might not be able to provide programmes that were fully integrated with the National Curriculum and were properly adapted to all pupils' needs. Additionally, Mills (1989, 2005) suggested that having a visitor delivering music exaggerated the elitist image of music as available only to some rather than to all. Further questions were raised as to whether a lesson with a visiting teacher had the same impact as if it was delivered by the usual classroom teacher and was consistent with other delivery throughout the school. It was argued that from the students’ perspective they valued lessons with a visitor less than with their permanent teacher (Mills, 1989).

In the current climate, budget restrictions have impacted on the landscape of music education in primary schools. In most schools, it is generalist teachers who are responsible for teaching music. There are some advantages to this. Generalist teachers have much more thorough knowledge of individual children, their abilities, needs and growing understandings. Moreover, classroom teachers have better understanding and capacity about how music might fit into the daily routine of the class and the whole school. They are able to use students' successes in music to encourage progression elsewhere. Their lessons might integrate more purposefully with the National Curriculum on a subject level but also through cross-curricular links. Most generalist teachers do not usually possess such in depth expertise and practical skills as music specialists. However, this is true for most subjects that they teach. The question is how extensive does their knowledge and understanding need to be to enable them to deliver good quality music lessons. Generalists who are excellent practitioners might be more effective than specialist, visiting teachers (Jeanneret and Degraffenreid, 2012). To achieve positive outcomes for children, knowledge and confidence in music have to be integrated with broader elements of pedagogical practice which consider how children learn, what does development in music look like, what musical expectations are appropriate for pupils at different ages and how to engage children. The primary teacher has an important role in deciding how music is structured and delivered in school (De Vries, 2014). What experiences children are provided with has influence on their developing sense of musical identity, and through this the development of musical skills (Hargreaves et al., 2012a). How then is it best to prepare non-specialist teachers to build skills to confidently teach music and what kinds of support and training would be required?

Several organizations have undertaken a variety of actions to address this issue, providing teachers with additional training and improving the provision offered by the schools. The impact on teaching by one such project - a primer from the Voices Foundation - was evaluated by Rogers and colleagues (2008). This teacher training programme was prepared on the basis that the class teacher should have sufficient skills to enable the children to learn. Through a whole school approach and close cooperation with advisors, teachers were given opportunities to learn, to translate what they had learned into practice and be given effective feedback which enabled them to further their development. In previous studies teachers felt that receiving support from a specialist musician was the most beneficial form of training in teaching music and the programme successfully followed this suggestion. The researchers established that most teachers reported gains in knowledge and understanding of musical concepts such as pulse, pitch, and rhythm. They felt that their musical skills were developed in terms of theoretical knowledge and practical abilities. The programme positively influenced their singing skills and increased the repertoire of songs and improved their ability to assess children's musical development and their progression in singing. Teachers highly valued working with subject coordinators which supports the suggestions of Mills (2005) about the need for a champion of music within the school. They also suggested that the programme should consider different approaches for different Key Stages. The report confirmed that generalist teachers can develop the skills they need to teach music in the primary school.

In another project, Hallam and colleagues (2009) investigated a training programme offered by the EMI Music Sound Foundation. Additionally to researching what impact the training programme had on teachers it also examined how teachers assessed their preparation for teaching music and what they expected from the CPD provision. The report stated that there was an urgent need for better initial training and continued development to provide teachers with specific musical skills, musical vocabulary and confidence in delivering music lessons. This was to be supported by a well-defined and organized curriculum which would enable teachers to plan for progression and properly assess pupils' attainment. Teachers reported that too little time was spent on music in their initial training and that what was offered was inadequate for their needs, in particular in terms of Key Stage 1 (KS1). The teachers who had previously taken part in various forms of training in music spoke about the difficulties that they had experienced. They included no follow up training, training not oriented to KS1, and that the material covered in training was not accessible for them. The overarching aims teachers had whilst attending the EMI Sound Foundation training were to enhance their confidence in teaching music and to gain the ability to help the children to progress. Apart from this, many other purposes were mentioned by the teachers. They wanted to be able to use music to enhance pupils' concentration, listening skills, and attention span. Further requirements were to foster enjoyment of music amongst pupils and increase their confidence. Developing musical skills in pupils including musical vocabulary and concepts and gaining new ideas about how to introduce these concepts in an engaging way were also raised by the teachers. They pointed to the need for support in classroom management during music lessons and developing strategies to deliver whole class activities without creating overpowering chaos and noise. Furthermore, additional purposes like new ideas for KS1 and cross curricular links were proposed. Teachers' assessment of the gain from the programme was that it helped them to understand and deliver the requirements of the National Curriculum. It also provided them with new ideas, enabled more singing, facilitated using musical activities throughout the school day and made teachers feel more confident and enthusiastic about teaching music.

Taking account of the earlier research, the music programme created for the current study was aimed at non-specialist primary teachers and did not require any equipment or resources which would stretch schools' budgets. Based around popular nursery rhymes the activities were easily accessible even for teachers who were not confident in singing in front of the class. The programme addressed the need for clearly specified progression and provided teachers with guidance about how to assess students' skills and their advancement. All activities were explicitly suited for Foundation Stage (FS) and KS1 pupils and were arranged to promote a range of competencies. These were: the development of musical abilities like singing, clapping, and playing percussion instruments with elements of composing; the improvement of musical understanding of concepts and vocabulary; building social skills through working in pairs and groups; and creating opportunities for children to enjoy the music making and to enable all children to succeed. Once the programme was implemented, teachers were invited to observe or participate in lessons, they were also provided with planning guidance, explanation of how to deliver the lessons and how to assess pupils' learning.

1.3.2 Why rhythm?

Previous research examining causation between participation in music and the enhancement of spatial-temporal reasoning has suggested that using rhythmic activities has the strongest impact on spatial reasoning skills (Hetland, 2000a; Shaw, 2000; Rauscher and Le Mieux 2003; Rauscher and Hinton 2004; Thaut, 2007; Rauscher, 2011). Unfortunately, at the moment, our understanding of brain activity during the processing of rhythm is too limited to be able to explain this phenomenon. The most advanced commentary on this comes from Thaut (2005, 2007). He refers to the temporal character of music as one of its most important characteristics. Its linearity combined with texture makes it possible for both sequentiality and simultaneity to be expressed at the same time (Thaut, 2005). This two-dimensional temporality created by pattern structures with a variety of symbols related with each other generate and convey the symbolic meaning of music. Complex neurological activity is required to process musical patterns and structures created from rhythm and sound (often multiple at the same time). The strong notion of temporality in music cognition stems from the earlier work of Serafine (1988) who described listening not only as perception of musical events happening in time, but also the active element of organizing and construing of these events into a coherent structure. Serafine also saw the temporal processing of music as happening on two levels which she called succession and simultaneity. Her explanation suggests that succession results from motivic chaining; patterning, which includes repetition, alternation, and modulation; and phrasing. Simultaneity on the other hand relates to combining and organizing musical events. Although repetition, alternation, and modulation are used here specifically in describing cognition in music, the similarity to processes used in spatial-temporal reasoning should not go unnoticed. Thaut (2007) proposed further that the time organization that occurs in the human brain is not unique to music and findings from studies related to rhythm might provide an insight to more general functioning of the brain. These two kinds of thinking, sequential and simultaneous, are also present when solving spatial-temporal tasks hence the temporal character of both activities might be the commonly shared cognitive element.

A further concept contemplates the use of fractions and proportions in rhythm and points out that processing of these requires math-specific skills (Shaw, 2000; Schlaug et al., 2005; Jones, 2011). Understanding of ratio enables children to calculate fractions, divisions and proportions, while pattern recognition is used in spatial-temporal tasks and in a broad variety of mathematical tasks. Schlaug et al. (2005) linked this skill with learning and using rhythmic notation while Gordon (1993) saw it as processing structures of sound.

1.3.3 Are the non-musical values of learning music a threat to music being valued for its own sake?

An ongoing discussion considers the aims of music education and whether the emphasis on the non-musical values of music instruction is compatible with the aims of music teaching itself. Shrinking school budgets, time limitations, and systems of school evaluations based on students' results in the UK have challenged the place of the arts and humanities in the curriculum in favour of subjects in which pupils sit SATs in primary schools and take increasingly popular STEM subjects in secondary schools. In such a situation, the arts, and music in particular, have to defend their position. This has often been done by emphasizing the non-musical skills that can potentially be achieved through learning music. With the threats to music education it seems that looking for solutions which support a balance between these two purposes, not losing the focus on purely musical aims is the most appropriate approach.

Throughout the centuries of Western civilization, music has been an intrinsic part of our lives and played many roles within the spiritual, intellectual and community aspects of life. Young people have been educated in music not only to develop their aesthetic sensitivity and gain purely musical experience. Moral, physical and intellectual benefits of studying music have been considered just as valid (Elliott, 2012). Is musical experience indeed possible without the involvement of non-musical perspectives? In some cultures, there has been a close relationship between aestheticism and morality. Activities of high aesthetic value have been regarded as moral. Other cultures and religions taught music to further faith, patriotism or citizenship. All of these non-musical benefits of learning music became part of a broadly understood education, they were accepted but only rarely were they considered more than a secondary outcome of music education (Elliott, 2012).

More recently research in cognitive psychology has changed the balance. This has been the case particularly when the findings of academic studies have been misinterpreted and bent to fit the point of view of policy makers keen for a quick fix to improve children’s attainment in reading, writing and mathematics (Allsup, 2014). Generally, in these examples, it is the enhancement of achievement that is emphasized rather than improvement to education. In the US funds for music education have been tied to the effectiveness of these in supporting academic performance. In some US states, all mothers were issued with CDs of Mozart's music to stimulate their children’s intelligence (Swaminathan, 2007). Many educational music programmes were designed to introduce music as tools to teach other core subjects as if the only value of teaching music was perceived to be its support for learning science, mathematics, and language (Rauscher, 2002).

Moreover, such a perspective extends beyond educational settings. Miell, MacDonald, and Hargreaves (2005) proposed that "people in contemporary society use music as a resource, […] we use music in order to achieve certain psychological states in different everyday situations" (p. 11). There is also increasing evidence of the impact of music con health and well-being from premature babies to the oldest old (see MacDonald et al. (2012). None of this detracts from the value of music for its own sake. The development of our understanding of how music affects us on cognitive, behavioural and social levels enhances the already known and appreciated high values of music. The functionality of music does not have to stand in the way of its aesthetics. If music can help us in facing the challenges of the modern life in an engaging, non-intrusive, inexpensive and side-effect-free way, why should it not? Utilizing music for these positive outcomes integrates four related disciplines. A conceptual model of such an alliance has been proposed by MacDonald et al. (2013) and recognizes music education, music therapy, community music, and everyday uses of music as equals, which nevertheless overlap. If music education not only provided students with specific musical knowledge, understandings and skills but also introduced them to the various functions of music including the way it can enhance their learning in other areas, it would support a stronger role of music in young people's lives.

In terms of education, brain research has assumed an influential role. New findings provide support for educational practices and shape teaching and learning by describing and explaining functional and structural changes grounded in the high plasticity of the brain. This has resulted in new teaching approaches and strategies used in learning in general and in learning music (Hodges, and Gruhn, 2012). The current study does not suggest that the functionality of music should replace the intrinsic value of music. Examining the academic attainment of the participants served the purpose of inquiring how learning music might be related to learning in other areas. In doing so, the programme supported music education and provided quality music lessons for the children. It also tried to find a way of expanding the knowledge of how to teach music in the early primary stage for educators, especially those who struggle with delivering music lessons in their classrooms. Above all, this research set out to understand better what happens when children learn music.

1.4 Chapter summary

In comparison with the growing body of evidence which links learning music with literacy and language skills, the possible relationship between music and learning mathematics is relatively under researched. In the academic literature, there is a well-established literature indicating a causal relationship between participating in musical activities and the development of spatial-temporal reasoning. With the similarities between the cognitive skills required to solve spatial-temporal tasks and abilities necessary in mathematics, the current research proposed that music might also influence the enhancement of learning mathematics.

In investigating such relationships and their potential causality, the current study followed the proposition that the development of spatial-temporal abilities will supplement the learning of mathematics. However, it also allowed for the possibility that the interaction between music and mathematics might demonstrate itself in other ways, namely through specific mathematical skills which are not obviously associated with spatial awareness. The research also investigated which musical activities might have a greater influence on mathematical abilities and whether these relationships are different for different groups of children: boys and girls, children with special educational needs (SEN), children for who English is an additional language (EAL), and children who are eligible for free school meals (FSM). Parallel to these academic aims was a consideration of whether the approach of the current study could be implemented in pedagogical practice and how this could best be achieved. The specific research questions are set out below:

Research questions to be addressed in the current study:

- How, if at all, does participation in music influence learning in mathematics and learning in other academic areas?
- Can teaching which has led to the findings of this research be implemented in the primary classroom practice?

More detailed sub-questions were developed supporting the multi-disciplinary methodological approach:

- How, if at all, does participation in music influence learning in mathematics?
- Does participation in music improve spatial-temporal skills? What is the relationship between the development of these abilities and learning in mathematics?
- In which mathematical abilities can change be observed? Which mathematical skills, if any, might be developed in a more significant way by a music intervention?
- What are the relationships between specific mathematical skills and achievement in music? Which particular musical activities might have the strongest impact?
- What are the long-term relationships between music and mathematics and is the impact sustainable?
- What is the impact of the programme on different groups of children (SEN, FSM, EAL, gender differences)?

1.5 Organization of the thesis

Chapter 2 frames the theoretical bases upon which the current study was undertaken. Three sub-sections illustrate the inter-disciplinary character of the research and set it within the broad field of psychology of music, music cognition and the cognition of mathematics.

The methodology of the research, the tools, procedures and measurements adopted in the study are described in chapter 3. This also provides a detailed commentary of the design of the music programme.

Chapters 4, 5, 6, and 7 contain the analyses of data related to the relationships between the outcomes of the research for the different cohorts of children. As the study progressed in three stages, the order of the chapters follows this pattern: data from the pilot study in chapter 4, data from the main study in chapter 5, data collated from groups of the same age throughout the intervention in chapter 6, and data collected a year after the programme was finished in chapter 7.

Interactions between variables are set out in chapters 8, 9, and 10. These chapters also correspond to the stages of data collection: pilot study in chapter 8, main study in chapter 9, and longitudinal analysis in chapter 10.

Chapter 11 considers the possible differences which the music instruction might have had on children of different gender, socio-economic background, ethnicity, and educational needs.

Chapter 12 summarizes the key findings, discusses the findings and relates them to the theoretical foundations of the academic literature, sets out the limitations of the research and considers the current study's contribution to knowledge.

Chapter 2: An interdisciplinary review of literature

This chapter provides the theoretical framework for the current study. Three sub-sections illustrate the inter-disciplinary character of the research and set it within the fields of psychology of music, music cognition and the cognition of mathematics. A broad spectrum of issues is considered including the enhancement of cognitive and social skills through music, the impact of music on the brain, and the relationships between spatial skills and the development of mathematical thinking. The three parts serve the overall goal of investigating the impact of music on the learning of mathematics with a possible mediating role played by spatial-temporal reasoning.

2.1 The role of music in raising attainment - psychological studies into developing cognitive and social skills through music.

2.1.1 Introduction

The term the "Mozart Effect" was coined by the press in relation to a study by Shaw, Rauscher and Ky (1993) in which college students listened to 10 minutes of the Sonata for Two Pianos in D Major K. 448 by Mozart. Prior to and following that they completed a spatial-temporal reasoning test. Those listening to the music scored higher than the control group. The effect lasted for about 10 minutes. Understandably those findings attracted extensive interest from media; a possibility of becoming smarter just by listening to the music was very tempting as a means of enhancing educational outcomes. The coverage was enthusiastic and not always accurate. There was misunderstanding in relation to the effect of listening to music and the impact of active engagement in making music on cognitive skills. This chapter summarizes the findings in both areas of research with particular emphasis on the enhancement of learning mathematics.

2.1.2 Impact of listening to music on intellectual performance

Studies into the impact of listening to music on task performance have had mixed results. In early studies in the 1950s, Hall (1952) concluded that having music playing in the background while undertaking academic work improved pupils' scores in reading, helped with general classroom behaviour and was particularly beneficial to students whose results were below average. Since then several studies have focused on pupils with behavioural difficulties

(Scott, 1970; Savan, 1998; Hallam and Price, 1997). All of them found that background music reported as "calming" improved pupils' attitude, concentration and performance in solving mathematical problems. A study in a mainstream school (Hallam and Price, 1997) found that background music improved the rate of pupils' work on mathematical problems but the accuracy of that work did not change. Overall, it seems that background music can change listeners' moods which in turn can enhance concentration, and in that way facilitate learning.

Research focusing more directly on the "Mozart Effect" has also had mixed results. Hallam (1996) found that children's scores on two spatial reasoning tasks did not differ between listening to Mozart, popular music or a talk on research methods. A later reanalysis of these data (Hallam and Schellenberg, 2005) showed that the children performed significantly better after listening to the popular music, further supporting the notion that the impact on mood and arousal mediated any effect on cognitive scores. In contrast, Rideout (1998) successfully replicated the original study (Rauscher, Shaw, Ky 1993) showing a Mozart effect. Nantais and Schellenberg (1999) compared how children performed after listening to Mozart, Schubert or a story. They established that all three options brought about changes, but the outcome depended on the individual child's preference once again supporting that it was the emotional arousal following the favourite stimulus that caused improvement rather than the genuine development of mental skills. A meta-analysis of 36 studies undertaken by Hetland (2000a) confirmed the possibility of a moderate occurrence of the "Mozart Effect" and specified that only some cognitive skills improved, in particular spatial-temporal reasoning. Ivanow (2003) used music by Mozart and Bach and found that the impact was greater with Mozart. Overall, the findings where music is used either prior to or during undertaking academic work suggest that it is the impact of music on arousal and mood which mediates the outcomes.

The Boston Project took a different approach. Listening to music was still the main activity, but the music was played by a group of musicians, who also explained and discussed musical ideas with the children. The scheme was prepared with teachers. The cross-curricular links were very strong and the interaction with musicians helped the pupils. "Listening to music, with instructions about particular things to listen for, seems to help children from sound to sense. It helps develop their ability to think abstractly" (Perret and Fox, 2006, p.135). This development and others such as better concentration, motivation and more acute listening significantly improved pupils' attainment. Of course, it is possible that simply having more adults in the classroom made teaching and learning more effective, but the musical input cannot be dismissed.

There has also been research which has suggested that music has an influence on children's ability to memorise information. For instance, Wolfe and Hom (1993) used melodic phrases to help children (5-year-olds) to memorise telephone numbers. This strategy speeded up the learning. This way of using music to organize information has also been used in learning and recalling number concepts including multiplication tables with both melodic and rhythmic patterns used as prompts (Clauson and Thaut, 1997).

2.1.3 The influence of music training on spatial-temporal reasoning and other cognitive skills

Many studies have been designed to test the hypothesis that training in music improves spatial-temporal performance and other intellectual skills. Academics have theorized as to how such development occurs, what kind of music has the most pronounced results, what are the best conditions for it to occur and what is the durability of the enhanced performance. The next section addresses these issues.

AGE OF PARTICIPANTS

As studies on brain development in musicians suggest (Schlaug et al., 1995, Pantev et al., 1998), music training changes the organisation of the brain and affects neural structures. This research has also shown that the earlier the music training starts the greater the extent of change. Partly based on this, much research into the impact of music instruction on spatial-temporal reasoning has concentrated on young participants. For instance, Rauscher et al. (1993b; 1997) found a positive enhancement of spatial reasoning in children as young as 3-years-old. Other studies (Costa-Giomi 1999, 2000; Graziano et al. 1999; Gardiner et al. 1996; Rauscher and Zupan 2000; Rauscher 2002, Rauscher and La Mieux 2003; Schellenberg 2004) involved children of preschool or early primary school ages. Their findings suggest that the earlier the training started, the greater the increase in spatial abilities. This raises the question as to whether there is an age limit past which such relation will not take place. The oldest children to participate in such research were 9 years old (Costa-Giomi 1999; Graziano et al.1999). Their performance still improved after learning to play the piano or learning the keyboard compared with computer lessons. The results differed in Rauscher and Zupan's (2000) study, where the achievement of the children who started music instruction at the age of 7 was similar to control groups. In the same experiment, children who started training before 5 years of age scored significantly higher than other groups, similarly to Costa-Giomi (2000).

LENGTH OF PROGRAMMES AND SUSTAINABILITY OF ENHANCEMENT

The duration of programmes used in intervention studies has varied between six weeks and three years. Although it seems logical to assume that the longer the instruction the greater the impact, a meta-analysis by Hetland (2000b) suggested that interventions lasting only six weeks brought similar changes to those which lasted up to two years. Unfortunately, the frequency of music lessons and their length were not taken into account in this analysis although these might be contributing factors. The length and frequency of lessons might influence the extent of musical learning leading to differential improvement of other abilities. A further question is whether music enhances spatial-temporal reasoning in a continuous way. In her study, Costa-Giomi (1999) showed that in the third year of learning the piano, students from the intervention group scored the same as the control group despite having scored higher in the previous two years. This raises the issue of possible saturation in spatial-temporal reasoning development related to music training. It is also possible that in the third year the children were less dedicated in their learning of music, or perhaps as they approached preadolescence their hormone levels might have affected their performance. In contrast, a longitudinal study in two public elementary schools (Rauscher and Zupan, 2000) demonstrated that children who received four consecutive years of keyboard training continued to score higher than other groups throughout entire time. Overall, the findings from these studies are mixed and do not provide overwhelming evidence of the long-term effects of music on temporal-spatial reasoning or how long the period of training should be, although Rauscher (2002) suggests that at least two years of instruction are needed for sustained enhancement.

LESSON FORMAT

Despite the fact that there are different theoretical bases for why learning music enhances other cognitive abilities, all agree that the more successful the music training, the greater the improvement in other skills. This suggests that more efficient lesson formats should bring about stronger effects. According to Hetland (2000b) individual lessons lead to better spatial-temporal performance, with group instruction still having a moderate impact on such performance. More recent studies (Rauscher 2002, Rauscher and Le Mieux 2003, Schellenberg 2004) have found improvement in all cases of individual, small group and larger group lessons.

MUSICAL ACTIVITIES USED IN A PROGRAMME

A wide range of instruments, activities and notations have been used in interventions exploring the impact of music instruction on spatial-temporal reasoning. Keyboard/piano tuition has used the most frequently, also various tuned and untuned percussion instruments, through to singing. All of these methods have enhanced spatial-temporal abilities and sometimes other skills, for example mathematical skills. In those studies, which used keyboard and singing, greater changes occurred in the groups playing keyboards (Rauscher et al.1993b, Rauscher et al., 1997). Where rhythmic instruction was involved, the highest scores were recorded in those groups which included exercises with rhythm (Rauscher and Le Mieux 2003, Rauscher and Hinton 2004).

The use of traditional musical notation was considered in two meta-analytical approaches. Vaughn (2000) reported that enhancement in mathematical performance was as effective with reading notation as without. In Hetland's review (2000b), the use of music notation brought about greater improvement if combined with learning the piano. Using improvisation or composition in the programmes did not produce different results from programmes which did not include such activities.

THE RELATIONSHIP BETWEEN PARTICIPATION IN MUSIC AND THE DEVELOPMENT OF MATHEMATICAL AND OTHER COGNITIVE SKILLS

The majority of studies have concentrated on testing children's spatial-temporal skills. There is strong evidence that those skills can be improved by musical training. Interestingly, when other cognitive abilities have been tested, for instance, pictorial memory (Rauscher and Zupan 2000), spatial recognition (Rauscher 1994, 1997), and number recall (Rauscher and La Mieux, 2003) there has been no significant improvement.

Schellenberg (2004) used an IQ test and a standardized test of academic achievement to observe whether there were changes after a programme of musical activities. The findings showed a small increase in IQ in those groups who did keyboard or voice training (based on Kodaly method) compared to drama or control groups. The results in other subtests (including those testing mathematical skills) showed similar relationships apart from the changes in social behaviour which were present in drama group but not in any of the other groups.

Several studies have measured whether there was any impact on mathematics. Gardiner et al. (1996) provided some pupils with seven months of supplementary music and art lessons. Those children had higher scores in standardized mathematical tests than control groups. Unfortunately, all of the experimental groups did both music and arts so either of those disciplines might have been responsible for this result. Similar findings occurred in a study where children were divided into four groups: keyboard and spatial-temporal training on the computer, computer training with English instruction, computer training or no programme (Graziano et al. 1999). Again, the scores in mathematical reasoning of the children who participated in music were significantly higher but it was not possible to separate the impact of keyboard from the computer training. In a study by Rauscher and Zupan (2000) children who started keyboard lessons at the age of 3 scored higher on spatial-temporal and arithmetic tests throughout two years of training and even two years after the instruction was terminated. More recently (Rauscher and La Mieux 2003), children who received keyboard lessons, singing training or rhythmic instruction scored higher than controls in arithmetic tests, with the rhythm groups scoring higher on sequencing and arithmetic tasks.

A study by Neville and colleagues (2008) examined the differences in results between four groups of pre-schoolers who received music training; attention training; no training and general teaching delivered in a small group; and no training and general teaching in a large class. Music instruction was delivered daily and included listening to music, making music, moving to music and singing. The intervention lasted for eight weeks. Out of a variety of tests, a statistically significant change was recorded in numeracy and visual cognition for the music group and the attention group. Children from the music group performed especially well in verbal counting and estimating magnitudes.

Chinese elementary students who received long term music training were compared with a control group by Yang and colleagues (2014). The results showed that music instruction had impact on some rather than all mathematical skills. The authors suggested caution in interpreting whether learning music independently contributed to academic achievement or whether that also related to other variables, for example parents' education.

A study by Rauscher and Hinton (2011) in which children younger than 7 received music instruction led to conclusion that through such an intervention spatial-temporal skills and numerical skills improved more in children who participated in music training compared to the control group. This impact persisted for two years after the programme was ended. The children who in the intervention learned to play violin scored better than others on phonemic awareness tests which was related to better reading acquisition compared to other children who took part in the experiment.

In a correlational study, McDonel (2015) found strong correlations between musical aptitude, rhythm achievement and scores in numeracy tests. However, the sample size was very small so caution was needed in interpreting the findings.

Some studies have concentrated on the impact that learning music might have on the development of specific cognitive skills which are considered useful in acquiring mathematical understanding, for instance, notions of proportions, fractions and patterns. In an intervention in which preschool children learned to play the piano for six months, Graziano, Peterson and Shaw (1999) found that there was significant improvement in spatial-temporal skills in the children from the intervention group. The authors suggested that this had an impact on the learning of proportional mathematics and fractions as showed by the results in Math Video Game and Math Video Game Evaluation Programme where the children from the music group outperformed their control group peers. Also, Courey and colleagues (2012) examined how learning music developed children's understanding of fractions. Their programme for 8 and 9 years old pupils was delivered twice a week for a period of six weeks and involved analysing rhythms and music notation as a means of learning mathematical ratios and proportions. Children from the intervention group performed better than the control group in solving computational problems associated with fractions. Patterning skills were investigated in a study by Wade (2012) but the small sample size meant that the findings were inconclusive.

Although much of academic literature points to the positive impact of participating in musical activities on learning mathematics, there are also examples which have shown less strong or no relationships. Two experiments by Rickard et al. (2012) revealed inconclusive results. The first was based on a music programme already existing in a school and involved students aged 10 to 13. Out of drama, art and music groups, there was some improvement within the music group in a non-verbal IQ test but not in academic achievement. The second intervention was provided externally over six months and included playing music with percussion instruments, composing, improvising, playing in a group, singing, active listening and analysis of a wide range of styles. As the programme was introduced in a private school, all of the students were of a middle or high economic status. Three groups took part in the intervention: music, drama and additional activity. Students from the music group achieved better results in mathematics but this effect was also observed in the drama group. The age of the children may also have been a factor in the outcomes of this research. A similar study by Costa-Giomi (2004) with children aged 9 – 10 from low income families involved three years of weekly individual piano lessons. All the children who participated in the study were also given a free instrument to practice at home. Self-esteem and musical understanding were greater for the music group but their academic achievement in mathematics and English as measured by standardized tests was no different from the control group.

2.2 Participation in music and the brain

2.2.1 Introduction

Processing music, as is the case for many other conscious cognitive processes is spread over many areas of the brain within both hemispheres and takes place through synaptic connections within the brain. The cortex contains billions of neurons interconnected into a system of neural networks which form a pattern of connections. Each unit contains neurons linked together through synapses. These are not parts of neurons but spaces between neurons which are necessary for neurotransmitters carrying chemical or electrical message to travel from one neuron to another. Each neuron can be connected with as many as 10.000 cells and different cognitive processes activate different parts of this network. Each neuron can also belong to several neural groups at the same time. The activity of neurons synchronically firing is responsible for forming mental representations and other cognitive processes. This wiring of the brain is a combination of genetic determinants and environmental conditions. Heredity is responsible for about 40 percent of short-term and 70 percent of long-term connections (Flohr, et al., 2000). This suggests that a large proportion of neural networks are shaped by environmental influences. This model of brain responses to learning applies to learning in music. As Gruhn and Rauscher (2000) argue: "If neural networks function as the neural correlate for musical representations, then learning must be related to physiological conditions in the brain, this is, to the activity of neurons, to the connectivity among neurons, cell assemblies, and brain areas, and to the neuronal plasticity of the brain – especially the establishment, growth, and progressive differentiation of genuine musical representations with respect to their strength, localization, and extension in both hemispheres." (p.447)

2.2.2 Modular and unitary theories of mind

There are two main groups of theories explaining how the brain works. The modular approach suggests that different processing is carried out by distinct brain structures and each module is dedicated to particular kinds of information or function (Gardner, 1993). These modules are distributed throughout various parts of the brain. From the modular perspective, learning is based on comparing new data with the existing storage of knowledge which might involve the content of the new information or the familiarity of its language. A gap between pre-existing knowledge and the input is noticed and that leads to adjustment in neural networks to accommodate the new information. This adjustment might take the form of enhancement within the network or of forming new connections between networks. Connectionism theorises that the brain functions as a whole and that different areas of the brain might be used for a variety of cognitive tasks (Fiske, 1996). In connectionism learning is explained as constant matching of new input to old information and adjusting our storage of knowledge to the new information which then affects our future potential outputs.

It is possible that both these theories are relevant. They are not mutually exclusive. Newer perspectives suggest the existence of specialised submodules which work in connected networks. Their coordinated activity might be led by supermodules (Flohr and Hodges, 2002). That proposition is similar to the trion idea by offered by Shaw (2000) in which the brain is constructed out of cortical columns made of minicolumns referred to as trions. This model of the cerebral cortex was developed by Shaw to provide the neuroscientific context for the relationship between music and spatial cognition. According to the model, the trion is a unit of neural activity which has three levels of firing. A cluster of trions can make a firing pattern and the variety of spatial-temporal firing patterns between trions results in higher brain functions. Specific brain functions depend on firing in specific brain areas but it is also possible that many other areas are involved in each cognitive function.

Conceptually the idea of the enhancement of other cognitive skills through musical training can be placed in either modular or connectionism theories. Assuming that the brain works as a conglomerate of modules operating within their specific functions, near or far transfer of skills offers one way of explaining such impact. Following the idea of the brain working as a whole with sets of connections and networks, musical training increases the number of connections which then can be used in other cognitive activities. The following sections will consider further both, modular and unitary theories and their attempts to explain the relationship between learning music and learning mathematics.

2.2.3 Modularism and transfer

One of the possible explanations of the relationship between music and other intellectual skills on a cognitive level set within the modular concept of the brain is the theory of transfer. The definition offered by Rauscher (2011) states that transfer: “occurs when a person applies knowledge or skills that have been learned in one context to new contexts." (p.249) Such a form of learning is generally seen as dependent on similarity between the applied skills or on an overlap between the areas in which transfer is to occur. Most definitions mention two components of transfer: tasks (what is to be transferred) and context (how is the skill used) (Jellison, 2006). Lehmann and Davidson (2002) suggested that the transfer of skills depends on the domain-specificity of skills. According to Gardiner (2000) transfer is based on developing and exploiting similarities for processing across domains. Also, transfer may vary at different levels of the skill. Salomon and Perkins (1989) have also considered the: “amount and distance of transfer. Transfer from A to B involves more distance to the extent that B is more remote or novel with respect to A. Transfer from A to B involves greater amount of transfer to the extent that the A learning makes a bigger difference to B performance.” (p.116-7)

In view of that, psychologists have described two kinds of transfer, near and far transfer. Near transfer occurs when the skill or knowledge is applied to a very similar task or situation, or the skills used are of a similar nature. Far transfer requires greater adjustment of knowledge or skills to use it in a less analogous circumstance. Although the condition that learning must appear in the primary domain so transfer can occur to other disciplines might seem obvious, the level of that learning might play an important role in how the learned skill might be applied in another domain. Salmon and Perkins (1989) offered a concept of high-road and low-road transfer in which high-road transfer relies on the learners’ deliberate and mindful abstraction of a concept in contrast to relatively spontaneous low-road transfer. “The low-road mechanism involves the spontaneous, automatic transfer of highly practiced skills, with little need for reflective thinking. [...] The high-road mechanism involves the explicit conscious formulation of abstraction in one situation that allows making a connection to another.” (p.118) In low-road transfer “a cognitive element is learned and practiced in a variety of contexts until it becomes quite automatic and somewhat flexible because of the variety. On a later occasion in another context, the stimulus characteristics sufficiently resemble those of one of the earlier picture contexts to trigger automatically the element. The next context also resembles the earlier ones sufficiently so that the somewhat flexible element suits the new context. [...] The key aspects of this process of low-road transfer are varied practice and practice to automaticity.” (p.120)

For centuries, music has been perceived as an area of knowledge and skills which develops a variety of abilities which might be used in different contexts. Abeles et al. (2002) talked about general transfer where music training promotes a variety of outcomes. They can be viewed in three categories: cognitive, socio-cultural and personal learning. Many of these abilities like: making connections, constructing and organising of meaning, confidence, and task persistence can be used in more general fields. Another possibility suggests that transfer might depend on belonging to a specific musical culture or tradition. There is an agreement that musical skills are rather specific and most of them require their own specialised training. The same can be said about the skills acquired in music training in distinctive musical traditions. It is possible that some elements of transfer might occur between similar skills or similar traditions (Lehmann and Davidson, 2002).

Some psychologists link transfer with the proportion of cognitive elements shared in areas or tasks. This is how Abeles et al. explain specific transfer – "a person trained in a task is more likely to be successful in a second task if two activities share very similar or common elements." (p. 933). That concept is very difficult to demonstrate especially in domains which use complex cognitive skills, like music. It is possible to theorise that there are many similarities between cognition in music and mathematics but specifying the shared elements is far more challenging if one also considers the possibility of occurrence of near and far transfer. The way we recognize rhythm might be based on understanding of a part-whole concept with ongoing division or multiplication of the beat. That may require similar cognitive skills as the ability to calculate proportions, fractions and percentages in mathematics. In the study by Rauscher (2003) children who received rhythmic instruction outperformed their peers, who had piano or singing lessons, in mathematical tasks involving part-whole calculations. It is possible that rhythm perception is more spontaneous than continuous calculation, especially in situations when the notation is not present. It may be that this calculation becomes automatic with training and through that intensifies the transfer. Perhaps the ability to interpret rhythmic notation is one of the shared elements in such transfer.

In her meta-analysis, Hetland (2000b) stated that reading music notation is not related to the enhancement of spatial-temporal skills unless it is combined with playing the piano. However, reading music notation is not quite the same as reading rhythmic notation. Mills and McPherson (2006) described differences between these two competencies in more and less experienced musicians: "the mechanics of reading notation involve the co-ordination of a number of different skills. Highly developed readers of notation display an ability to link the sound with the notation [...]. Young instrumentalists however, may have more trouble with reading rhythm than pitch, because pitch production with many instruments is possible without internalization of pitch, while rhythm production is difficult without auditory coding" (p.160). Additional complexity related to this discussion is created by the fact that reading instrumental music differs from reading music for singing. When a child sight-reads a vocal piece, they have to audiate both pitch and rhythm. Gordon (1993) explained audiation as a process combining perception and internal hearing which: "takes place when we hear and comprehend music for which the sound in no longer or may never have been physically present." (p.13) While sight-reading an instrumental piece, the player may not need to audiate pitch because the instrument is a mediator of pitch, although this varies enormously depending on the instrument being played. For many stringed instruments audiation is crucial. However, whatever the instrument the player still has to inwardly hear the rhythmic pattern to be able perform it (Mills and McPherson, 2006). Schlaug (2002) linked reading music with specific mathematical skills: "Mathematical skills may well be enhanced by music learning because understanding rhythmic notation actually requires math-specific skills, such as pattern recognition and an understanding of proportion, ratio, fractions, and subdivisions" (p.226). With such a wide range of skills required to read music and different conditions responsible for specific situations, the potential cognitive overlap with mathematics is rather difficult to reject but attempts to understand the mechanisms behind it remain challenging.

Additionally, important implications for that discussion derive from the dichotomy between rhythm and metre perception. As Jordan-DeCarbo (2002) describes: "Rhythmic organisation is based on a developing understanding of two interrelated aspects of temporal sound phenomena – the rhythmic figure and meter. The figure is perceived as a cluster of sounds (five or less); the meter is an organisation that underlies the surface or figural events" (p.222). That suggests possible differences in processing rhythm and meter by the brain. According to Jones (2011), "rhythm perception is innate, based upon an automatic, primitive, universal process that is governed by hard-wired, domain-free grouping principles" (p. 87). Perception of meter is more flexible, susceptible to training and as a skill it is viewed as domain-specific. This approach is supported by Trehub (2006) who suggested that children, unlike adults, are very flexible in their meter perception which questions the previously accepted idea of the inherent character of that skill. The view of rhythm perception being inborn might indicate that whatever connection with spatial-temporal and possibly mathematical skills is, it is already set within the brain and is not responsive to instruction. However, if meter perception with its plasticity in relation to musical exposure and its openness to training, was related to spatial-temporal abilities, it might play a role in the potential enhancement of attainment in mathematics.

Following the suggestion of transfer occurring more readily in situations where the domains in which transfer occurs share cognitive elements many authors point to a wide range of abilities which might be shared between music and mathematics. Schellenberg (2003) considered the temporal character of processing music of particular importance and mentioned the ability to deal with constantly changing information and segregating parts of a stream of information. Norton et al. (2005) discussed learning structures and rules, spectral and temporal discriminations. Rauscher (2011) adopts a different perspective: "both music and mathematics employ and manipulate symbols, they both investigate and develop patterns [...], and they are both abstract constructions." (p.250) The notion of representation in music is described by Gruhn (1997): "the sound of music is never represented fully by a picture or theoretical terms, rather it is processed and mentally stored as the soundstructure itself" (p.37). This points to additional similarities with mathematics. Also, Gardiner (2000) suggested that mathematics and music may require similar, mutually supportive representations. He considered that this transfer might be brought about through changes of specific representations which lead to unification and make it possible for these to be used in different domains. In their study, Hannon and Trainor (2008) concluded that music training develops some domain-specific processes like frequency-coding mechanisms and multisensory timing connections which create their own systems of structures and representations which then can be used in other cognitive areas like mathematics. These statements are supportive in demonstrating the relationship between cognition in music and mathematics but neither of these complex domains is understood well enough to comprehensively compare the cognitive elements which might be shared between them.

Although the concept of transfer is widely accepted in psychology, there are some difficulties with explaining transfer (Gardiner, 2000). The first relates to what can be transferred and how similar the skills have to be to be applicable in other contexts. The second suggests that if transfer is a dialogue within the brain, it may work in both directions which would pose the challenge of how to frame consideration of the possible both sidedness of learning. The final question relates to how skills and information might be stored in the brain and whether transfer requires that some form of representing information is moved from one place in the brain into another place. With these deliberations in mind, Gardiner offered the alternative concept of mental stretching. He defined this as a process in which one can change to a new way of representing and thinking about information. Mental stretching is based on the detection of similarity between things, the possibility that thinking within different contexts might be similar, and the development of thinking through learning in one domain which can help to adapt analogous thinking in another area. The challenges discussed by Gardiner do not however interfere with the idea of transfer so strongly as to rule it out and the proposed approach offers a slightly different explanation of how the process occurs whilst supporting the existence of the process itself. As the current state of knowledge in cognitive neuroscience cannot confirm either theory, further studies are needed to explain the mechanism of transfer and to affirm either modular or unitary models of learning.

2.2.4 Connectionism and changes in the brain after musical training

The idea of connectionism is based on the concept of plasticity which is a form of adaptation of a sensory or motor system to environmental stimuli. In terms of brain plasticity, Peretz and Zatorre (2009) suggested that: “properties of nervous system neurons as well as the neural circuitry are malleable” (p.367). Hodges (2006) linked cognition and learning with plasticity: “brain structures are not rigidly defined, rather they are malleable. Brain structures can change over time as a result of learning experiences” (p.54). That ability of the brain might be one of the possible explanations for music instruction having an impact on a variety of cognitive abilities, including spatial-temporal reasoning and mathematics. Besler (2002) stated: “that there is a relationship between the development of specific brain areas and musical activity had been demonstrated in various studies.” (p.1071). This section will consider the implications that learning and practising music has on brain.

Many research projects have explored the relationship between participation in music and changes in neurochemistry and the neuroanatomy of the brain (Schlaug, 2011). Hodges (2006) suggests that: “Although genetic influences are important, there are also indications that musical training changes the brain and that the earlier the musical instruction begins, the greater the changes. These changes can be seen in structure (i.e. morphological or anatomical changes) and in function (i.e. brain activations in terms of cerebral blood flow, electrophysiological responses, etc.)” (p.61). Many researchers have investigated structural changes in the brains of adult musicians (Sergent, 1993; Schlaug et al., 1995; Pantev et al., 1998; Schlaug, 2001; Sluming et al., 2002; Hutchinson et al., 2003; Gaser and Schlaug, 2003; Sluming et al., 2007; Stewart, 2008; Tervaniemi, 2009; Hyde et al., 2009; Paulson et al., 2013). These changes have been observed in different areas of the brain confirming that processing music occurs in a variety of networks throughout the brain rather than in specific music centres.

There are also a wide range of conditions which influence the changes. These can be grouped into: the kind of musical activity, instruments played (string and wind instruments which predominantly use a singular melodic line, versus keyboard with a range of notes played at the same time, versus singing), the level of musical expertise, the length of time of involvement in music, and the age at the beginning of music training. Also, an ability to read music notation may play a role as observed by Stewart et al. (2003). Hodges (2006) reported that listening to music or playing instruments resulted in significant positive changes in electrical brain activity. There is also a positive correlation between years of playing and density of gray matter in musicians, especially within the Broca’s area of the brain (Sluming et al., 2002; Sluming et al., 2007). Training in music increases connectivity (Rauscher and Gruhn, 2007). Music instruction may be one of the ways of stimulating more efficient synaptic connections. Patston et al. (2006) adopted this approach and implied that musical training has an impact on musicians developing the left hemisphere to perform cognitive activities usually performed by the right hemisphere. That also corresponds with the notion that learning music enhances not only auditory, but perceptual and cognitive skills. Some functional differences might have been related to how well the task was learned and whether it had become automatic. A study by Jancke et al. (2000) compared a tapping task performed by pianists and non-musicians. In professional pianists both the primary and secondary motor cortex was activated less than controls. This suggests that once the task had been learned, and perhaps habituated (e.g., scales), performing it reached greater efficiency and a smaller number of active neurons was required.

Many studies into the brains of adult musicians and non-musicians have shown that in many areas of the brain those of the musicians are different from non-musicians and these differences are of both structural and functional character. These findings however are correlational and do not determine a causal relationship between musical instruction and changes in the brain. It is possible that these differences were present prior to training in music and were instrumental in the individual choosing that kind of training in the first place or in exposing a musical orientated range of skills, interests or abilities. To ascertain a causal relationship between musical training and changes in the brain it is necessary to undertake a comparison before the start of training and at some point throughout the instruction both of which should be compared with control groups.

Several studies have examined changes in the brain whilst learning music. A study of the developing brains of children undertaking lessons of music was proposed by Hyde and her colleagues (2009). Their research described structural brain changes in six-year-old children after 15 months of music training when compared to controls. The experimental group received 30 minutes of individual keyboard lessons while the controls took part in music classes in school which consisted of weekly 40-minute group lessons during which the children played with drums and bells and sang. Brain changes in the experimental group were consistent with those differences found between adult musicians and non-musicians. These children also showed some enhancement in motor abilities and auditory melodic and rhythmic discrimination. They did not however show greater change than the controls in visual-spatial skills. This suggests that the predominantly rhythmical instruction received in music classes by the control group might have enhanced their spatial skills so that they were comparable to those of the instrumental group. The authors unfortunately only reported the differences between groups, not the progression in each skill over time but it is safe to assume that both kinds of music instruction had similar effects on the visual-spatial skills of the children.

Schlaug et al. (2005) undertook a study of five to seven-year-old children who were given 14 months of musical training and found some brain effects following instrumental music training. The impact was small, mainly in fine motor and melodic discrimination which are both closely related to training. Follow up research with older children aged between nine and eleven who had instrumental training for four years, showed stronger effects within the close motor and auditory domains and also some additional transfer effects. However, it is important to note that the findings had a correlational rather than causal character. The influence of age differences was also observed by Trehub (2006): “The available evidence is consistent with greater flexibility on younger than in older brains. For example, children show similar patterns of brain activation when they are engaged in melodic and rhythmic processing, in contrast to adults, who show right hemisphere dominance for melodic processing and left hemisphere dominance for rhythmic processing" (p.37).

A study with preschool children by Flohr, Miller and deBeus (2000) in which the children received ten weeks of music instruction looked at differences in EEG measures when listening to music and when performing a visual-spatial task between a group with music training and a control group. The brains of the musically trained children, showed different activation patterns in the same areas which are believed to be related to spatial-temporal reasoning. These activation patterns when listening to music were similar to those of adults who had had musical training. The researchers also observed lesser activity in both, left and right temporal lobes. With training, the brain adapts to different cognitive functions and performing them requires less effort. It has been suggested that the observed decrease is correlated with brain efficiency and that it is possible that such brain activity associated with music training helps in other cognitive tasks. Additionally, when resting or listening to music, the brains of musically trained participants have shown increased connectivity between different brain locations compared to the control group. Considering visual-spatial tasks, it is important to note that although there were differences in EEG between the two groups, the scores on the tests were very similar. That may suggest that in this case musical training did not improve the results on the spatial task but the cognitive processes used in solving it were more efficient. Unfortunately, as the study did not measure the time that the children took to solve the task, it is impossible to say whether brain efficiency determined how quickly the task was completed.

2.2.5 Spatial-temporal reasoning and music

Spatial-temporal reasoning abilities are of particular interest in this study as they may provide a bridge between learning music and mathematics. The concept of spatial-temporal reasoning was coined by Shaw, Rauscher and colleagues as an outcome of observing how participation in music impacted differently on different spatial skills (Rauscher et al., 1993b, Rauscher et al, 1994). Using a battery of spatial tests which measured a variety of spatial abilities, they found out that the scores on one of the tasks improve significantly after music instruction, while the results on other tests remained at a similar level to prior to intervention. The task - Object Assembly - asked the children to arrange pieces of a puzzle to form a meaningful whole without showing them what the finished picture was to look like. The researchers suggested that what differed this task from the others was that the pieces needed to be put together in a particular order to accomplish the final picture while the sequential order in other tasks was not relevant (Rauscher et al., 1997). This temporality added an additional dimension to the otherwise spatial task, hence the researchers renamed this particular skill as spatial-temporal reasoning. Because of the specific context where this phenomenon was observed, the literature which describes and defines it is limited. The references presented here are the only ones which are relevant.

Rauscher et al. (1997) defined spatial - temporal reasoning as “the ability to transform mental images in the absence of a physical model” (p. 2). Grandin, Peterson and Shaw (1998) described the key features used in spatial-temporal reasoning as the transforming and relating of mental images in space and time, the use of symmetries to compare physical and mental images, and temporal sequencing. A spatial-temporal task usually contains a whole segmented into random pieces. To solve the puzzle, it is necessary to formulate a mental image and put the pieces together in a sequential order. These elements are very similar to what Clarke and Krumhansl (1990) described as the necessary steps in perceiving a musical piece where the segmentation of a whole piece of music, finding the relationships between the pieces in a sequential order, and creating a mental plan of the pieces facilitates patterns of organisation of the whole piece. Cooper (2000) viewed spatial - temporal reasoning as an abstract model of cognition and proposed a more detailed description of elements that constitute this concept: pattern seeking, recognition, retention, and recall; visualizing imagery; perceiving figures as wholes; generating a whole image from a fragment; grasping the whole of a problem; understanding spatial relationships from multiperspectives and among internal movement of parts; maintaining orientation within space; and mentally manipulating shapes within two- or three-dimensional space.

In view of these interpretations spatial - temporal reasoning can be conceptualised as mentally imagining and manipulating shapes and structures, often without the presence of physical objects, while following a particular order of operations. Overall, spatial - temporal reasoning allows individuals to visualize problems and potential solutions. Through mental imagery, the individual develops and evaluates patterns which can change in space and time. All of the approaches described above point to spatial imagery together with temporal, sequential ordering as the cognitive elements which define spatial – temporal reasoning as opposed to spatial recognition. These skills are considered to be high level mathematical abilities useful for example in learning proportional reasoning (Rauscher et al. 1997; Grandin et al., 1998; Shaw, 2000). Tran et al. (2012) argued that spatial-temporal skills induce advanced understanding of mathematical concepts such as fractions, proportions, symmetry, and other arithmetic operations. The current research set out to further examine the impact of active engagement with music on spatial - temporal cognition and investigate its connection with the learning of mathematics.

Similar to the different theoretical models of the brain and theories of learning mentioned previously, justification for the relationship between music and spatial-temporal reasoning follows the dichotomy between connectionism and modular theory: the neural connections as described by Sporns (2011), and the near transfer as outlined by Jordan-DeCarbo and Nelson (2002). Connectivity is supported by Shaw (2000), who implied that musical and spatial processing overlap in the brain and as a result of this connections in the cortex, the development of certain kinds of musical and spatial, especially spatial-temporal abilities, is intertwined. Near transfer "proposes that several kinds of thinking are required to learn and make music. Because music-making and spatial abilities are both multidimensional processes, it is logical that a range of spatial skills might be improved because of the practice required in the music-making process" (p.219) (Jordan-DeCarbo and Nelson, 2002).

Hetland (2000b) in her meta-analysis of 67 published and unpublished studies which involved over 4,500 participants confirmed the presence of a phenomenon similar to the so called Mozart effect on a specific type of spatial skill which involved mental rotation in the absence of a physical model. This finding was academically robust and had a moderate effect. Another meta-analysis of 15 studies (Hetland, 2000a) looked at the relationship between spatial-temporal reasoning and participation in making music. The author reported that there was a moderate effect and that active music learning supported the enhancement of spatial-temporal abilities. However, these results should be treated with caution as there are still many questions about the mechanisms behind the relationship, the properties of music which enhance spatial tasks, whether these effects are long-lasting and how this knowledge might be used in education. There are suggestions that "complex" music or music possessing symmetry might activate the right hemisphere and through that enhance spatial tasks. How that might work has not been explicitly specified. Relating to the type of musical activity which may enhance spatial-temporal skills, it has been suggested that the enhancement is related to rhythmic elements.

Enhanced spatial-temporal skills have been found in adult musicians. In a study by Pietsch (2012) students who undertook additional training in sports or music demonstrated a better performance on mental rotation tasks when compared to students of education science who did not have that kind of training. Research examining performance on a three-dimensional mental rotation task of professional musicians and non-musicians (Sluming et al, 2007) found that members of orchestras outperformed controls in such tasks. The authors linked this with more pronounced development of Broca's area in the brains of musicians. These findings are supported by Mark (2002) who suggested that according to brain imaging studies, the areas of the brain which are activated whilst performing music and spatial-temporal tasks are proximate. In another study by Sluming (2002), musicians performed better than controls in tasks involving spatial skills, confirmed by better results on a line orientation test. Similarly, Patston (2006) found that musicians managed to find the middle of a horizontal line more easily than controls. These last two findings might be particularly important in linking music with mathematics as the ability to visualise a horizontal line and localize a middle and proportional distance on it is closely related to the notion of the mental line used for a variety of mathematical operations as described later (Gunderson, 2012).

2.3 Maths Cognition and Spatial Abilities

2.3.1 Introduction

As presented in the previous chapter, there is strong evidence that participation in music improves the development of spatial abilities, especially in young children. The research reported in this thesis tries to build further on those foundations and establish whether participation in music and the impact it has on refining spatial skills might have an impact on learning mathematics. Although spatial skills seem related to mathematical abilities and Shaw (2000) categorised spatial-temporal reasoning as a high level mathematical skill, this connection is less straightforward than often assumed. Spatial-temporal reasoning not only contributes to different areas of learning mathematics but also changes with the age of the pupil and their mathematical competency. The following sections investigate those relationships and explore how the development of spatial abilities might influence number sense and other early mathematical skills.

2.3.2 Preschool mathematics

The learning of arithmetic begins much before formal mathematics education in school. Some number processing is present even prior to the development of speech and language. Preschool children present an understanding of estimation and comparison of quantities often before they can count or use number words. They have sense of ordinality (Kaufmann, 2008) and they use and develop strategies and procedures in solving problems (Bisanz et al., 2005, Van Nes, 2009). Even very young children are capable of discriminating between small sets of items which contain different numbers of objects. Sensitivity to increasing quantity by adding objects and decreasing it by removing items, in children, depends on observing ordinal relations among numbers (Bisanz et al., 2005). This skill, related to addition develops earlier than subtraction, and both are present in children older than 3 years old. From that approximation, children develop greater accuracy up to the point when they are able to provide exact solutions to arithmetic problems. That happens usually by the age of 4 or 5 years old. “At the same time children develop rules and concepts, at lease in prototypic form, that inform and constrain their growing ability to manipulate numbers arithmetically.” (Bisanz et al., 2005, p.159).

These developmental changes have been the subject of many recent studies and a model of acquisition of mathematical skills and their relationships with other cognitive abilities has been proposed by Krajewski and Schneider (2009). This model assumes three main phrases in the development of competency in mathematics. They are:

1. *Basic numerical skills*, in which two separate ways of acquiring mathematical knowledge are apparent – an inborn ability to discriminate numbers present in children as young as 9-months-old and verbal learning of number words and their correct sequences. Particularly within the second skill the main determinant of progress is verbal abilities, including phonological awareness.
2. *Quantity – number concept* which makes children realise that quantities and counting words are related and that counting words have a quantitative meaning. That is later translated into gaining the first idea of cardinality, although that is imprecise to start with. Firstly, children learn to distinguish between number words that belong to different categories like unitary numbers versus tens or hundreds. The perceived difference is quite inaccurate (a bit, much more, etc.). Later, with growing understanding of the exact meaning of number words, children become able to discriminate much more closely with relationships between quantities being more precise. This phrase is far less reliant on verbal abilities, whilst visual - spatial skills play an important role.
3. *Number relationships* with growing precision in understanding quantities. Children gain the ability to compose and decompose quantities (for example that number 9 might be considered as 4 and 5 or 2 and 7). They also learn that differences between two quantities can be measured by a third quantity which enables them to ascertain relationships between numbers more precisely. Also at this level, children's visual – spatial skills play a vital role and non-verbal representations of magnitudes are essential to solve such problems (Rasmussen and Bisanz, 2005).

This model confirms a strong relationship between children's spatial skills (Cheng and Mix, 2014), the visual – spatial components of working memory and the development of mathematical abilities.

A different, broader model was proposed by Spelke (2008). This sets out three main systems which support young children's learning in mathematics and science. These are:

1. *System for representing small exact numbers of objects (up to 3)* – children use it in learning the meaning of number words and verbal counting. This system is also used in learning about the mechanical properties of objects.
2. *System for representing large approximate numerical magnitudes (for example about 20)* – children use it in learning symbolic arithmetic and logical properties of arithmetic.
3. *System for representing geometric properties and relationships* – children use it for example to make sense of symbolic maps.

All three of these systems are malleable and relatively independent in young children. Later on, as children develop the basic concepts and operations of mathematics they learn to connect these different systems which enables them to further develop their understanding. Pairing representations of small, exact numbers with large approximations allows the building of further number concepts. Linking representations of numbers with representations of space helps in creating mental number lines which are central to understanding relationships between numbers and calculations. Relating representations of objects and representations in space is involved in recognising geometrical relationships among a set of objects and develops further understanding of maps.

A study by Spelke (2008) compared performance in tasks measuring performance in all these systems by students aged 5 – 17 with no music training, with sports training, with training in other art forms and with music training which was considered on three levels of intensity: moderate, intense and highly intense. The first experiment on children who had low levels of music training did not show that such instruction specifically enhanced any core mathematical skills. The second experiment included students with mixed levels of music training. The children with intense music instruction outperformed the others in all tests related to spatial awareness. In the third experiment, students with extensive music training again achieved higher scores in tests of sensitivity to geometry, including the task which assessed children's ability to relate numerical and spatial magnitudes and involved operations on a mental number line.

Further individual differences in learning mathematics have been associated by Geary (1994) with three groups of factors:

- number sense and understanding mathematical operations,
- ability to choose and use strategies in problem solving, and
- working memory.

Later studies have confirmed the importance of these factors. The following sections examine the connections between spatial reasoning and each of these areas.

2.3.3 Number Sense and Mental Number Line

NUMBER SENSE IN MATHEMATICAL DEVELOPMENT

Number sense is one of the earliest mathematical skills and has been defined in many ways. It is the ability which allows us to process numbers including determining quantity, comparing quantities, conducting numerical operations and developing and using a variety of strategies in order to solve mathematical problems (Van Nes and De Lange, 2007). It enables children as young as 3 years old to quickly recognize quantities up to 3 without counting (subitizing), to use one-to-one correspondence which is responsible for counting each object only once, to use count words in the same order across different sets (stable order), to compare small physical and numerical quantities, to be aware that whilst counting the last count indicates how many items are in a set (cardinality) and to transform small sets by adding or taking away (Jordan et al., 2008). There are significant individual differences in children's number sense and knowledge of verbal and numerical number systems which often are associated with their learning abilities and experience. Whilst the first is mostly neurologically determined, children's experience might be expanded through games and number activities in early childhood. Unfortunately, this is often in parallel with social status and parents' awareness of the necessity of such development. As a strong predictor of achievement in mathematics in primary school, the importance of number sense is emphasized by many authors (Geary, 1994; Jordan et al., 2008; Geist et al., 2013; Booth and Siegler, 2008). The differences in children's initial mathematical knowledge might have large and long-term consequences as they predict achievement in mathematics in the later stages of education (Ramani and Siegler, 2008).

Jordan et al. (2008) named the following components of number sense: counting, number knowledge and number operations. Whilst developing *counting* skills, children memorise the sequence of counting words and use that in counting physical objects. Later they learn to count objects in any direction, even if the sets contain of a variety of objects. As they progress in doing that they also start to remember some number facts which will be useful in their further mathematical operations. *Number knowledge* starts developing very early and even before children can count, they are able to compare small quantities, although this is based on visual approximation rather than counting (at least in the early stages). The understanding of magnitudes, numbers and their order results in the formation of a mental number line which is essential to later mathematical development with the accuracy of children's estimates on number line being a strong predictor of achievement in general mathematics (Jordan et al., 2008; Gunderson, 2012).

Some researchers have suggested that comparing quantities and counting appear in young children as two separate abilities (Griffin, 2004) neither of which show thorough understanding of quantities or numbers, both relying on using physical objects. At the age of four children still cannot integrate these two skills and only around the age of five or six do they develop a single concept in which the quantity and the number become connected and might be understood without the involvement of physical counters. It is only with experience that children learn to understand the meaning of numbers as representations of quantities which enables them to combine counting and number knowledge into one structure. The forming of this structure is the foundation of further mathematical development (Van Nes and De Lange, 2007). Within *number operations*, children learn first how to solve nonverbal tasks which already require the use of mental representations. The ability to create and use mental representations of numbers and number operations is important in solving mathematical problems (Geary 1994). Later on, children gain the ability to understand mathematical semiotics like words, terms and signs and to apply this knowledge in calculating verbal problems (Bisanz et al., 2005).

MENTAL NUMBER LINE AND ITS RELATIONSHIP WITH SPATIAL SKILLS AND ACHIEVEMENT IN MATHEMATICS

As mentioned earlier, preschool children learn to count in a rota memorization process whilst the ability to compare quantities is based on visual rather than mathematical judgement. To be able to recognize these two schemes as part of the same operation and to use this concept in further learning, children have to be able to create mental representations of magnitudes. In doing so they use a variety of spatial associations and learn to organize quantities into spatial structures. These mental representations are a platform for children to gain understanding of the meaning of numbers and quantities. In such mental models children create an internal representation of physical objects and manipulate it to achieve a solution to the problem (Bisanz et al, 2005). People use a variety of ways to represent numerical magnitudes. The most often used are logarithmic and linear representations.

At first the representations of numerical magnitudes are ordered in a proportional or logarithmic pattern, where smaller numbers are easier to distinguish than bigger numbers, which later, with growing mathematical knowledge and experience, evolve into a linear construct, mental number line (Siegler and Booth, 2005). In logarithmic ruler representation, the subjective magnitude is a logarithmic function of the objective quantity, whilst in linear representation the subjective magnitude is a linear function of the objective quantity (Ramani and Siegler, 2008). In Western cultures, both of those have a left-right orientation with the left side associated with smaller or odd numbers and the right side with bigger or even numbers (Fias and Fisher, 2005) which might be determined by reading from left to right. Butterworth and Varma (2013) argue: "We also think of numbers in a spatial way. This is partly because we see numbers spatially arrayed in everyday life [...] There is even an unconscious association between small numbers and the left of space, and large numbers and the right side" (p.212). This phenomenon was first examined by Dehaene (1997) in several studies in which participants were asked to respond to numbers with right and left keys. With the speed of reaction measured, the respondents used left keys consistently faster whilst small numbers were displayed and right keys when the numbers became larger. This association became known as the SNARC effect - Spatial – Numerical Association of Response Codes. Butterworth and Varma (2013) further investigated the relationship between number and spatial skills and suggested that the areas in the parietal cortex which are involved in the SNARC effect are not only also involved in number processing but also in spatial cognition.

The age when children start using linear representations over logarithmic ones for numbers 0-100 is usually between kindergarten and second grade (6 – 8 years old) and for numbers 0-1000 between second and fourth grade (8 – 10 years old) with some adults even retreating back to logarithmic lines in unfamiliar arithmetic problems (Booth and Siegler, 2008). Ramani and Siegler suggested that: "Increasing reliance on linear representations of numbers seems to play a central role in the development of numerical knowledge." (p.376) Many researchers have found that there is a relation between constructing spatial representations and mathematical performance and this can be developed in a range of ways in preschool and early school years leading to better arithmetic learning (Gunderson et al., 2012; Ramani and Siegler, 2008; Booth and Siegler, 2008; Van Nes and Doorman, 2011). The fluency of using mental representations can be developed through exposition to activities which involve spatial reasoning, for example the use of linear numerical board games, rulers, graphs and number lines. Booth and Siegler (2008, p.1029) proposed that "accurate pictorial representations, such as diagrams and graphs, may be particularly useful for promoting mathematical learning. Like manipulatives, they provide a visual representation of the meaning of mathematical operations. Unlike manipulatives, they are not tempting objects for play and other activities that may interfere with their connection to mathematical operations. [...] accurate representations of numerical magnitude promote arithmetic learning, [...] providing pictorial information that illustrates mathematical relations in a transparent way can improve math learning as early as first grade."

Ramani and Sieger (2008) further developed these ideas and found that children from low-income families performed similarly to their peers on nonverbal tasks, whilst in problems involving verbal or written numerals their results were much lower. This suggested that their natural ability to perform mathematical operations on physical objects was the same for both groups, but further development of numerical knowledge and understanding the relation between quantities and numbers was less in children from low-income families. They proposed that this might be related to the amount of time which children spend on playing games involving counting. The results of two experiments showed that although playing games improved children mathematical skills, the outcome depended on the kind of game the children played. The only games which had such impact used boards with numbers arranged in a linear pattern. Games with counting coloured spaces, with numbers scattered on the board or computer games were not correlated with enhanced mathematical skills. The results were positive in either home or school environments. The researchers concluded that playing board games with numbers organised along a line improved accuracy and linearity of magnitude representations which had a positive impact on general understanding of numerical magnitude. Playing such games enhanced children's achievements in tasks involving numerical comparison and number line estimation tasks. These findings support a proposition by Booth and Siegler (2008, p.1018) that: "external representations, including pictorial, graphic, and diagrammatic forms, are an important part of mathematics education [...]. They are thought to increase understanding of mathematical concepts by helping children build relations among mathematical ideas."

As children develop their accuracy in using linear number lines their numerical reasoning also improves (Gunderson, 2012) in a variety of mathematical skills like categorizing and recalling numbers, symbolic and numeric estimation (Booth and Siegler, 2008) and eventually translates onto other tasks which do not require spatial representations. Research shows that accuracy on the number line is strongly related to children's spatial skills (Geary, 1994; Ramani and Siegler, 2008). Gunderson (2012) led a set of two studies which researched the relationship between children's early spatial skills and the development of their number line knowledge and whether spatial skill was a predictor of children's mathematical learning assessed with a numerical task and if that relationship was mediated by children's knowledge of number line. In the first study, children's spatial skills, number line knowledge and achievement in mathematics and reading was measured. At the end of the year number line skills were tested again and those children who had higher level spatial skills at the beginning of the year had better results on the number line. Children's spatial skills were a strong predictor of scores on the number line even whilst controlling for initial scores in mathematics and reading.

The second study looked at the relationship between early spatial skills (measured at the age of 5), number line knowledge (tested at 6) and approximate symbolic calculation skills (tested at 8). The results showed that spatial skills were a strong predictor of number line and calculation skills. When spatial skills and number line were included in a regression model, only number line was a strong predictor. This suggests that number line plays a mediating role between spatial and calculation skills. Overall both studies suggest that initial spatial skills in children have a positive impact on their learning mathematics through supporting the shift between logarithmic and linear number line representations. Children's calculation skills were measured in two tasks of the same nature, using clusters of dots in one and numbers in the second. The findings showed that results in the symbolic test were impacted by spatial skills whilst the results in the non-symbolic test did not follow this pattern. As the number line is a model representing symbolic numbers this finding is consistent with previous studies researching similar tasks involving numerical estimation, for instance, Booth and Siegler (2008). Despite controlling the outcomes for reading and vocabulary performance it is possible that more general cognitive abilities facilitated the outcome. Also, the extension of the relationship between spatial skills and exact numerical tasks is not yet clear.

2.3.4 Spatial Skills, Structuring, and Strategy Choice

SPATIAL SKILLS AND STRUCTURING

With the development of number sense, children discover easier ways to count and learn how to use them in solving mathematical problems more accurately and more efficiently. They gain deeper understanding not only of magnitudes but also of a variety of their representations and ways of operating them, and in doing so they employ spatial sense. Within the very broad term of spatial sense, there are three components which contribute to mathematical thinking: spatial visualisation, geometry and spatial orientation (Van Nes and De Lange, 2007). Spatial visualisation enables us to mentally move, rotate or transform images of objects or their spatial representations. Geometry provides the knowledge and understanding of shapes and figures as well as geometrical structures and patterns which might be transferred into more general domains. Spatial orientation allows the comparison of figures and shapes, understanding relationships and proportions between objects and relating these experiences to surroundings and positioning within space. These skills are crucial in organising newly acquired knowledge as they provide a platform for structuring new concepts into previously gained frameworks. This ability is not only essential in mathematics but also in other scientific and more general learning. In their learning, children improve the ways that they organise new information and gain the ability to amend their strategies depending on the requirements of a problem and in doing so reach a higher level of understanding. According to Carr and Hettinger (2003), structures and strategies provide the means to organize and process information, they “allow us to create symbolic representations of our experiences and to reorganize and compile information into larger, logical units” (p.34).

In mathematics, the awareness of spatial structures and the ability to use them in a variety of contexts shortens the process by which children determine quantities, and compare and calculate them. Facing a group of objects, children’s initial reaction is to count them unitarily. Although successful with small magnitudes, this strategy becomes time consuming and difficult with larger numbers. Many children then employ a way of organising the objects in a way which enables them to count them reliably, whether this is undertaken physically or mentally. However, some children do continue to count unitarily and not develop that form of spatial awareness. As using structures simplifies the development of more formal mathematical concepts and operations, such inability can hamper mathematical development and is a predictor of lower achievement and possible difficulties in proceeding to more sophisticated numerical procedures (Butterworth, 1999; Mulligan and Mitchelmore, 2009).

Spatial structuring is essential to many mathematical activities of a numerical or geometrical nature. Van Nes and Dorman (2011) described mathematical skills which rely on spatial structures:

- composing and decomposing of quantities (understanding that 6 = 3 + 3 but also 4 + 2 or 1 + 5),
- counting and grouping,
- part – whole knowledge in addition, multiplication and division,
- comparing a number of objects,
- patterning,
- building a construction of blocks,
- ordering, generalising and classifying,
- and more sophisticated mathematical operations like algebra, proving, predicting, mental rotation on manipulation of structures.

The authors also suggest a set of activities which if used at an early age can develop children's spatial structuring ability and support children who already at preschool might be experiencing learning difficulties in mathematics. Those activities were: recognizing and comparing configurations (for example symmetric like dots on a dice, double-structures like egg cartons or five-structures like sets of fingers), recognizing and comparing structured and unstructured objects like dominoes, dice, building blocks), creating and describing patterns, building and analysing 3D constructions and determining the number of blocks in the construction, determining and comparing of unstructured quantities.

Within mathematical development, spatial structuring together with an early spatial sense contributes to an early number sense. Van Nes and de Lange (2007) proposed that the ability to imagine a spatial structure (related to a specific magnitude) and to mentally manipulate it helps in understanding quantities and the process of counting and makes it less time consuming. That description of visualising a spatial structure and manipulating it is parallel to the definition of spatial-temporal reasoning offered by Shaw (2000) and later demonstrated to develop as a result of participation in music (Rauscher et al., 1993; Rauscher et al., 1995; Rauscher and Zupan, 2000). There are many different ways of developing spatial skills. Any of them can be beneficial and engaging in music making is one possibility. Structuring as a way of organising components is regularly used in both mathematics and music with regularity or patterning being important in both. In mathematics, numerical or spatial patterns provide structures for problem solving whilst in music patterns and relationships between elements of a pattern give sounds a structure which enables music perception. The role of patterns, relations and transformations in both mathematics and music is paramount and those who recognise such structures are likely to acquire understanding of representations, operations and concepts.

THE USE OF STRATEGIES AND STRATEGY CHOICE IN MATHEMATICS

In solving arithmetic problems children use a variety of procedures and choose them depending on the difficulty of the problem. Carr and Hettinger (2003) defined mathematical strategy as a "method used to solve a mathematics problem" (p.34). In the theoretical framework proposed by Siegler and Booth (2005) they described four characteristics of the use of strategies. They were:

- "variability of strategies and representations" – in solving problems most people use a range of strategies rather than just single one,
- "strategy choice" – decisions about which procedure is to be used from the whole range are not random but are taken after consideration of the problem whilst efficiency and accuracy are the principles of strategy choice,
- "changes in strategy use" – with experience and understanding gained, the way people use strategies changes and that change often determines success in mathematics,
- "individual differences" – as the strategy choice is closely related to other cognitive abilities, there are differences between individuals in adaptability and proficiency in using strategies (p.199).

Children are inconsistent in choosing procedures to solve arithmetic problems and the way they make those decisions is not yet fully understood (Rasmussen et al., 2003). Typically, children in solving simple addition problems count both addends (e.g., 4 + 2) with or without using fingers in the process. In doing so children adopt one of three counting procedures:

- min – in which they start with a larger number and then count on the value of a smaller number,
- max – smaller number is a starting point and the larger number is counted on,
- sum – counting both quantities starting from 1.

Preschool children use strategies based on counting or retrieval, and within the last group three procedures have been identified: guessing, retrieval and decomposition (Bisanz et al., 2005). Retrieval and decomposition are closely related. In retrieval children use long-term memory representations to solve a problem. Decomposition involves retrieving a partial sum and then manipulating it, for example, 7 + 8 might be solved as 7 + 7 with the answer retrieved from memory and adding 1 to the sum. Bisanz et al. (2005) also described four counting strategies divided into *overt*, for example counting fingers, finger recognition where a child looks at the fingers but does not count them, counting without an external representation; and *covert* when children do not show overt signs of counting and probably retrieve solutions from memory. Facing an arithmetic problem children attempt first to use covert procedures and gain the answer from memory, if this is unsuccessful they move to overt strategies.

The main purpose of using different procedures is to increase efficiency and accuracy, but what exactly determines the further choices remains a continuous research subject. There are significant differences between individuals in adapting successful strategy choice. Some children are able to make the right strategy choices which are characterised by a balance between the amount of time needed to solve the problem (efficiency) and the likeliness of obtaining the correct answer (accuracy). On the other hand, some children are consistent in choosing poor strategies or giving any answers that come to mind, even though they are unlikely to be accurate. Children who approach all mathematical problems by using the same strategy, for example memory retrieval or finger counting in all calculations, are likely to fall behind their peers who use alternative strategies. Their mathematical achievement is usually much lower. What is crucial for the study reported in this thesis is the fact that choosing strategies is also associated with spatial skills hence more developed spatial skills influence arithmetical achievement (Geary, 1994).

What are the factors influencing children's acquisition of strategies and how does the choice of strategies develop? The ability to make good choices appears to be determined by good understanding of basic number and arithmetic concepts and by working memory. According to Siegler and Booth (2005), the choice of strategies is not a set skill but increases with the adoption of new strategies, with using relatively advanced strategies more often and with building proficiency in executing existing strategies. The more advanced use of alternatives in problem solving is not the goal in itself. It also helps develop further mathematical skills, for example, building representations on a number line. Siegler and Booth (2005) proposed that with age, children improve their accuracy of number line estimations through an increase of strategy choices. That has a strong relationship with the development of counting skills and the more thorough understanding of numerical magnitudes.

The use of problem-solving strategies develops through increased understanding of numerical facts and mathematical operations but also through children becoming more familiar with a variety of strategies. Experience of using alternative procedures helps them in gaining further expertise in mathematical processing and in turn developing more adaptable use of strategies. This enrichment continues to a point of attainment described by Geary (1994). He suggested that as expertise in mathematics grows, pupils become less reliant on strategy choices because they have gained enough knowledge which can easily be retrieved from memory or they can use procedures learned and practised to the extent of becoming automatic. As soon, as those methods start being more efficient and reliable in terms of obtaining the correct result, strategy choice is used less often, mostly in situations where the other methods fail to solve the problem. Those children who continue to have to choose strategies are likely to struggle with mathematics.

2.3.5 Working Memory

Many procedures leading to solving mathematical problems like identifying and comparing quantities, creating mental representations of those quantities or performing calculations rely on the use of working memory. Geary (1994) suggested that in preschool children, the faster the retrieval of basic arithmetic facts from working memory, the better arithmetic achievement. Working memory has an impact on the use of counting strategies and on mathematical reasoning as it enables the storing of important information whilst performing mathematical processes (Krajewski and Schneider, 2009). LeFevre et al. (2005) described four characteristics of working memory: it not only stores but also processes information; it depends on central control of all the processes bringing them together; it is limited by the internal volume used for storage or processing; and it involves general and specialised aspects. Although the general and domain-specific areas of working memory might have different capacities, larger general working memory is useful in acquiring new knowledge and processes which are domain-specialised. Gaining further practice and expertise in specific cognitive tasks, leads to easier access to mental representations and makes mental procedures more efficient. Domain-specific working memory reduces the capacity needed for those problems.

When solving a nonverbal arithmetic problem, children construct internal representations of the numbers of external objects and their transformations and use those mental models to find the answer. In operating these models, working memory is used in its general and domain-specific capacities. Verbal problems need to be transformed into representations first before mental models are created. This makes them more difficult for preschool children (Bisanz et al., 2005). Assuming that preschool children solve mathematical problems through use of mental models and the internal representations are of a spatial character, Rasmussen et al. (2003) investigated different components of working memory and discovered a strong relationship with the visual-spatial memory. This study looked into how children used inversion, what determined the use of inversion over addition and subtraction and whether the use of inversion depended on other cognitive abilities. Inversion was described as the ability to notice the characteristics of a number in order to solve an arithmetic problem and use it rather than addition or subtraction (calculating skills). For example, in a problem like 5 + 3 – 3 observing that the two threes cancel each other out rather than calculating the answer through adding and subtracting. The findings of the research showed that the use of inversion depended more strongly on working memory than counting skills.

As the mental models that children construct use spatial representations, the capacity of visual-spatial memory plays an important role in developing this way of approaching arithmetic problems (Rasmussen et al., 2003) while other components of working memory are less influential. In a study by Rasmussen and Bisanz (2005) different components of working memory, for example, phonological, visual-spatial and central executive functions were considered in solving non-verbal and verbal problems. In preschool children, visual-spatial memory was the best predictor of high achievement in non-verbal tasks which suggests that in solving arithmetic problems they used mental models. This relationship was not present in older children as they become more efficient in calculating and relied less on mental models. Krajewski and Schneider (2009) also stressed the role of the visual-spatial component of working memory, especially in acquiring quantity – number understanding and further mathematical processes based on determining relationships between quantities (as in model described above).

Working memory is an important cognitive process used in solving mathematical problems. Different kinds of working memory are used in different problems and the way it is used changes with age and depends on the level of expertise and difficulty of the problem. According to LeFevre (2005), in mathematical cognition, working memory is correlated not only with problem complexity but also a code-specific processing. The following section considers the use of codes and representations specific for mathematics.

2.3.6 Code processing and the use of representations

All areas of mathematics including arithmetic, algebra, word problem solving or geometry involve using, transforming and operating a variety of codes or representations. Duval (2006) defined representation as “something that stands for something else” (p.103). Quantities, magnitudes and properties are represented in different graphic and verbal forms and that instigates the cognitive processes specific for mathematics. Additionally, any calculation uses a variety of signs and requires continuous exchange between different kinds of representations and symbols or different operations. Acquisition of a representations system is vital for learning mathematics. Children who are poor at organising pictorial or iconic representations in their work and lack structure use whilst solving problems are likely to underachieve in mathematics.

From the early-years children learn to access representations in many different ways. "During the preschool-years children begin to use external representations (e.g., fingers), word-based representations (e.g., six) and verbal counting and alternative internal representations (e.g., number line) to represent numbers and relations as well as to solve arithmetic problems." (Bisanz et al., 2005, p.159). This requires the development of cognitive systems specific for mathematics which according to Duval have three main characteristics: semiotic representations play a paramount role; there is only single access to knowledge objects; and there is a large variety of representations and their operations. In mathematics, the objects of knowledge are only present through their representations. Because they cannot be perceived, observed or measured with instruments the role of representations is paramount. "The only way to have access to them [mathematical objects] and deal with them is using signs and semiotic representations" (Duval, 2006, p. 107). Understanding symbol systems is key to talking and learning about numbers and arithmetic (Butterworth and Varma, 2013). Representations are not only used to define mathematical objects but also to work with them. Using not only representations but also their transformations, makes the process even more complex. Unlike other disciplines in which objects can be first observed and then named (double access), mathematical objects are not accessible through perception which leaves only single access to the knowledge object. Another difficulty faced by students in mathematics is the variety of representations. "The comprehension and production of numbers require an understanding of and the ability to access representations of the associated magnitudes [...]. In addition, children must learn to process verbal (e.g., "three hundred and forty two") and Arabic representations (e.g., "342") of numbers" (Geary and Hoard, 2008, p.255). Children need to not only learn different semiotic representation systems but also to gain the ability to switch between different kinds of representations and to translate magnitudes from one representation to another, for example, from numerical to algebraic notation or from language describing geometrical properties to measuring the magnitudes.

Because of the parallel systems of representations present in mathematics, solving problems can involve two types of transformations: treatment and conversion (Duval, 2006). In treatment, the transformation occurs within the same register, for example solving an algebraic equation or calculating a problem which uses decimal fractions. Conversion uses the same objects but the transformations of representation will include changing a register, for example solving a word problem by using equations or calculating a fraction through using a graphic diagram. Conversions require recognition of the object in two different representation systems and the ability to use the both systems which makes it more complicated than treatment.

Even though code processing and the use of representations as a single access to knowledge object are considered specific for mathematics, their processing is associated with more than just calculation functions which greatly complicates understanding of cognition in those activities. There is a continuing dispute between authors about the role of language in arithmetic. Some authors suggest that magnitude processing which uses mental representations is independent of language (Kaufmann, 2008). Others suggest that numerical processing is dependent on language either totally or partially, whilst others theorize that some mathematical activities are independent of verbal skills and some are related to language. Dehaene et al. (2005) proposed a triple code model which divides the way we use representations into three interconnected systems, each used in solving certain mathematical problems. Depending on the activity, mathematical processing might be either related to language or be independent of it. This theory is supported by neuroimaging evidence in which number activations in the brain occurs within three circuits, out of which two were associated with functions broader than calculation and the third was more domain specific and completely independent of language. Although these conclusions are offered cautiously considering the limitations of brain-imaging techniques, they support a suggestion proposed by LeFevre et al. (2005) that "recent brain-imaging research is consistent with the view that different mathematical tasks implicate different brain processes" (p.368).

2.4 Chapter summary

The review of literature revealed that there is some evidence that listening to music improves intellectual performance. However, this impact seems to be related to arousal and emotional responses which in turn influence performance rather than to the enhancement of cognitive abilities. Background music might aid learning through bringing about a change in mood resulting in better concentration, attitude and behaviour.

In contrast, active engagement with music and in particular rhythmic instruction has been shown to enhance spatial-temporal reasoning and other cognitive abilities. More research is needed into how this might translate into learning mathematics. It is possible that spatial-temporal reasoning mediates the impact of music on performance in mathematics. The exploration of this phenomenon is one of the aims of the current study.

With the mounting evidence of the impact of musical training on the structure and functioning of the brain and of music enhancing spatial-temporal reasoning there are still many unanswered questions. Modern neuroscience has led to a greater insight into the working of the brain but also faces many challenges, especially in disciplines which require complex cognitive skills like music and mathematics. Studies of the brains of musicians are not able to demonstrate causality in relation to brain differences and unequivocally link them with musical training. Also, brain imaging methods are undertaken while individuals are resting rather than actively processing music and as Koelsch (2003) has suggested, temporal sampling in fMRI is sparse.

The use of a wide variety of measures of spatial reasoning impacts on the findings of research. Studying mathematical cognition is also difficult and the findings are not conclusive. Kaufmann (2008) commented that: "developmental brain imaging studies in the field of numerical cognition are scarce and moreover, difficult to compare to each other because the methodological approaches employed are not readily comparable (p. 3). With rapidly advancing brain imaging technologies neuroscientists and psychologists continue to investigate processing in music and mathematics and possible relationships between them. While the current study is not directly concerned with the study of the brain, it offers the opportunity to deepen our understanding of the nature of the musical activities which may contribute to the enhancement of mathematical skills and the processes underlying this.

Spatial skills are widely used in many levels of mathematical thinking and their development is considered a strong predictor of achievement in mathematics in primary school and other stages of education (Jordan et al., 2008; Geist et al., 2013 and Booth and Siegler, 2008). These abilities are engaged with from a very early age not only in geometry, but also in number sense and understanding mathematical operations, and the ability to choose and use strategies in problem solving. Whilst developing their number knowledge, children begin construing a mental number line which is a way of organizing quantities into spatial structures. This is used throughout the lifetime in a variety of tasks related to calculation and comparison of quantities. The proficient use of mental number line is likely to lead to high attainment in mathematics.

Children learn to create internal representations of physical objects and to manipulate them to find solutions to problems. The fluency of these mental representations can be enhanced by the development of spatial reasoning. Studies have shown that spatial skills are strong predictors of scores in tasks involving number line (Gunderson, 2012), Number line seems to be a mediator between spatial and calculation skills. Spatial structuring, together with an early spatial sense, contributes to an early number sense. The awareness of spatial structures and the ability to internalize and operate them in a variety of contexts improves the process by which children determine quantities, compare and calculate them. This process is both spatial (structuring) and temporal (patterning). Such progression from counting unitarily makes the process less time consuming and less prone to errors. Spatial skills also facilitate a wider use of different strategies and the choice of the most appropriate strategies which leads to more efficient and accurate problem solving. The research reported here intends to explore the relationships between active engagement with music, spatial reasoning and performance in mathematics.

Chapter 3: Methodology

3.1 Introduction

This chapter outlines the process of setting out to further understand the relationship between music and mathematics. With much research demonstrating the positive influence music has on skills integral to learning, there is a need to transfer this academic knowledge to educational settings and to provide teachers with effective and systematic ways of using it in practice. Merging the theoretical frameworks outlined by previous research in this area with pedagogical experience, this study aimed to explore possible links between learning music and mathematics and to investigate the practical, educational implications of such a relationship. The key four stages of this research are described in this chapter:

- Refinement of the research problem;
- Research design and research methods;
- Intervention and testing;
- Data collection and analysis;
- Validity, reliability and ethical issues in the study.

3.2 Refinement of the research problem

As an outcome of the "Mozart Effect", pressure from the media and the demand for "quick-Mozart-fixes" from the public, many subsequent studies were devoted to uncovering the possible impact music might have on intellectual abilities in general and more specific cognitive skills. Despite growing knowledge of these processes, there are many areas which still require investigation. The popular view of music being related to mathematics does not have much scientific evidence supporting it, apart from the relationship with certain elements, for instance, spatial-temporal abilities. There are many questions which remain to be answered. For instance, does spatial-temporal reasoning feed into learning mathematics? How, if at all, are spatial-temporal skills used in solving mathematical problems? Are mathematical skills associated with participation in music and how might this interaction work? The numerous questions which remain unanswered required refinement and organisation in order to develop a systematic academic enquiry. With the primary aim of "making a contribution to knowledge" (Robson, 2002, p. 30) and awareness of existing research in this area, a proposal examining how learning music might be related to learning mathematics was a credible next step and set the direction for this investigation. Specifically, the idea of searching for the psychological mechanisms behind any relationship between music and mathematics, through considering both music and mathematics as requiring the combination of many cognitive abilities and looking for possible relationships between them seemed appropriate.

With a strong body of evidence that participation in music facilitates the development of spatial-temporal skills (Rauscher, 2003a; Rauscher, 2011; Rauscher and Zupan, 2000; Hetland 2000a; Hallam, 2015; Persellin, 2000) and Shaw's (2000) suggestion that spatial-temporal reasoning is a high mathematical skill the current study set out to explore the relationships between three cognitive abilities: musical skills, spatial-temporal thinking and mathematics and the possible causational relationships between them. For instance, as music instruction enhances spatial-temporal skills does it also improve mathematical abilities? Does the enhancement of spatial-temporal reasoning facilitate the development of mathematical skills? Does participation in music influence learning mathematics in other ways without the involvement of spatial-temporal skills? Indeed, does music instruction have any effect on learning in mathematics? With all these questions in mind, this study aimed to explore two main research questions:

- How, if at all, does participation in music influence learning in mathematics and learning in other academic areas?
- Can teaching which has led to the findings of this research be implemented in the primary classroom practice?

To support the development of the methodology of the study, the research questions were divided into more detailed sub-questions:

- How, if at all, does participation in music influence learning in mathematics?
- Does participation in music improve spatial-temporal skills? What is the relationship between the development of these abilities and learning in mathematics?
- In which mathematical abilities can change be observed? Which mathematical skills, if any, might be developed in a more significant way by a music intervention?
- What are the relationships between specific mathematical skills and achievement in music? Which particular musical activities might have the strongest impact?
- What are the long-term relationships between music and mathematics and is the impact sustainable?
- What is the impact of the programme on different groups of children (SEN, FSM, EAL, gender differences)?

With many possible approaches to examining these research questions, the introduction of a musical intervention, based on a thorough literature review and analysis of the impact of such programmes, was decided to be the most appropriate and academically robust way of undertaking such an inquiry (Bryman, 2012). Participation in the intervention by an experimental group, assessment of their performance, and comparison with the achievement of a control group placed the study as an experimental design. The perspective brought from a literature search suggested that the research should concentrate on children of early primary school age.

Establishing what needs to be investigated in a study, drives the design of it, the methods, and the instruments used (Bryman, 2012). This research was designed to explore the relationships between spatial-temporal, mathematical and musical skills. A decision was taken that all of these skills would be assessed using numerical scales. All data collected were of a quantitative nature.

To broaden the approach, the collection of qualitative data was considered. Two possible sources of such data would have been the teachers and the pupils. There were two possibilities in relation to obtaining data from the teachers. Inquiry into any observed changes in children attitudes to learning or behaviour would indicate whether there was any noticeable impact of the intervention on the children other than their academic attainment as measured on tests. These data might be influenced by many confounding variables which would be impossible to identify and be open to bias. Additionally, any qualitative forms of data considered would not be robust and objective enough to ensure the reliability of findings. Such data could not be linked solely with the participation in the programme. It was therefore decided that it would not add to the value of the study.

Another possibility was to seek professional feedback on the music programme. This would serve to improve the programme pedagogically. That possibility, however, would depend on teachers' regular participation in the lessons and would add significantly to their workload. This was considered unacceptable ethically and also impractical. Secondly, feedback about the programme would provide information which was not strictly relevant to the relationship between learning music and the learning of mathematics.

A short questionnaire was also considered to collect data from the children but as many of the children could not write by the end of the study, a decision was made to use focus group interviews. In the pilot study the information derived from this was very limited. Most children enjoyed the programme but they could not articulate whether it had an impact on their learning or behaviour. In view of this a decision was made that the main study would be based on quantitative data.

Research carried out within an educational setting requires the utmost consideration of ethical issues and a high level of preparation and organisation in delivering the intervention, collecting the data and scrutinising the process throughout. Threats to internal validity and limitations of the study were considered. The selection of the participating school was not completely random, as the project required the researcher to deliver the music programme once a week for two years. The possible location of school was therefore limited. However, many measures were taken to assure that the sample was representative of the population of early years' primary pupils in the UK, and to address concerns regarding the generalisability of the findings. These issues will be discussed in the later sections of this chapter.

The research proposed to create a bridge between academic study and practical application in the classroom. The intended outcomes were specified as:

- Obtaining better knowledge of how music can influence the learning of mathematics and whether the proposed musical activities develop mathematical skills.
- Developing a programme for the use of primary school teachers who are non-specialists in music in which some of the musical activities not only follow the UK National Curriculum but might also be effective in improving learning mathematics, and learning in general.

There is an ongoing discussion about whether music in primary schools should be delivered by specialist or non-specialist music teachers. While there are countless unquestionable positives in employing music specialists for teaching music in the primary school, there is also the important consideration that "generalist teaching allows greater opportunity for music to become embedded in daily classroom activities and furthermore offers the advantage that the class teacher has a depth of knowledge relating to individual children that a specialist cannot match" (Hallam et al., 2009, p.4).

Leading researchers and educators have suggested that the best way of developing high quality music education is for a range of organisations to work together including schools and music hubs which incorporate music services and other organisations working towards a common goal of providing high quality music education. It has been argued that this should:

- be a "partnership between classroom teachers, specialist teachers, professional performers and a host of other organisations, including those from the arts, charity and voluntary sectors" (Henley, 2011, p. 3),
- include "staff development and teacher professionalism; and partnership working between schools, with other services and the wider community" (Jaffrey et al., 2006, p. 18),

- include "training in basic musical skills for classroom teachers who have little or no experience, [...] providing training for music specialists in relation to how to successfully apply their musical knowledge and skills at Key Stage 1. The evidence also suggests that the issue of planning for progression through Key Stage 1 needs to be incorporated into both of these types of training." (Hallam et al., 2009, p. 65).

In view of these arguments, it was proposed to create and use in the study a music programme, which could be used by teachers who were not specialists in music, which addressed many elements of the National Curriculum, which embedded planning for progression, and which provided a training opportunity for the participating teachers. The development of the musical intervention programme will be described in more detail later in this chapter.

3.3 Research design and research methods

With a cross-disciplinary theoretical background in the psychology of music and neuropsychology of music, the research adopted a quasi-experimental design. I prepared a programme of musical activities and taught it to children in early primary classes over a period of two years. This longitudinal approach provided an appropriate set of data for analysis. Parallel classes in each school year served as control groups. The involvement of different groups of participants in the intervention is presented in Table 3.1.

Table 3.1 Pupils' participation in the study

November 2012 – July 2012	**Pilot study:***60 pupils in intervention groups, and 60 pupils in control groups from reception and year one classes.*
October 2012 – July 2013	**Full-scale intervention:***90 intervention participants including the previous 60 continuing the programme, and a new group of 30 from a new intake reception class. The control groups consisted of the same 60 children from previous year and an additional 30 from the parallel reception class.*
September 2013 – July 2014	**Follow up:** *the intervention was withdrawn but further data from teachers' assessments in mathematics was collected to observe potential sustainability of any enhancement in learning.*

During this time, three sets of quantitative data were collected from the intervention groups. Only two sets of data were collected from the control groups as they did not participate in the music programme.

1. Performance on spatial-temporal and memory tests which children completed at the beginning of the programme and at the end of each year,
2. Data from teachers' assessments in mathematics at times decided by teachers throughout the academic year.
3. Data from the assessment of children's musical skills occurring throughout the school year.

Data were analysed every year. The music programme was slightly adapted according to the findings. The procedure for collecting the data and the timetable for the tests are described in more detail later in the chapter.

3.3.1 Procedure

The research was carried out in three phases over three academic years. During the first year, a pilot study was undertaken. At the beginning of each academic year, the participating school randomly splits the number of children from each year cohort into two parallel classes. Through blind selection a Year 1 and a Foundation Stage class were randomly assigned to take part in the music intervention. That made the sample of 60 children from the Year 1 and the Foundation Stage (Reception) classes who are referred to as ***music 1*** (Year 1) and ***music 2*** (FS). Control groups were made up of another 60 children of the same age from parallel classes in the same school and became groups: ***control 1*** and ***control 2***. The experimental groups had music lessons lasting 30 minutes once a week in groups of about 15 pupils. The lessons took place in a music room equipped with a selection of untuned percussion instruments. Control groups were engaged with normal school activities including ICT, group reading, phonics, school assembly. The whole project had a longitudinal character. The pilot study was designed so that the data could be included with other data later in the analysis providing that no major changes were required. During the second year, the same children participated in the study with the addition of another 58 children in a new reception class, out of which 30 took part in the music programme and became ***music 3*** whilst the other 28 were a control group, ***control 3.*** In the third year, the intervention was withdrawn but children's attainment data were still collected to enable an assessment of whether the possible enhancement in pupils' learning might have had a sustainable effect. Table 3.2 presents the timetable of the project.

Table 3.2: Timetable of the research project

	October 2011 – July 2012 **Pilot study**	*October 2012 – July 2013* **Main study**	*October 2013 – July 2014* **No intervention, school assessment data collection**
music 1	*music programme in Yr1*	*music programme in Yr2*	*Yr3*
control 1	*no intervention*	*no intervention*	
music 2	*music programme in FS*	*music programme in Yr1*	*Yr2*
control 2	*no intervention*	*no intervention*	
music 3		*music programme in FS*	*Yr1*
control 3		*no intervention*	

3.3.2 Sampling

THE SELECTION OF THE PARTICIPATING SCHOOL

The choice of school for the project could not be entirely random because of the long-term commitment in running the programme over two years. As I was a governor in a local primary school at the time, it seemed logical to consider that school for possible participation. However, to ensure the external validity of the study the chosen school had to fulfil certain conditions to be representative of UK primary schools. Several criteria relating to the school's academic attainment and the school's characteristics were taken into account to determine whether the school met such requirements. These data from the school were compared with the national data from the Department of Education's website. Over 70% pupils from the possible participating primary school had achieved level 4 or above in both English and Maths in 2011. This was very close to the national average of 74%. 95% of pupils reached the expected progress level in English and 91% in Maths compared to the national average of 89% and 87%. Closer assessment of students' progress showed an average point score of 28.3 at the possible participating school as opposed to 27.6 nationally (see Table 3.3).

As presented in Table 3.3, the percentages of children with Special Educational Needs and Disabilities (SEND), children eligible for free school meals and overall and persistent absence in the school considered for participation in the research, were very similar to national averages. The higher than average proportion of children for whom English was not their first language was not considered a disadvantage as throughout the music programme the teacher would model most of the activities and the children would observe the presentation and base their own actions on that. This pedagogical approach is often used in the early primary years, it is considered inclusive and effective for all pupils, and children are used to being taught through modelling. All these conditions ensured that using this method would be appropriate for the study and should not affect the outcomes of the research.

Table 3.3: Characteristics of the participating school in comparison to the national average

Characteristics	School considered for participation in %	National average in %
Percentage of pupils with SEND Statements or School Action Plus	7	8
Percentage of pupils for whom English is not their first language	44	18
Percentage of pupils eligible for free school meals	20	19
Overall absence	5	5
Persistent absence	3	3

Once it was clear that the school met the requirements for generalisation for the findings, both head teachers were briefed on the aims of the research, its theoretical foundations, the proposed methods and the outline of the intervention and agreed for the school to participate in the study. Relevant teachers were also informed about the research, and its aims, application and timetable were explained. All of them agreed to take part. Letters to the parents explaining the study and asking for their consent for their children to partake were issued. None of the parents opposed their child's participation.

PARTICIPATING PUPILS

As previous research in this field suggests that enhancement of spatial reasoning is stronger in younger children, the two youngest classes were chosen to take part in the experiment during the pilot study. There were 29 5-6 year olds in the Year 1 class who for the purpose of this study became the group ***music 1*** and 31 4-5 year olds from the Reception class – ***music 2***. The school participating in the experiment had two classes in each school year and children were designated to classes through random selection. That practice was known to the researcher and was deemed sufficient to ensure randomness of belonging to the experimental or control groups. One class through random selection was assigned to be the intervention group and the other the control group. Those groups who did not take part in the intervention became ***control 1***(Year 1 children) and ***control 2*** (Reception class children). The size of the sample – 60 intervention participants and 60 children in the control group for the pilot study and the enlargement to 90 pupils in each group for the main study was considered appropriate for the statistical techniques proposed.

As pupils participating in the intervention were in different classes and were taught by different teachers it was important to consider whether that could affect the outcomes of the research. Each school in England has an internal system of moderating teachers' practice and the participating school was no exception. Throughout the year, teachers, especially within the same school year, regularly met and ensured that their teaching was as similar as possible. They often planned lessons together, and also used the same assessment criteria. Additionally, pupils' achievement was moderated and scrutinised by the senior management in the school. All of the results were input into a variety of programmes, for instance, Raise Online, which tracks students' progress. If the data collected throughout the experiment were in any way skewed, it would be very transparent on the progression diagrams. Also, the fact that the study had a longitudinal character and over a period of two years, pupils were taught by different teachers in a variety of groupings strengthened the unity of pedagogical practice. These conditions were considered sufficient to assume that the outcomes of the study were not biased because children were taught by a variety of teachers.

The ethnic background of the pupils was diverse with 66% of British origin, 28% Pakistani, 2% Hungarian and 4% Polish. The school was located within a disadvantaged area with many low-income families. The proportion of participants benefitting from the Pupil Premium and receiving free school meals was high, 45 out of 180 children, a quarter of the pupils. Within the groups participating in the project, there were 38 children with Special Educational Needs and Disabilities, mainly with mild difficulties, with five at School Action Plus and one with a SEND statement. Predominantly the difficulties were related to speech, language and communication needs; moderate learning difficulties; and behavioural, emotional and social difficulties. One child had a mild hearing impairment and one was diagnosed as being on the autistic spectrum. These needs did not impede the pupils in a way which would require withdrawing them from the study.

3.4 Intervention and testing

3.4.1 Development of the intervention programme

Many studies in this area reported in the literature have been based on very distinct programmes, often delivered by highly trained musicians or involving advanced and expensive equipment (Gromko and Poorman, 1998; Rauscher and Zupan, 2000; Rauscher 2003; and Perrett and Fox, 2006). In many of these studies, participants were taught individually or in small groups, purchase of instruments might have been required from the parents of participating children, and sometimes the contents of the programme would not fit with the learning objectives of the UK National Curriculum. Previous studies have frequently not been able to be replicated without serious difficulties because of the lack of information about the musical intervention. Interventions have also often been impractical in schools because they required highly trained musicians to deliver them. More importantly, the methods adopted involved only a small minority of students because of time or budget constraints. Taking this into account it was advisable for the present research to include more children. With the knowledge presently available, it seemed desirable to attempt to find a more accessible and sustainable music programme which could be delivered to all children. This was instrumental in designing the current research. Another vital decision taken at this point, related to the nature of the musical intervention. It was important to create a musical programme which could be used by teachers who were not specialists in music.

In creating the intervention programme there was a need to ensure that it not only took account of previous findings in this area but also complied with the requirements of the UK National Curriculum. This process was guided by two main objectives:

- Using musical activities which were more likely to positively affect children's spatial-temporal development.
- Creating a bank of activities that could be used by teachers who were not specialists in music and which would not require expensive equipment.

Existing research had suggested how different kinds of musical activities might affect mathematical skills and which of them might be more effective in enhancing those skills. Unfortunately, much of the literature did not describe in detail the nature of the musical activities which were adopted and the pedagogical methods used. The most transparent in terms of teaching methods, were the studies undertaken by Rauscher (1996, 2000; 2001). One of the projects by Rauscher and Zupan (2000), which was successful in developing children's spatial-temporal reasoning, became the starting point in creating my own scheme. This project used rhythmic instruction as well as teaching the children to play keyboards. The lessons involved ear training, notation, rhythm activities, improvisation and dynamic exercises. The programme was delivered twice a week over a period of eight months. Lessons lasted 20 minutes and children were in groups of ten. It was led by a music specialist. The details of the programme were obtained from the researchers who kindly shared their ideas with me through an email:

"...The music teacher involved in the study spent a significant amount of class time app. 1/4 - 1/3 in beat keeping, movement, and music-related kinaesthetic activities as well singing familiar songs from traditional folk and early childhood repertoire. Lots of left and right hand differentiation games as well as specific attention focused on impulse control chants and games

e.g. "Jello in the bowl, Jello in the bowl, wiggle waggle, wiggle waggle, Jello in the bowl" only allowing the children to move on the "wiggle, waggle" and freezing on the rest of the rhyme - both on the keyboards and in patting and rhythm instrument playing. [...]

We utilized the Alfred Method Book after first playing many of our vocal repertoire sol-mi pieces like "Cuckoo in the Clock" "One, Two Tie My Shoe", "Rain, Rain Go Away" "See Saw Up and Down" as we believe it was very important for the children to initially sing the piece and know it well before playing it on the keyboard. All of the Alfred pieces were sung before playing and represented on charts before seeing the notation in the book. The children were on the black keys for much of the instruction time and only moved to the white keys for the last month or month and a half.

Since the keyboards were right in the kindergarten classrooms we really encouraged the teachers to allow as much "free play" and "experimentation" time on the instruments as they were able and found this also enhanced the children's familiarity and facility with keyboard geography."

These descriptions were instrumental in the development of the programme of musical activities which was used in this study. As noted before, in previous studies a variety of musical activities was used and the most effective in developing children's spatial-temporal reasoning were rhythmic exercises. Playing keyboards also brought similar results. This programme built on this previous work and focused on rhythmic instruction with elements of singing, learning to read musical notation and creating music. Rhythmic exercises included maintaining a steady beat, recalling and reproducing rhythms, creating rhythms within different time signatures, performing simple polyrhythms, using rhythmic patterns to create and perform simple structures like rounds, ternary form, rondo, movement with rhythm, and playing untuned percussion instruments alone and in group arrangements. During the music lessons, children took part in a variety of activities involving singing, playing percussion instruments, clapping and tapping rhythms, movement with music. They also learned some musical terms and their meanings, elements of musical notation and gained some knowledge of the science of sound. These weekly sessions were 30 min. long and were based in the music room (apart from singular occasions related to some school events, when the whole class lessons occurred in the classrooms). Usually half of a class took part in the music lesson at one time followed by the lesson with the other half (apart from rare situations when it was necessary for the school to have both groups in the music lesson at the same time). Their teachers were encouraged to come to the lessons and either actively take part or observe to develop their own expertise of teaching music. Three teachers took this opportunity on occasions and one participated regularly. The details of the lesson plans can be found in the appendices. One example is included below (see Appendix 1 for the music programme).

'Twinkle, Twinkle'

1. Singing welcome,
2. Trip to the woods – *When you hear a tambourine pretend you're a butterfly, a drum – a bear and stand still when there is no rhythm*,
3. Singing Twinkle, Twinkle matching fast beat clapped by the teacher,
4. Singing the tune counting to four, *Clap and stomp your foot at one*,
5. In two groups, one group claps at 1, the other group claps the 2, 3, 4, repeat to ensure that all the children clap their parts correctly,
6. Change the roles,
7. Give out three groups of instruments: drums, shakers, tambourines, children try out their instruments following teacher's gestures showing the volume,
8. Children imitate the beat conducted by the teacher,
9. Drums play the 1, shakers and tambourines play the 2, 3, 4,
10. Pass your instrument to the left, repeat exercise 7, 8, 9,
11. Once again pass the instruments and repeat 7, 8, 9,
12. *Stand up, march to the beat given by the teacher, sing 'Twinkle, Twinkle' and play the rhythm*.

As previous research in this area had already demonstrated that learning music improves spatial-temporal reasoning, it was important to focus on transferring this knowledge into pedagogical practice. Most previous experiments have involved specialist musicians as teachers, innovative settings or expensive equipment. This was necessary for the purposes of those studies but did not provide schools with a sustainable way of delivering music instruction. Taking account of this, it was decided that a programme devised for the current study was to be appropriate for any ordinary primary school, would require only resources which are widely available in primary schools and could be adopted by any teacher who was not a specialist in music. At the moment, many teachers do not feel they are well prepared or comfortable with leading music lessons (Hallam, Creech and Papageorgi, 2009) and a programme with lessons planned for progression to be delivered by generalist teachers would be helpful. Additionally, the music programme used in the current study provided teachers with an organised and accessible forms of assessment which would inform their further practice. Hallam et al. (2009) showed that even a day of specific training in teaching music could bring about significant change in teachers' confidence and attitudes towards music. Teachers participating in the programme developed for use in this study were able to observe experimental lessons, join in with the activities or ask about any issues related to the scheme. Some teachers used this opportunity and regularly watched the lessons. Towards the end of the study, all teachers whose pupils participated were provided with detailed lesson plans and training in how to employ the scheme in their pedagogical practice.

3.4.2 The measures adopted

Most research projects in this area have found that active engagement with music improves the development of spatial-temporal skills. This study was designed to gain further insight into that relationship and to investigate whether that development had an impact on learning mathematics as spatial-temporal reasoning is considered to be an element of mathematical ability. It was also possible that there was another relationship between learning music and learning mathematics in which spatial-temporal reasoning played a lesser role. To ascertain whether this was the case, it was essential that the collected data took account of children's performance in all these aspects. Throughout the project, participating children were tested in three areas:

- Spatial-temporal reasoning,
- Mathematical attainment,
- Musical ability.

All testing was arranged to cause as little disruption to children's learning as possible.

The timetable of all assessments is presented in Table 3.4.

Table 3.4: Timetable of assessments in the study

	Group	09/ 11	01/ 12	04/ 12	07/ 12	09/ 12	01/ 13	04/ 13	07/ 13	07/14
Teachers' assessment in reading, writing and mathematics	***music1 control1***	✓	✓	✓	✓	✓	✓	✓	✓	✓
	music2 control2	✓			✓	✓	✓	✓	✓	✓
	music3 control3					✓			✓	✓
Teachers assessment in specific mathematical skills	***music1 control1***	✓			✓	✓			✓	
	music2 control2					✓			✓	
	music3 control3									
Picture test, puzzle test and memory test (by the researcher)	***music1 control1***	✓			✓				✓	
	music2 control2	✓			✓				✓	
	music3 control3					✓			✓	
Assessments of musical skills (by the researcher)	***music1***	Only the music groups, throughout the year, starting from January 2012								
	music2	Only the music groups, throughout the year, starting from January 2012								
	music3	Only the music groups, throughout the year, starting from January 2013								

TESTING TEMPORAL AND MEMORY SKILLS

To assess children's spatial-temporal reasoning two tests were used, a picture test and a puzzle test. They were created by the researcher and followed the form of tests from similar studies. Both tests contained two elements defined by Rauscher and Shaw (1998) as an intrinsic part of spatial-temporal skill: the construction of mental images, and temporal ordering.

The ***Picture test*** contained four pieces of a puzzle, which needed to be put together to form a picture of an elephant. The original picture was not provided, so the children had to create a mental image and then to rotate the pieces and put them together in a particular order to make a picture. This test imitated the Performance sub-test of the Wechsler Preschool and Primary Scale of Intelligence Revised (WPPSI-R) used previously in similar studies (Rauscher et al, 1997; Rauscher and Zupan, 2000) where children were asked arrange pieces of a puzzle to create a meaningful whole. "Performing this task required forming a mental image of the completed object and rotating the puzzle pieces to match the image. Performance was facilitated by putting the pieces together in a particular order, defining the spatial – temporal nature of this task". (Rauscher et al., 1997, p. 4).

All the pieces were arranged in the same pattern for each child. Children were asked to finish the picture as quickly as they could and the time it took them to finish the picture was measured. Time of the completion of the task in seconds was recorded and became the variable "picture test". There were two identical sets of the test cut out of A4 card.

The ***Puzzle test*** consisted of a set of colourful blocks, which needed to be ordered on a rectangular shaped base as prescribed in the template. This task contained both of the elements required for spatial – temporal reasoning – the formation of a mental image and temporal ordering. In this test, mental imagery did not involve forming a mental depiction of a physical object but required constructing the organization of a set of objects to produce a given sequence. It comprised relating and combining spatial elements, rotating them and establishing interrelationships between components to fit the picture. Using both, picture and puzzle tests in the study ensured that different elements of spatial - temporal reasoning were captured. In both tasks the participants needed to follow a sequential order, because if the first or any other elements were put in the wrong place it would be impossible to finish the task. These children who didn't first work out what the completed image would look like, and attempted the task by randomly trying the pieces in different places, usually took much longer to solve it.

Year 1 and 2 pupils were asked to use 12 pieces and reception classes used six pieces as they found 12 pieces too difficult. Time of the completion of the task was recorded in seconds and became the variable "puzzle test". Two identical sets of IQ puzzler were used in this test.

As sequencing was an important part of these tasks, both spatial and temporal skills were tested. To ensure the internal consistency of these tests, the Cronbach's alpha was calculated based on the data collected on the 120 participants participating in the pilot study. For the ***picture test*** Cronbach's alpha was .98, and for the ***puzzle test*** it was also .98, suggesting good internal reliability.

Additionally, the children's ***pictorial memory*** was tested to check whether results on this task improved as a result of participation in the music programme. The use of a picture memory test in addition to the other tasks was designed to act as a control for a possible Hawthorne effect. With the prediction that spatial-temporal reasoning improves through active engagement with music, a lack of significant enhancement in a different task but enhancement in spatial-temporal reasoning would suggest that the music activities had been responsible for the enhancement of spatial-temporal skills, rather than just the presence of a new programme.

To ensure proper control for Hawthorne effect, it was important, that the test would not involve either the formation of mental images or temporal ordering. A visual memory test fulfilled such condition. In this test, children were given a worksheet which depicted 20 objects, looked at it and tried to memorise the objects for a period of 30 seconds. The picture was then turned over and the children were asked to recall as many objects as they could. The number that they remembered was recorded. This measurement became the variable "memory test". The reliability of the scale in this test was confirmed by a high Cronbach's alpha .94.

Testing spatial-temporal and memory skills adopted the following procedure. A pair of children was taken out of the classroom into a quiet area in the school, one of them waited, while the other started with the ***memory test***. Both then completed the ***picture test*** and the ***puzzle test.*** The second child then completed the ***memory test***. During the spatial-temporal tests children sat back to back so they could not look at what the other child was doing. To avoid the possibility that the child who did the ***memory test*** second might have had a slight advantage over the first, the second child was asked to read a book during that time. This solution was considered more ethical than having to disturb children's learning twice to do the test separately.

TESTING MATHEMATICAL SKILLS

Another set of data collected assessed children's mathematical skills. These assessments were undertaken by their class teachers, as it was assumed that professionals' judgement and expertise was more accurate than that of the researcher. This also minimized the amount of disruption to the children's learning and ensured that the teachers' workload was not enlarged by their participation in the study. The challenge of adopting this approach was to ensure that the teachers were not biased in their assessments. The assessment system in primary schools is prescribed in much detail and the monitoring of progression is a continuous and thoroughly scrutinised process. If at any point the recorded attainment of any pupil was overrated, the following set of assessments (possibly in the next class by another teacher) would highlight the problem. If this issue did not emerge within the school, at the end of Year 2, pupils take SAT exams which although they are marked by the teachers are moderated by the Local Authority to ensure that marking is consistent. Additionally, as the testing was undertaken by several teachers it was unlikely that bias would be consistent. Furthermore, mathematics attainment data was collected over a period of three academic years, during which time several measures were employed throughout the school to ensure the consistency of assessment. Ecological validity was also likely to have been enhanced. As Bryman (2012, p.53) put it "...the fact that the students and the teachers seem to have had little if any appreciation of the fact that they were in fact participating in an experiment may also have enhanced ecological validity." This intervention did in fact resemble such a situation in many ways.

Mathematical attainment was formally tested at the beginning of the programme and at the end of each term. Pupils were assessed by their teachers in specific areas of mathematics and English as described in the Primary Framework for Literacy and Mathematics (2006). In mathematics, these are: using and applying mathematics (problem solving, communicating, reasoning, counting and understanding numbers); calculating (knowing and using number facts, solving numerical problems); understanding shapes (properties of shape, properties of position and movement); measuring, handling data and using and applying mathematics (processing and representing data, interpreting data). Throughout the time of the intervention, all pupils from year 1 onwards were assessed in formal assessments measured in sublevels and recorded within the pupils' progress school system four times a year. Additional information about pupils' progress in mathematics came from informal testing done throughout the year, which was broken up into more specific skills. Those skills in Year 1 were: number recognition up to 10, number recognition up to 20, counting to 10, counting to 20, 2D shapes, 3D shapes, and practical addition and subtraction. In Year 2 the measured skills were: counting up to, counting back from, sequencing numbers to 20, recognising numbers to 20, one more, one less, counting objects accurately, adding to 10, taking away from 10, problem solving adding and subtracting, 2D shapes, 3D shapes, attributes of shapes, line of symmetry, symmetry patterns, capacity litre, capacity prediction.

This assessment was measured on a three-step scale ranging from "no understanding of concept", through "beginning to understand concept" to "fully understands concept". In their assessment teachers used standard Assessing Pupils' Progress tools. For assessment in mathematics, all teachers in the participating school used a variety of learning objectives and the children were checked against them throughout the lessons with an overall score recorded each term which then was transferred into national levels of progression.

Assessment of children in the Foundation Stage was based on the Early Years Foundation Stage Profile and followed assessment scales in six areas of learning. For the purpose of this research, data were collected in four of these areas: *personal, social and emotional development*; *communication, language and literacy* which consists of language for communication and thinking, linking sounds and letters, reading and writing; *problem solving, reasoning and numeracy* with three subareas: numbers as labels and for counting, calculating and shape, space and measurement and *knowledge and understanding the world.* The Reception classes were assessed slightly differently but through discussions with the teachers, the data were adjusted to match that collected from the rest of the pupils in the school to enable necessary comparisons. In Foundation Stage, children's skills are assessed on an eight-step value scale with one being the weakest and eight the most advanced. From Year 1 onwards pupils are assessed using levels and sub-levels. There was a need to adapt the foundation stage assessment to include sub-levels so that all of the results could be included in the same interval scale for the analysis. Following recommendations from three foundation stage teachers (two of whom were not involved in the project) it was decided that the first three (1-3) grades would be equivalent to the breadth of one sub-level, another three (4-6) would be equivalent to another sub-level and the last two (7-8) could also be considered as a sub-level. Despite this attempt to make the results comparable, there were, however, some differences in assessing children between the foundation stage and the rest of the school. These differences might have had an impact on the collected data. All data from assessing children' mathematical skills were transferred into a database.

TESTING MUSICAL SKILLS

In deciding what data should be considered in the analysis, it was assumed that the level of pupils' attainment in music might play a mediating role in the likelihood of enhancement in their learning of mathematics. If learning music was to have an impact on learning mathematics, it seemed plausible that the greater the development of the musical skills in each individual, the greater should be their achievement in mathematics. Hence testing musical ability could provide additional insights into the processes of transfer. Similarly, as in other school subjects, assessment occurred during the lessons through observation of the children whilst they performed specific tasks, for example keeping the beat, recalling rhythms, recognising rests of different lengths, creating rhythms in a given time signature. The musical skills of the children from the intervention groups were systematically evaluated by the researcher on a three-point scale: no competence in the skill, some competence in the skill, reliably competent in the skill. The musical skills assessed in the first year of the programme were: keeping a beat with the group, keeping a beat individually, singing and clapping the beat, singing and clapping the rhythm, walking to the beat and repeating one bar of a 4-beat rhythm. The musical skills assessed in classes who participated in the second year of music programme were: clapping a strong beat in a 4-beat bar, clapping a strong beat in a 3-beat bar, repeating 2 bars of a 4-count rhythm, imitating a rhythm for 4 bars and keeping in time, playing a bar of rhythm from simple notation, and improvising a 4-beat bar of rhythm. The assessment had an informal character and it was based on observation of individual children during lessons. These observations were recorded and provided an overall picture of pupils' musical attainment and progression.

3.5 Data collection

Data collection processes are vital in ascertaining reliability and validity of a study. As suggested by Bryman (2012, p.13) “The assessment of research quality is an issue that relates to all phases of the research process, but the quality of the data-collection procedures is bound to be a key concern.” In this research, several measures were used to ensure consistency and reduce bias in data collection and to ensure that data were collected and treated in a way which would protect data from contamination. These procedures are described below.

Within several lines of data collection in this study, a number of strategies and standardizing efforts were employed to ensure consistency and reliability:

- Spatial-temporal and memory tests - all the children received the same instructions and no other communication was involved. Pieces of the puzzle were arranged in the same way for all the children and a mixture of children from intervention and control groups was sent by their teachers so each pair was in a different configuration.
- Academic attainment – data were collected by professionals who had knowledge and experience of using descriptors and indicators of national curriculum levels and sub-levels. Teachers’ assessment is often scrutinised by external parties, for instance, school improvement partners, Local Authorities, and is also moderated within the school. These procedures ensured the consistency of the assessment. This level of standardization was considered sufficient for this study. Children’s attainment was recorded by teachers with sub-levels and transformed into numerical data. In this continuous data, the interval between each sub-level was equal to 1 creating an interval scale variable. Additionally, teachers assessed children’s specific mathematical skills with indicators which were transformed into a numerical scale and created a group of ratio variables.
- Musical attainment was assessed in a way which would ensure the same conditions and expectations for all of the children. Assessments were made using sets of indicators which were transformed into numerical, ratio variables.
- Additional data relating to ethnicity, free school meals (FSM), special educational needs (SEN), and gender was taken from school records and coded into categorical variables.

These procedures were aimed at ensuring a high level of reliability and validity.

3.5 Validity, reliability, and ethical issues in the study

3.5.1 Validity and reliability

In designing any study, a rigorous scrutiny of the research framework and threats to validity and reliability is essential to ensure academic robustness determining the trustworthiness of the findings. The internal reliability and the stability of the measures used in this study were assured by using forms of assessment which were consistent over time and were not dependent on testers' subjective judgements. Whilst using multi-indicator scales, the level of relation between different indicators was checked through calculating Cronbach's Alpha. These procedures were put in place to ensure reliability and replicability.

Another criterion foremost in evaluating a study is "the integrity of the conclusions that are generated from a piece of research" (Bryman, 2012, p.47). Validity is concerned with whether the measurement of the concept proposed in the study really measures that concept. With many elements determining validity, several issues were considered in relation to threats to the validity of this study. With the hypothesis that participation in the music programme would enhance learning in mathematics, an experimental design with a presence of a control group was used to examine that relationship. Bryman (2012, p.52) suggested that "The presence of a control group and the random assignment of the subjects to the experimental and control groups enable us to eliminate [...] rival explanations". As it is possible in education that merely the presence of a new scheme, different place, grouping or teacher might bring about change in pupils' attainment, it was vital to consider that possibility. To control for such a Hawthorne effect, apart from spatial-temporal tests, a pictorial memory test was used. Performance for the control and experimental groups on the memory test should not differ as it should not be affected by the musical intervention. If it did differ other factors might be implicated. In contrast, the results on the spatial-temporal tests should be different between the intervention and control groups if the music intervention had had an impact.

Another important issue that had to be addressed was the possibility that some children might have better performance in all areas of school work and their higher achievement might not be related to participating in the programme. If this was the case, all of their assessments should be consistently higher than others. Any inconsistencies in assessments, particularly inconsistent results in specific mathematic skills tests would suggest that the enhancement was caused by the intervention. Evaluation of data in this area would provide evidence for such an eventuality.

As the study was quasi-experimental and the choice of school was not random, a randomised selection of pupils to take part in the intervention was important to ensure internal validity. Concerns for external validity were resolved by ensuring that the chosen school was close to national averages in as many measures as possible.

For me as a teacher, the ecological validity of this study was of particular importance. Throughout designing the study and preparing the music programme, the accessibility of the programme for most primary teachers in most ordinary settings was an imperative. The possibility that through music certain academic enhancement might be achieved not only in this particular study, but also in a wider educational context, was instrumental in the decisions made in planning this project. I was aware of the limitations that this might have had on the research but I felt that with the large body of evidence about the relationship between participation in musical activities and spatial-temporal reasoning already available, it was timely to propose a study which might offer a bridge between these academic investigations and pedagogical practice.

3.5.2 Ethical issues

To ensure that this research was conducted in an ethical manner and in compliance with the good practice guidance prescribed by BERA, several issues were addressed. The best interests of the participating children and teachers were the primary consideration. Before the project started the researcher had undergone a Criminal Records Bureau check. In contact with the pupils the requirements of Safeguarding Pupils were followed to make sure that no emotional or other harm could come to the participants. The research did not put any participants (pupils or teachers) at risk.

The children's parents or guardians were informed about the research through an information leaflet. This leaflet contained a form which could be used to opt the child out of the project, otherwise the parents/guardians were assumed to have given their fully informed consent for the child's participation. The children benefitted from taking part in a regular scheme of music lessons.

Participating teachers were fully informed about the aims, methods and possible outcomes of the research and agreed to participate in the project. Teachers who took part in the project were given an opportunity to train in delivering the music programme as it was introduced in their school and throughout the course of the intervention.

Only data essential to the research were collected. All data were treated confidentially and anonymously. At the beginning of the data collection, children's names were coded with numbers and throughout the research those codes were used to identify the participants. The decoding key was stored securely to ensure that nothing directly or indirectly led to a breach of confidentiality.

In the research, disruption to the normal working of the participants (both children and teachers) was minimal. The delivery of the programme was at a time which would otherwise have been used for the study of humanities or a school assembly. The teachers confirmed that the children's absence from these activities would not hamper their progress and that in their view the value of the music programme would compensate for the changes. Data collection from the testing undertaken by the teachers was also planned to not add to their workload. These data came only from assessments which teachers would normally perform during the school year.

Because of the need for a control group in the study, not all of the children were offered participation in the intervention programme. To deal with this inequality, all Foundation Stage and Key Stage 1 teachers were invited to observe the lessons, gain further training and were provided with guidelines about the music programme to enable them to use it in the future with all pupils.

The participating teachers and the head teachers were debriefed about the conclusions of the research and provided with copies of summarized findings from the study. The findings of this research were shared with participating children and their parents through issuing a letter summarizing the outcomes.

3.6 Chapter summary

This chapter described the refinement of the research problem in the current study, together with the design of the research, the methods adopted, and the procedure of the project. The selection of the school was explained, as well as the allocation of children to groups, both of which aimed to ensure a sample representative of UK primary schools. This chapter presented the development of the intervention programme and its relationship with the literature review. It also specified measures considered in the study, the ways of testing spatial-temporal, memory, mathematical and musical skills, and data collection. The chapter sets out procedures followed in the study to fulfil validity, reliability, and ethical requirements.

Chapter 4: Relationships between groups: Analysis of data from the pilot study

4.1 Introduction

This chapter summarises the analysis of the relationships between groups in the pilot study. The whole project had a longitudinal character and the pilot was designed to be an integral part which would be continued into the main study. Its findings provided a platform for adjustments to the intervention music programme, forms of assessment and testing and any other adaptations required in further sections of this research.

Research questions considered in this chapter are:

- How, if at all, does participation in music influence learning in mathematics?
- Does participation in music improve spatial-temporal skills? What in the relationship between the development of these abilities and learning in mathematics?

4.2 Method

4.2.1 Sampling in the pilot study

To adhere to the findings of previous research in this field, two youngest classes were chosen to take part in the experiment – 29 of 5-6 year olds from Year 1 class who for the purpose of this study became group ***music 1*** and 31 of 4-5 year olds from Reception class – ***music 2***. The school participating in the experiment has two classes in each school year and through a random choice one was selected to be an intervention group and the other one a control group. Those groups who didn't take part in the intervention became ***control 1*** (Year 1 children) and ***control 2*** (Foundation Stage children) and included 61 children. The ethnic background of the pupils was quite diverse with 68% of the British origins, 28% of Pakistani origins, 3 Hungarian and 2 Polish children. As the school is located within a disadvantaged area of town the proportion of participants eligible for free school meals was high with 33 out of 120 children. Within that group there were 25 children with Special Educational Needs and Disabilities, mainly with moderate learning difficulties, apart from 5 with School Action Plus and 1 with an SEND statement.

4.2.2 Procedure in the pilot study

The intervention took place over five terms – October 2011 to July 2012, during which time the pupils participated in the music programme delivered by the researcher. Prior to that and throughout the study, children learning and abilities were assessed following the timetable presented in Table 4.1.

Table 4.1: Timetable of assessments in the pilot study

	Class	September 2011	January 2012	April 2012	July 2012
Teachers' assessment in reading, writing and mathematics	Year 1	✓	✓	✓	✓
	FS	✓			✓
Teachers assessment in specific mathematical skills	Year 1	✓			✓
	FS				
Picture test, puzzle test and memory test (by the researcher)	Year 1	✓			✓
	FS	✓			✓
Assessments of musical skills (by the researcher)	Year 1	Only the music groups, throughout the year, starting from January			
	FS	Only the music groups, throughout the year, starting from January			

4.3 Results

4.3.1 Makeup of the groups in the pilot study

The participating classes were randomly assigned as intervention and control groups and the data collected at the beginning of the programme was compared between those groups to gain a better understanding of how the children in those groups performed prior to the intervention. There were four groups altogether, ***music 1*** and ***control 1*** (in Year 1 at the time of the intervention) with 29 and 30 children respectively and ***music 2*** and ***control 2*** (Reception class) with 31 and 30 children. The size of the sample – 60 intervention participants and 61 children in the control group was considered appropriate for the statistical techniques proposed for the study. This size of sample ensured that the parametric techniques used in the analyses were appropriate even if the assumption of normal distribution was violated in any of the sets of data (Tabachnik and Fidel, 2001; Gravetter and Wallnau, 2004; Pallant, 2007).

4.3.2 Pre-intervention testing

At the beginning of the intervention, of the two older groups, ***music 1*** was slightly stronger in writing (mean difference [MD] = 0.1) and the puzzle test (MD = - 0.1), whilst ***control 1*** had better results in reading (MD = - 0.03), mathematics (MD = - 0.3), the picture test (MD = 1.93), and the memory test (MD = - 0.44). Where mean differences are negative this is because the scores of ***control 1*** were subtracted from ***music 1***. When ***control 1*** had a higher score, the difference was negative. To check whether the differences between those groups were statistically significant, an independent-samples t-test was conducted. Only the difference in mathematics was statistically significant (t (57) = - 2.063, p = .044 (two-tailed)). For all the other assessments, the differences in means were not statistically significant.

The scores of the two younger groups were also similar to each other with ***music 2*** being better in mathematics (MD = 0.03), the picture test (MD = - 2.39), the memory test (MD = 0.41), and the puzzle test (MD = - 0.44). ***Control 2*** scored higher in reading (MD = - 0.26) and writing (MD = - 0.13). The results from an independent-samples t-test established that the only significant differences were in reading (t (59) = -3.013, p = .004) and in writing: (t (59) = - 2.035, p = .046). All the other differences were not statistically significant.

4.3.3 Post-intervention testing

In the comparison of the final scores between the groups using an independent-samples t-test by the end of the intervention there were fewer significant differences between the groups than in the pre-tests. In none of the assessments was ***music 1*** significantly different from ***control 1***(p > .05). There were slightly better mean scores in writing (MD = 0.14), the picture test (MD = - 0.22), and the puzzle test (MD = - 0.22). ***Music 2*** was statistically significantly better than ***Control 2*** in reading (t (59) = 2.132, p = .037, MD = 0.31) and in the puzzle test (t (59) = - 2.697, p = .010, MD = - 0.59). For all the other assessments p > .05 with slightly better mean scores in mathematics (MD = 0.115) and the picture test (MD = - 5.0) for ***music 2*** and ***control 2*** achieving higher scores in writing and the memory test.

4.3.4 Change of scores over the period of the intervention

To see how the scores had changed over the period of the intervention, paired-sample t-tests were performed. Apart from one variable (marked with an asterisk), in all other t-tests p = .0001 (two-tailed) suggesting that the differences in scores between the beginning of the study and the end were statistically significant. Table 4.2 presents values of t, difference in means and the Pearson's correlation coefficients. In most cases the significance value for the Pearson's correlation was p = .0001, all other instances are marked in the table.

In the older groups, ***music 1*** outperformed their peers in mathematics, the picture and puzzle tests and slightly in writing. All areas of assessment were strongly correlated with the results at the beginning of study. ***Music 2*** achieved better in reading, mathematics, the picture and puzzle tests and slightly in writing. Only the picture and puzzle tests in ***music 2*** were strongly correlated with previous scores. The correlation for mathematics was moderate. In ***control 2*** this correlation was strong in the picture, memory and puzzle tests. Outcomes in bold indicate which group achieved greater progression.

Table 4.2: Changes in scores in different groups in all areas of assessment over the time of the intervention

	reading	Writing	mathematics	picture test	memory test	puzzle test
Music 1 group	t(28)= 11.07 MD = 1.51 r = .889	t(28)= 12.34 **MD = 1.44** r = .941	t(28)= 15.57 **MD = 1.79** r = .835	t(28)= -7.80 **MD = -4.17** r = .960	t(28)= 5.38 MD = 1.00 r = .933	t(28)= -8.08 **MD = -.33** r = .971
Control 1 Group	t(29)= 17.58 **MD = 1.6** r = .968	t(29)= 11.36 MD = 1.4 r = .928	t(29)= 15.09 MD = 1.56 r = .766	t(29)= - 8.858 MD = -2.46 r = .991	t(29)= 4.96 **MD = 1.2** r = .778	t(29)= -5.66 MD = -.21 r = .976
Music 2 Group	t(30)= 15.60 **MD = 1.58** r = .283, p =.124 (n.s.)	t(30)= 8.71 **MD = 1.06** r = .299, p =.102 (n.s.)	t(30)= 15.97 **MD = 1.45** r = .533, p = .002	t(30)= -7.96 **MD = -5.64** r = .974	* p = .296 (n.s.) MD = 0.19	t(30)= -6.41 **MD = -.32** r = .936
Control 2 Group	t(29)= 9.32 MD = 1.00 r = .333, p =.072 (n.s.)	t(29)= 7.37 MD = .96 r = .254, p =.254 (n.s.)	t(29)= 13.46 MD = 1.36 r = .271, p =.147 (n.s.)	t(29)= -5.58 MD = -3.03 r = .976	t(29)= 4.55 **MD = .667** r = .898	t(29)= -3.99 MD = -.18 r = .974

value of p = .0001 in all unmarked cases

4.3.5 The interactions between outcomes for control and intervention groups pre- and post-intervention

To assess the impact of the intervention versus belonging to the control group over time, a repeated measures analysis was used for the two different age groups in all six areas of interest across two time periods. Before proceeding with the analyses several assumptions were checked (Gravetter and Wallnau, 2004; Pallant, 2007). Descriptive statistics for these analyses for the older and younger groups are showed in tables 1 and 3, Appendix 2. The Levene's test of equality of error variances was calculated and at no point was the assumption of the homogeneity of variance violated (as presented in tables 2 and 4, Appendix 2). The assumption of the homogeneity of inter-correlations was not violated as shown by the Box's test of equality of covariance matrices presented in tables 2 and 4, Appendix 2. Wilks' Lambda was used to determine the interaction effect – it is a test which measures if the means of the groups are different on a characteristic, the closer it is to 0, the more the means of the groups differ (Cramer and Howitt, 2006; Pallant, 2007). Partial eta squared as a measure of strength of association (Tabachnik and Fidel, 2001) indicates what "proportion of variance of the dependent variable is explained by the independent variable." (Pallant, 2007, p. 208)

FINDINGS FOR THE OLDER INTERVENTION AND CONTROL GROUPS

The results of this analysis for the older groups are presented in Table 4.3. In reading, writing, mathematics and the memory test there was no statistically significant interaction between belonging to the intervention or control group and time with the levels of probability greater than alpha level of .05. The two cases where such relationship was statistically significant were the picture test (p = .006, partial eta squared = .125 which indicated a very large size effect) and the puzzle test (p = .041, partial eta squared = .071, a moderate effect) (Pallant, 2007; Cramer and Howitt, 2006). The main effect for the two conditions in those two assessments proved not to be statistically significant with the level of significance in the picture test (p = .69, partial eta squared = .003) and in the puzzle test (p = .62, partial eta squared = .004). There was a statistically significant effect for time in all the assessments with p < .0005 in all cases and partial eta squared above .14 indicating a large effect size. All statistically significant results are marked in bold.

Table 4.3: The impact of the intervention compared with the control over two time periods for the older groups (music 1 and control 1)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	.996	.61	.004	**.13**	**.000**	**.86**	.786	.001
Writing	.999	.77	.001	**.16**	**.000**	**.83**	.647	.004
Mathematics	.964	.14	.036	**.10**	**.000**	**.89**	.324	.017
Picture test	**.875**	**.006**	**.125**	**.31**	**.000**	**.68**	.699	.003
Memory test	.993	.51	.007	**.52**	**.000**	**.47**	.366	.014
Puzzle test	**.929**	**.041**	**.071**	**.37**	**.000**	**.62**	.621	.004

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Table 4.4 presents the results of a mixed between-within analysis of variance for the younger groups. Within the younger groups there was a statistically significant relationship between participation in the music programme as opposed to the control group and time in four areas. They were reading and the picture test (p < .05, partial eta squared = .14 which indicates a very large effect size) and the memory and puzzle test (p < .05, partial eta squared = .06) which implies a moderate effect size). In all cases the improvement over time was significant with all p < .05 and all partial eta squared above .14 (a large effect size). Only in the puzzle test was the main effect comparing the participation in the music program and the control group significant (p = .026 with a moderate effect size suggested by partial eta squared of .081).

Table 4.4: The impact of the intervention compared with the control over two time periods for the middle groups (music 2 and control 2)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	**.792**	**.000**	**.208**	**.16**	**.000**	**.83**	.783	.001
Writing	.995	.587	.005	**.31**	**.000**	**.68**	.447	.010
Mathematics	.993	.535	.007	**.12**	**.000**	**.87**	.486	.008
Picture test	**.878**	**.005**	**.126**	**.38**	**.000**	**.61**	.303	.018
Memory test	***.936***	***.048***	***.064***	**.81**	**.000**	**.18**	.696	.003
Puzzle test	***.928***	***.037***	***.072***	**.51**	**.000**	**.48**	***.026***	***.081***

4.3.6 Comparison of the changes in scores over time for the intervention and the control groups in each measurement area

Figures 4.1; 4.2; 4.3; 4.4; 4.5; 4.6 further illustrate comparisons of the performance on all six tests by the older and younger intervention and control groups over two periods of time. In all cases p = .0001.

In reading, as presented in Figure 4.1, both older groups performed at a similar standard with the difference in progression between the groups of -0.09. This number was calculated by subtracting the change in mean differences between the results pre- and post- intervention for ***control 1*** from the change in mean differences over the same two periods of time for ***music 1***. The younger intervention group not only started below the control group but also exceeded it by the end of the year. Their progression was 0.58. Output in bold indicates that the intervention groups outperformed the control groups.

Figure 4.1: Change in results in reading for the intervention and control groups over two periods of time

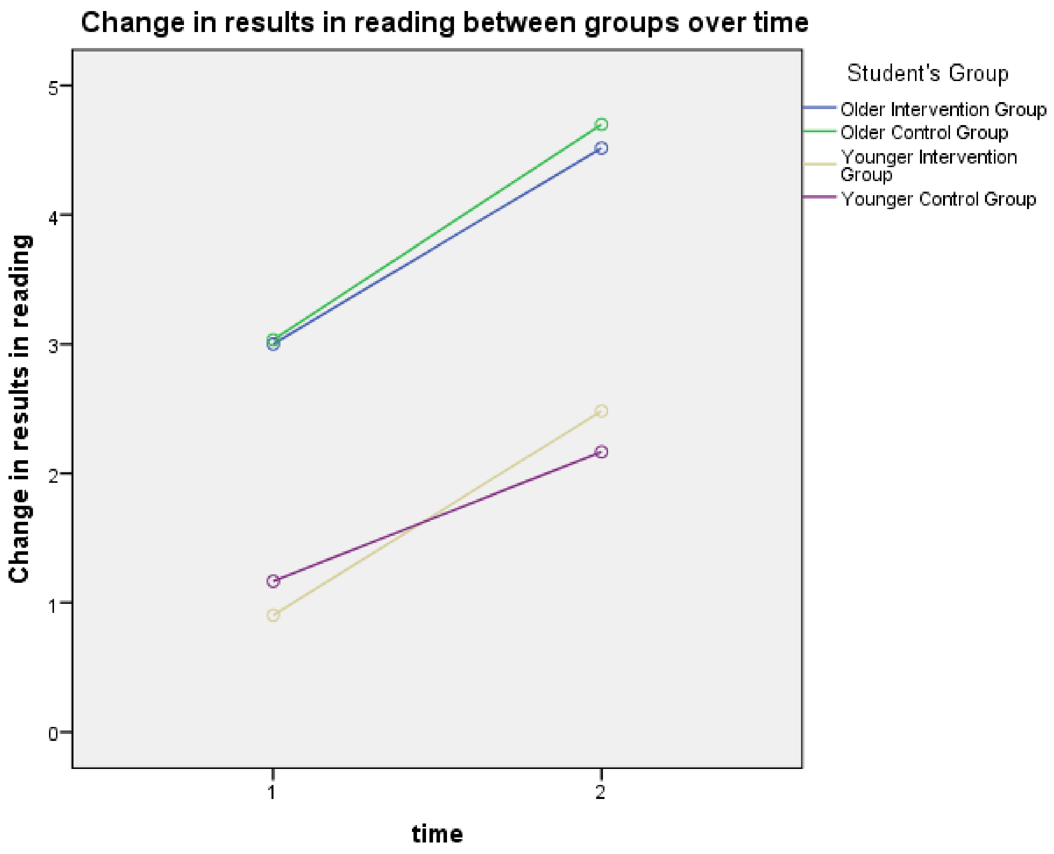
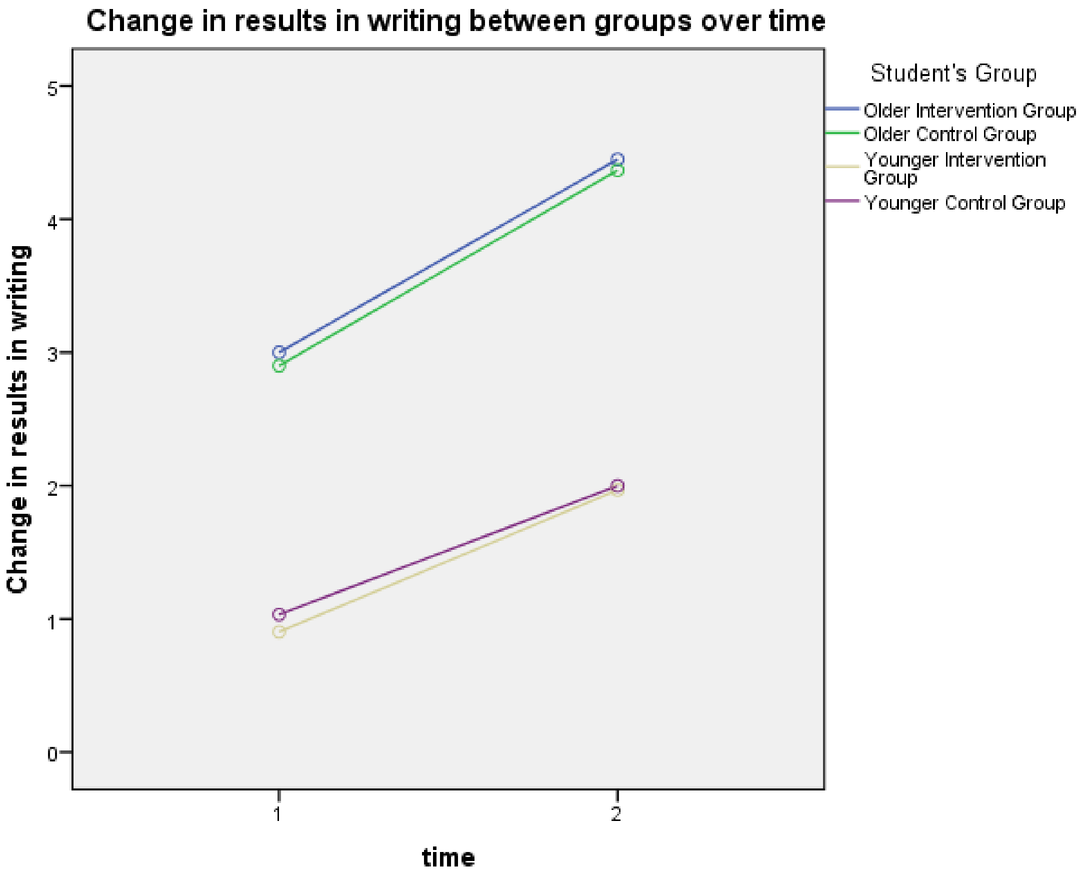


Figure 4.2 shows that in writing, both intervention and control groups of both ages progressed very similarly. For the older groups the level of progression was 0.04 and for the younger groups it was 0.1.

Figure 4.2: Change in results in writing for the intervention and control groups over two periods of time



In mathematics, the older intervention group started with much lower scores and over the period of the study reached a level similar to the control group with the progression equal 0.23, see Figure 4.3. Both younger groups had similar results at the beginning of the year and the intervention group progressed slightly better (0.09).

Figure 4.3: Change in results in mathematics for the intervention and control groups over two periods of time

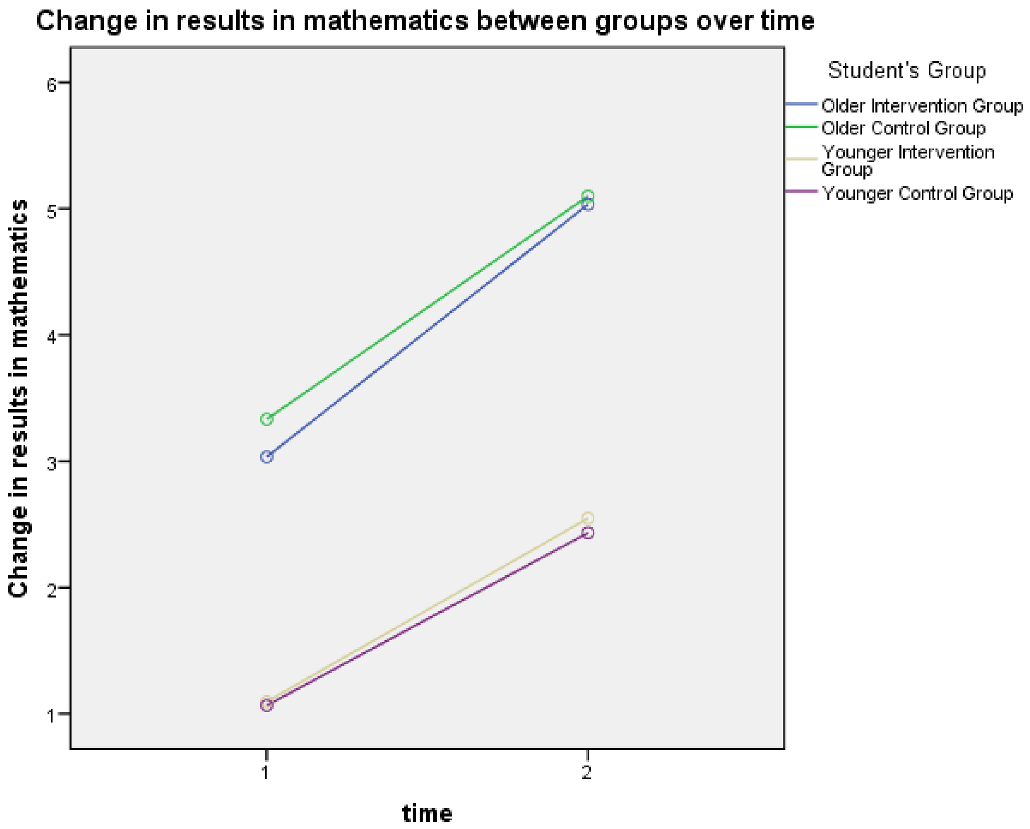
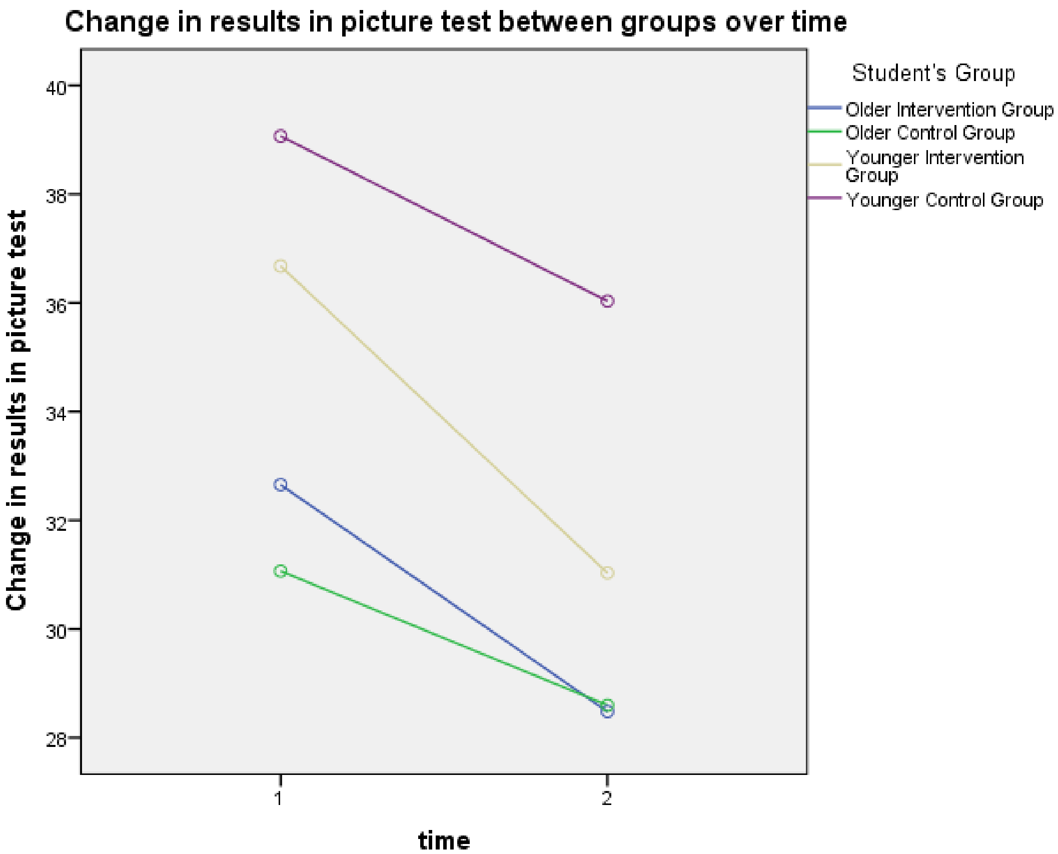


Figure 4.4 shows that in the picture test, ***music 1*** achieved lower scores than ***control 1*** at the beginning of the year, whilst by the end of the year their scores were similar. The progression level was 1.71. Out of the younger children, ***music 2*** was better to start with and continued to be better with a greater difference of 2.61 between groups at the end of the year.

Figure 4.4: Change in results in the picture test for the intervention and control groups over two periods of time



As presented in Figure 4.5, in the memory test, both older groups change of scores was very similar over time with the control group progressing marginally greater – 0.2. In the younger groups, the control group started below the intervention group and progressed more rapidly achieving progression of - 0.47.

Figure 4.5: Change in results in the memory test for the intervention and control groups over two periods of time

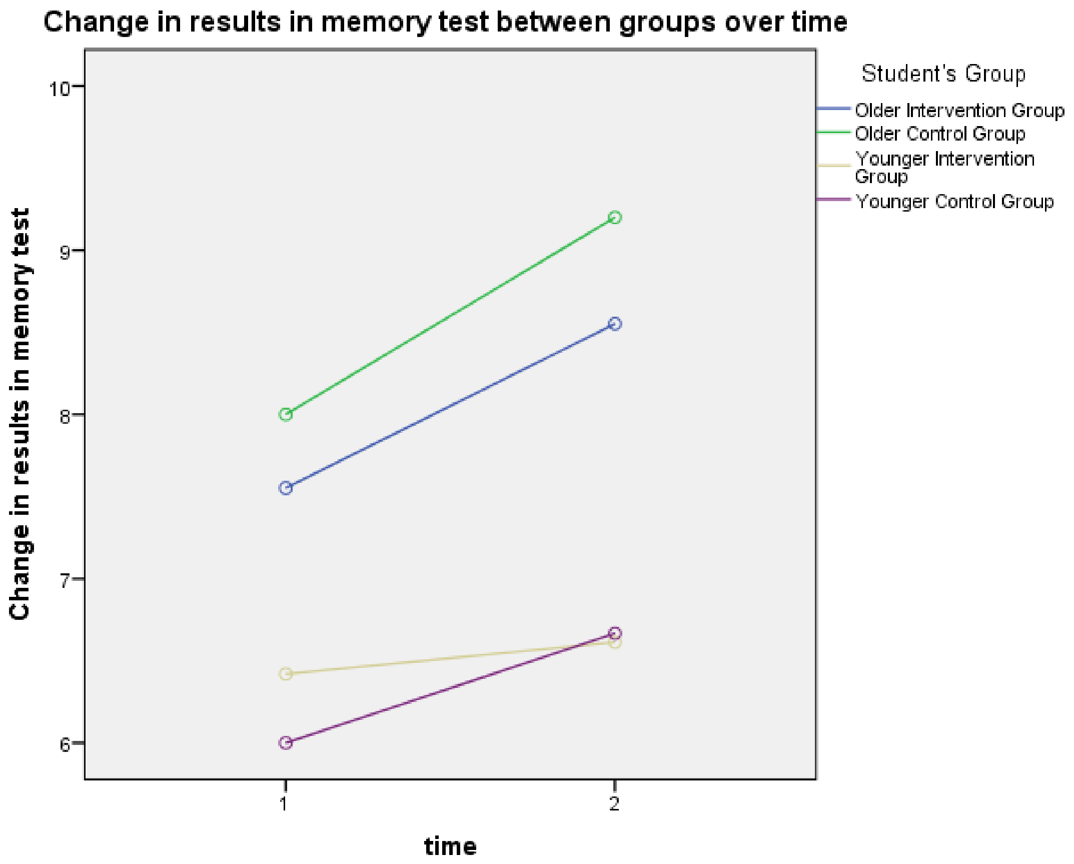
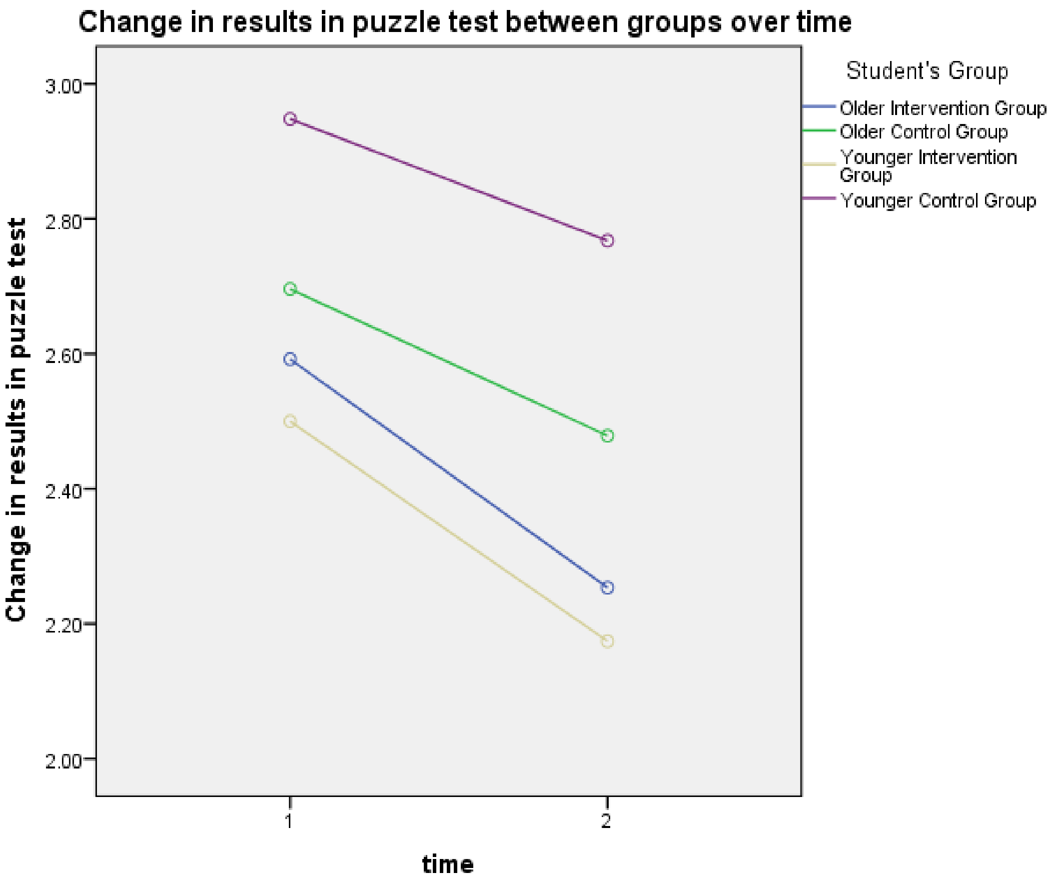


Figure 4.6 shows differences in results between the groups in the puzzle test. ***Music 1*** was slightly better at the beginning of the programme and that difference became greater towards the end by .012. ***Music 2*** also had better scores than the control group at the beginning of the study and progressed only slightly better than their peers with the difference of .014.

Figure 4.6: Change in results in the puzzle test for the intervention and control groups over two periods of time



4.4 Chapter summary

The theoretical framework underlying this study proposed that learning music would develop children's spatial – temporal skills which might subsequently have an impact on their learning of mathematics. Children who participated in a music programme should therefore show higher levels of achievement than their peers in spatial – temporal tests and in mathematics, whilst their scores in a memory test should be similar to those in a control group. The exploration of these relationships using data collected during the pilot study was the aim of the analyses presented in this chapter.

There were several statistically significant findings:

- In mathematics, the older control group had significantly higher attainment prior to the start of the programme. At the end of the year they still performed better than the music group but the difference was no longer statistically significant. This suggests that during the period of the intervention the progress of the music group was greater than that of the control group although this difference was not statistically significant when assessed using a repeated measures analysis.

- Both music groups showed greater change in both spatial-temporal reasoning tests over the period of the intervention when compared with the control groups. These differences were statistically significant.

- In the memory test, both control groups showed greater change over the period of the intervention than the music groups. For the younger group this change was statistically significant suggesting that the findings relating to spatial-temporal reasoning were not the result of a Hawthorne effect or more general intellectual development.

- In reading, the younger control group initially had higher scores. Following the intervention, the music group outperformed the control group. Their change in scores was statistically significant. This confirms the findings of previous research that rhythmic music instruction has a positive influence on reading.

Table 4.5 shows which groups achieved the highest scores in pre- and post- intervention testing and in the change achieved over the period of the intervention. All statistically significant cases are marked in bold.

Table 4.5: Higher achieving groups in pre- and post- testing and the progression over the period of the intervention

	Older groups ***music 1*** and ***control 1***			Younger groups ***music 2*** and ***control 2***		
	Pre-	Post-	Change	Pre-	Post-	Change
Reading	*control 1*	*control 1*	*control 1*	***control 2*** ***t(59) = -3.01*** ***p = .004***	***music 2*** ***t(59) = 2.13*** ***p = .037***	***music 2*** $\eta_p^2 = .208$ ***p = .000***
Writing	*music 1*	*music 1*	*music 1*	***control 2*** ***t(59) = -2.03*** ***p = .046***	*control 2*	*music 2*
Mathematics	***control 1**** ***t(57) = -2.06*** ***p = .044***	*control 1*	*music 1*	*music 2*	*music 2*	*music 2*
Picture test	*control 1*	*music 1*	***music 1*** $\eta_p^2 = .125$ ***p = .006***	*music 1*	*music 2*	***music 2*** $\eta_p^2 = .126$ ***p = .005***
Memory test	*control1*	*control 1*	*control 1*	*music 1*	*control 2*	***control 2*** $\eta_p^2 = .064$ ***p = .048***
Puzzle test	*music 1*	*music 1*	***music 1*** $\eta_p^2 = .071$ ***p = .041***	*music 1*	***music 2*** ***t(59) = -2.7*** ***p = .010***	***music 2*** $\eta_p^2 = .081$ ***p = .026***

*groups highlighted in bold showed statistically significant result

These data revealed that in both spatial – temporal reasoning measurements children from the intervention groups outperformed the control groups. As no such relationships were observed in the memory test, this indicates that participation in the music programme had a strong impact on pupils' spatial-temporal skills. This enhancement did not however facilitate the development of learning in mathematics strongly enough to show statistically significant progression. A thorough inspection of the relationships between the individual variables is described in chapter 8. This was undertaken to gain a deeper understanding of the possible influence of the music intervention. Chapter 5 sets out the findings from the main study.

Chapter 5: Relationships between groups: Analysis of data from the first year of the main study

5.1 Introduction

In chapters 5, 6, and 7 the proceedings of the main study are presented. After the first year of the pilot study two years of the main study were undertaken with the same children and an additional group of 58 pupils from the youngest intake to the Reception class. During the first year of the main study children from the intervention groups continued to have lessons based on the music programme whilst the control group had a mixture of other activities including assemblies, role play in the FS class, art, humanities etc. In the second year of the main study the intervention was withdrawn but pupils' attainment data were collected to explore any possible long lasting effects of the music programme. The results from this study were considered on three levels:

- comparison of the intervention and the control groups and relationships between variables during the second year of the music program (chapter 5);
- comparison of groups of children of the same age through different phases of the study (chapter 6);
- analysis of children's attainment once the intervention was stopped (chapter 7).

This chapter examines the first level - the analysis of the results from the second year of the study (first year of the main study) and addresses following research questions:

- How, if at all, does participation in music influence learning in mathematics?
- Does participation in music improve spatial-temporal skills? What is the relationship between the development of these abilities and learning in mathematics?

5.2 Method

5.2.1 Sampling in the main study

Apart from the 120 children who had already taken part in the pilot study and were described in the previous chapter, the main study involved the newest intake of children into the Reception class. Out of this group of 58 children, 30 were assigned to an intervention group (***music 3***) and the other 28 to a control group ***control 3.*** The ethnic background of these children was predominantly British (55%), with many Pakistani children (31%), some Polish pupils (9%), and 5% of other ethnicities. Twelve of the children were eligible for free school meals, 21% of the group. Twenty-two per cent of the children had Special Educational Needs or Disabilities, mainly moderate learning difficulties or speech, language and communication needs, while one child had an SEND statement relating to the Autistic Spectrum Disorder.

5.2.2 Procedure in the main study

The main study took place between October 2012 and July 2014 and was a continuation of the pilot study undertaken with the same children between October 2011 and July 2012. During the first academic year – October 2012 – July 2013 pupils participated in the music programme delivered by the researcher. After that, the intervention was withdrawn but the data related to children's academic performance was collected over the following year to examine whether any possible impact that the intervention might have had was sustainable over time. Throughout that period of time children's progress was assessed following the timetable presented in Table 5.1

Table 5.1: Timetable of assessments in the main study

	Class	September 2012	July 2013	July 2014
Teachers' assessment of reading, writing and mathematics	Year 2	✓	✓	✓
	Year 1	✓	✓	✓
	FS	✓	✓	✓
Teachers' assessment of specific mathematical skills	Year 2	✓	✓	
	Year 1	✓	✓	
	FS			
Picture test, puzzle test and memory test (data collected by the researcher)	Year 2	✓	✓	
	Year 1	✓	✓	
	FS	✓	✓	
Assessment of musical skills (data collected by the researcher)	Year 2	Only the music groups, throughout the year, starting from January		
	Year 1	Only the music groups, throughout the year, starting from January		
	FS	Only the music groups, throughout the year, starting from January		

5.3 Results

5.3.1 Makeup of the groups in the main study

The children in the participating classes were randomly assigned to intervention and control groups. The data collected at the beginning of the programme was compared between those groups to gain a better understanding of how the children in those groups performed prior to the intervention. There were six groups in total, a ***music 1*** and ***control 1*** (in Year 2 at the time if the intervention) with 29 and 30 children respectively, a ***music 2*** and ***control 2*** (Year 1 class) with 31 and 30 children, and ***music 3*** and ***control 3*** (Reception class) with 30 and 28 children. All together 178 pupils took part in the study, out of which 90 participated in the intervention.

5.3.2 Pre-intervention testing

In the pre-intervention testing, of the older groups, ***music 1*** was very slightly stronger in writing (mean difference (MD = 0.07) and the puzzle test (MD = - 0.22), whilst ***control 1*** had better results in reading (MD = - 0.18), mathematics (MD = -0.27), and the memory test (MD = - 0.65). Scores in the picture test were similar. The mean differences were a result of subtracting the scores of the ***control*** group from the ***music*** group. In reading, writing, mathematics, and the memory test when the ***control*** group had a higher score, the difference was negative. In the picture and puzzle tests the time in which the children performed the task was the measure, the less time took, the better result. If the mean difference was positive, the ***music*** group achieved a higher score. To check whether the differences between the groups were statistically significant, an independent-samples t-test was conducted. None of the differences were statistically significant. This meant that the pre-intervention scores for ***music 1*** and ***control 1*** could be considered as equivalent.

There were few statistically significant differences between controls and the intervention group in the middle group (***music 2*** and ***control 2***). ***Music 2*** was better in reading (MD = 0.31), the picture test (MD = - 5), and the puzzle test (MD = - 0.59), while other scores were similar in both groups: writing, mathematics, and the memory test. The results from an independent-samples t-test established that the only significant differences were in reading ($t(59) = 2.132$, $p = .037$) and in the puzzle test ($t(59) = -2.680$, $p = .01$). The other differences were not statistically significant. Apart from reading and the puzzle tests the scores for ***music 2*** and ***control 2*** were effectively equivalent.

In the youngest groups (***music 3*** and ***control 3***), ***music 3*** was better in all of the assessments: reading (MD = 0.21), writing (MD = 0.23), mathematics (MD = 0.28), and the memory test (MD = 0.26), while ***control 3*** scored better in the picture test (MD = 1.5) and the puzzle test (MD = 0.03) However, an independent-samples t-test showed that none of these differences were statistically significant. This meant that the scores for ***music 3*** and ***control 3*** could be considered as equivalent.

5.3.3 Post-intervention testing

In the comparison of the scores at the end of the intervention between the groups using an independent-samples t-test, there were no significant differences between ***music 1*** and ***control 1*** (p > .05 in all cases) with slightly higher scores in reading, writing, the picture and puzzle test in ***music 1*** and the memory test in ***control 1***, while performance in mathematics was the same in both groups. In the middle groups, ***music 2*** performed significantly better than ***control 2*** in the memory test (t (59) = 3.13, p = .018, MD = 1.29) and in the puzzle test (t (59) = - 2.43, p = .018, MD = - .51). For all of the other assessments the differences were not statistically significant with slightly higher scores in reading, writing, mathematics, and the picture test in ***music 2.*** In the youngest groups (***music 3*** and ***control 3***), the only significant differences were the scores in mathematics with ***music 3*** achieving better (t (56) = 2.164, p = .036, MD = .398). In the other tests ***music 3*** scored slightly higher than their peers in reading, writing, the memory test whilst in the puzzle test both groups performed the same. None of the other differences between ***music 3*** and ***control 3*** were statistically significant.

5.3.4 Change of scores over the period of the intervention

To establish the extent to which the scores had changed over the period of the intervention, paired-samples t-tests were performed on all groups in all of the assessment areas. All of the outcomes were highly statistically significant. Table 5.2 sets out the values of t, the differences in means and the Pearson's correlation coefficients. Greater values of differences in means between the same age groups are highlighted in bold. In most cases the significance value for the Pearson's correlation was p = .0001, all other instances are marked in the table.

In the older groups, ***music 1*** outperformed their peers in terms of change in all assessment areas. As was expected there were strong correlations between pre- and post-intervention scores in all of the assessments apart from the picture test. In the middle groups, ***music 2*** achieved greater change in writing, mathematics and the memory test than ***control 2***. For ***music 2*** all of the tests results were strongly correlated with previous scores. This was also the case for ***control 2*** apart from the memory test. Once the youngest groups were considered, ***music 3*** performed better than their peers, although in most areas the differences were very small. All the measures for the youngest groups were strongly correlated with achievement prior to the intervention.

Table 5.2: Changes in scores in different groups in all areas of assessment over the time of the intervention

	reading	writing	mathematics	picture test	memory test	puzzle test
Music 1 group	t(28)= 18.41 **MD = 4.03** r = .869	t(28)= 15.41 **MD = 3.62** r = .852	t(28)= 14.30 **MD = 3.44** r = .755	t(28)= - 1.98 **MD = - 1.75** r = .866 p =.057 (n.s.)	t(28)= 3.81 **MD = .82** r = .918	t(28)= - 5.81 **MD = - .21** r = .964
Control 1 Group	t(29)= 27.69 MD = 3.43 r = .885	t(29)= 20.79 MD = 3.16 r = .861	t(29)= 23.02 MD = 3.2 r = .778	t(29)= - .87 MD = - .8 r = .910 p = .391 (n.s.)	t(29)= 2.12 MD = .6 r = .680	t(29)= - 2.98 MD = - .15 r = .955
Music 2 Group	t(30)= 23.38 MD = 3.32 r = .734	t(30)= 26.58 **MD = 3.45** r = .710	t(30)= 26.44 **MD = 3.61** r = .582	t(30)= - 3.58 MD = - 3.09 r = .940	t(30)= 9.33 **MD = 1.80** r = .814	t(30)= - 4.00 MD = - .13 r = .959
Control 2 Group	t(29)= 20.95 **MD = 3.43** r = .716	t(29)= 23.02 MD = 3.2 r = .841	t(29)= 22.88 MD = 3.4 r = .376	t(29)= - 4.61 **MD = - 3.26** r = .962	t(29)= 1.81 MD = .467 r = .580 p = .08 (n.s.)	t(29)= - 5.27 **MD = -. 21** r = .976
Music 3 Group	t(29)= 21.87 **MD = 2.20** r = .859	t(29)= 28.43 **MD = 2.23** r = .893	t(29)= 26.44 **MD = 2.36** r = .825	t(29)= - 9.34 **MD = - 5.46** r = .929	t(29)= 4.18 **MD = .70** r = .708	t(29)= - 6.33 **MD = - .21** r = .968
Control 3 Group	t(27)= 41.79 MD = 2.07 r = .935	t(27)= 35.40 MD = 2.10 r = .893	t(27)= 27.00 MD = 2.25 r = .561	t(27)= - 7.08 MD = - 3.17 r = .978	t(27)= 3.43 MD = .64 r = .491	t(27)= - 5.00 MD = - .18 r = .956

value of p = .0001 in all unmarked cases

5.3.5 Interactions between outcomes for the control and the intervention groups pre- and post-intervention

As comparisons of change in performance over the two periods of time showed some differences between intervention and control groups it was important to assess whether these differences were statistically significant and to investigate the impact of belonging to the intervention versus the control group over time. To examine this, a repeated measures analysis was used for the two different age groups in all six areas pre- and post- intervention. Before proceeding with ANOVA descriptive statistics and several assumptions were checked (Gravetter and Wallnau, 2004; Pallant, 2007). Tables 5, 7, and 9 in Appendix 2 present the descriptive statistics for all three age groups. The Levene's test of equality of error variances was calculated and at no point was the assumption of the homogeneity of variance violated (as presented in tables 6, 8, and 10 Appendix 2). The assumption of the homogeneity of inter-correlations was not violated as showed in the results from the Box's test of equality of covariance matrices presented in tables 6, 8, and 10, Appendix 2. Wilks' Lambda was used to determine the interaction effect – it is a test which measures if the means of the groups are different on a particular characteristic, the closer it is to 0, the more the means of the groups differ (Cramer and Howitt, 2006; Pallant, 2007). Partial Eta Squared as a measure of strength of association (Tabachnik and Fidel, 2001) indicates what "proportion of variance of the dependent variable is explained by the independent variable." (Pallant, 2007, p. 208)

FINDINGS FOR THE OLDER INTERVENTION AND CONTROL GROUPS (MUSIC 1 AND CONTROL 1)

Table 5.3 shows that for the older children (***music 1*** and ***control 1***) in writing, mathematics, the picture, memory and puzzle tests there was no statistically significant interaction between belonging to the intervention or control group and pre- and post-intervention performance. The only case where there was a statistically significant interaction was reading (p = .019) with partial eta squared = .092 which indicated a moderate effect (Pallant, 2007; Cramer and Howitt, 2006). There was a substantial effect between pre- and post-intervention scores in reading, mathematics and writing with the partial eta squared greater than .90 in all three cases, with a moderate effect in the memory and puzzle tests, and a small effect for the picture test. These findings were significant statistically (p < .05). There was no main effect main for participation in the music program against the control group in any of the six assessments with p > .22 throughout. All the statistically significant results are highlighted in bold.

Table 5.3: The impact of the intervention compared with the control over two time periods for the older groups (music 1 and control 1)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	P	Partial Eta Squared
Reading	**.908**	**.019**	**.092**	**.060**	**.000**	**.94**	.766	.002
Writing	.955	.108	.045	**.087**	**.000**	**.91**	.445	.010
Mathematics	.986	.372	.014	**.089**	**.000**	**.91**	.636	.004
Picture test	.990	.456	.010	**.934**	**.05**	**.06**	.810	.001
Memory test	.993	.521	.007	**.781**	**.000**	**.21**	.325	.017
Puzzle test	.982	.312	.018	**.628**	**.000**	**.37**	.224	.026

FINDINGS FOR THE MIDDLE INTERVENTION AND CONTROL GROUPS (MUSIC 2 AND CONTROL 2)

Table 5.4 presents the results of the analysis of variance for the middle groups (***music 2*** and ***control 2***). As presented, there were no significant interactions between being in the middle intervention or control group and pre- and post- performance in reading, writing, mathematics, and the picture, and puzzle tests. The only statistically significant interaction was in the case of the memory test (p = .0001, the partial eta squared .229 which indicates a very large effect). In all cases the difference between pre- and post- performance was statistically significant with large differences in reading, writing and mathematics and moderate differences in the picture, memory and puzzle tests. The main effect comparing taking part in the intervention or control group was significant in the puzzle test (p = .012 and partial eta squared = .103, large effect size). However, it is important to observe that this interaction was in favour of the control group. The music intervention group achieved higher scores in the puzzle test at the end of intervention, but had higher scores at the beginning so their improvement over time was not as great as for the control group. These differences are presented graphically later in the chapter.

Table 5.4: The impact of the intervention compared with the control over two time periods for the middle groups (music 2 and control 2)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	P	Partial Eta Squared
Reading	.996	.611	.004	**.057**	**.000**	**.943**	.216	.026
Writing	.971	.191	.029	**.046**	**.000**	**.954**	.682	.003
Mathematics	.981	.295	.019	**.046**	**.000**	**.954**	.167	.032
Picture test	1.0	.880	.000	**.647**	**.000**	**.353**	.117	.041
Memory test	**.771**	**.000**	**.229**	**.540**	**.000**	**.460**	.120	.040
Puzzle test	.967	.162	.033	**.573**	**.000**	**.427**	**.012**	**.103**

FINDINGS FOR THE YOUNGEST INTERVENTION AND CONTROL GROUPS (MUSIC 3 AND CONTROL 3)

For the youngest groups (***music 3*** and ***control 3***) there was a significant relationship between the participation in the music programme in comparison with the control group in relation to pre- and post- test performance in the picture test (p = .003, partial eta squared = .144, a very large effect). All six areas of assessment showed statistically significant improvement over time (p < .05) and large effect sizes with partial eta squared greater than .14 (Pallant, 2007). The main effect comparing participation in the music programme and the control group was statistically significant in mathematics (p = .032, a moderate size effect suggested by partial eta squared at the .079). Table 5.5 presents the results of the analysis of variance for the youngest groups (***music 3*** and ***control 3***).

Table 5.5: The impact of the intervention compared with the control over two time periods for the youngest groups (music 3 and control 3)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	P	Partial Eta Squared
Reading	.978	.267	.022	**.039**	**.000**	**.961**	.169	.033
Writing	.972	.210	.028	**.029**	**.000**	**.971**	.121	.042
Mathematics	.984	.346	.016	**.038**	**.000**	**.962**	***.032***	***.079***
Picture test	**.856**	**.003**	**.144**	**.293**	**.000**	**.707**	.875	.000
Memory test	.999	.820	.001	**.660**	**.000**	**.340**	.265	.022
Puzzle test	.992	.506	.008	**.467**	**.000**	**.533**	.872	.000

5.3.6 Comparison of the intervention and the control groups by changes over time in each measurement area

Figures 5.1, 5.2, 5.3, 5.4, 5.5, and 5.6 illustrate the changes in measures in all six areas of testing for the older (***music 1*** and ***control 1***), middle (***music 2*** and ***control 2***) and youngest (***music 3*** and ***control 3***) intervention and control groups at the two times of testing (data collected pre- and post-intervention over the period of the first year of the main study). As expected there were positive changes in all of the scores for all of the students over the period of the school year. The key question for the research presented here was whether there were greater changes in the music groups as opposed to the control groups.

In reading, as set out in Figure 5.1, the oldest groups ***music 1*** started the year marginally below their peers and finished it with slightly better results. The middles groups (***music 2*** and ***control 2***) had a very similar progression pattern with the intervention group starting and finishing with slightly higher scores. Similarly, the progression for the youngest groups (***music 3*** and ***control 3***) were parallel with the intervention group starting and finishing with slightly higher attainment. In all cases p = .0001. To further examine the difference in progression over the two periods of time before and after the intervention between music and control groups, the mean difference was calculated. The difference between ***music 1*** and ***control 1*** (the oldest groups) was **0.2**, between ***music 2*** and ***control 2*** (the middle groups) was - 0.11, and for ***music 3*** and ***control 3*** (the youngest groups) was **0.13**. The scores supporting the hypothesis that participating in the music programme had a positive impact on the children's learning are highlighted in bold.

Figure 5.1: Change in results in reading for the intervention and the control groups over two periods of time

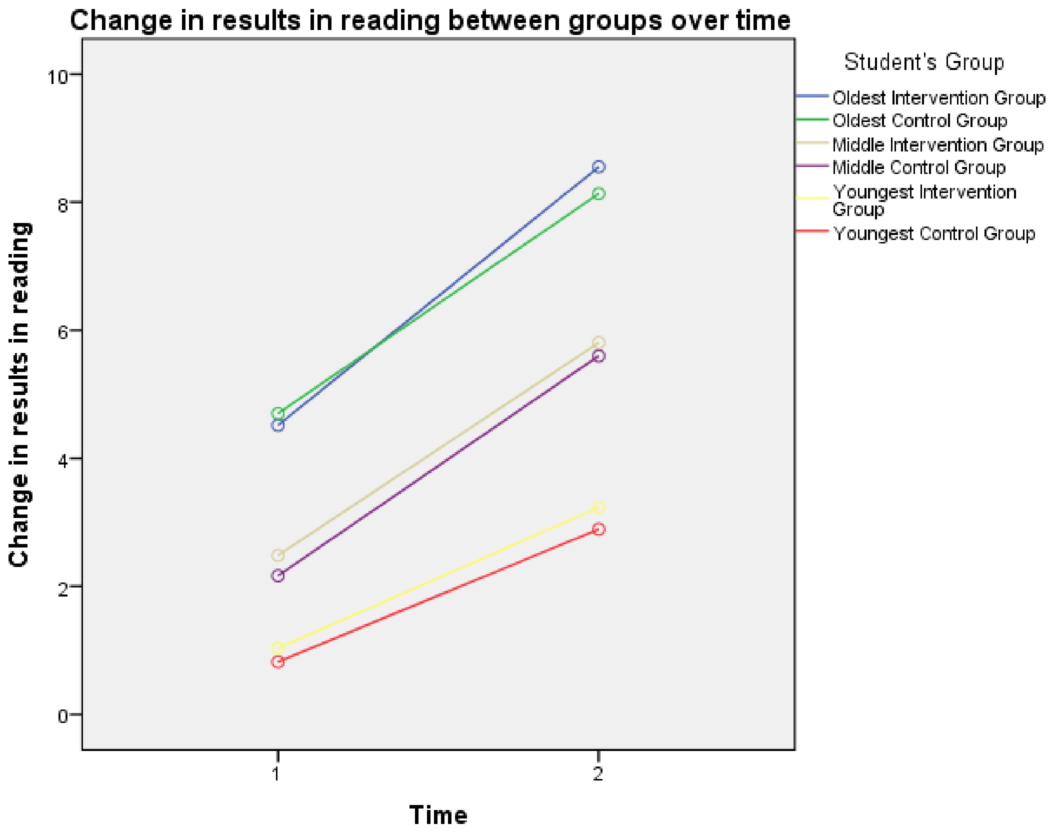
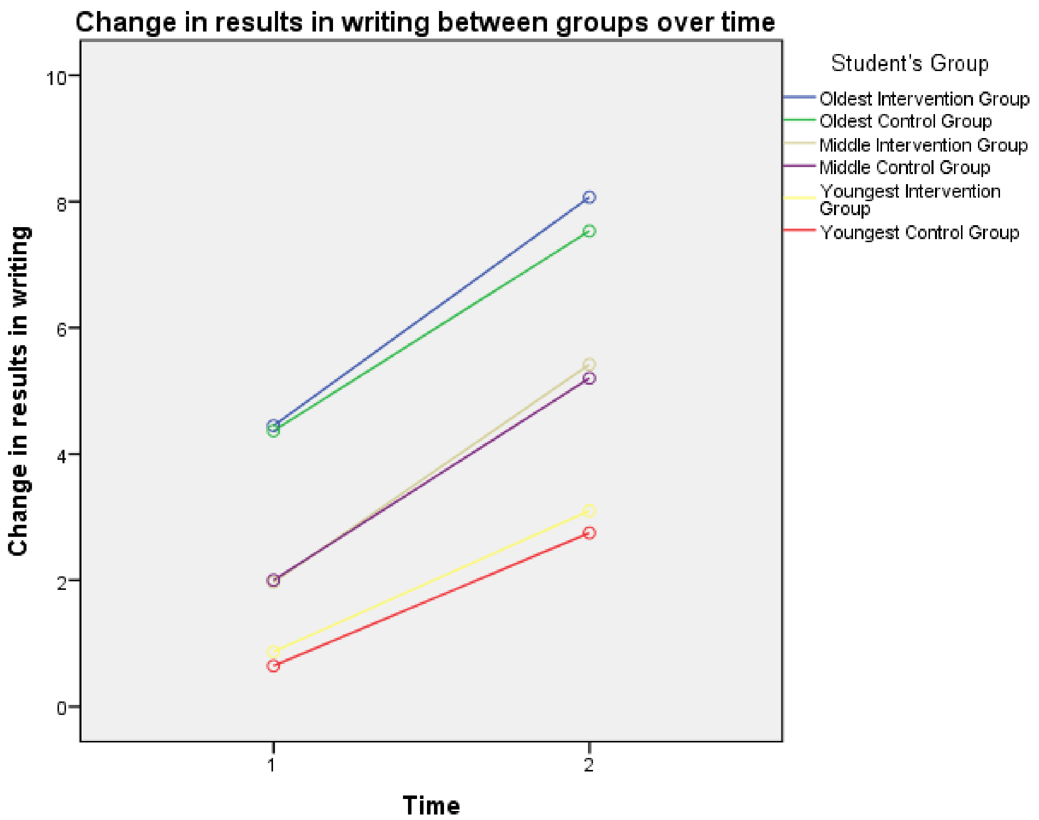


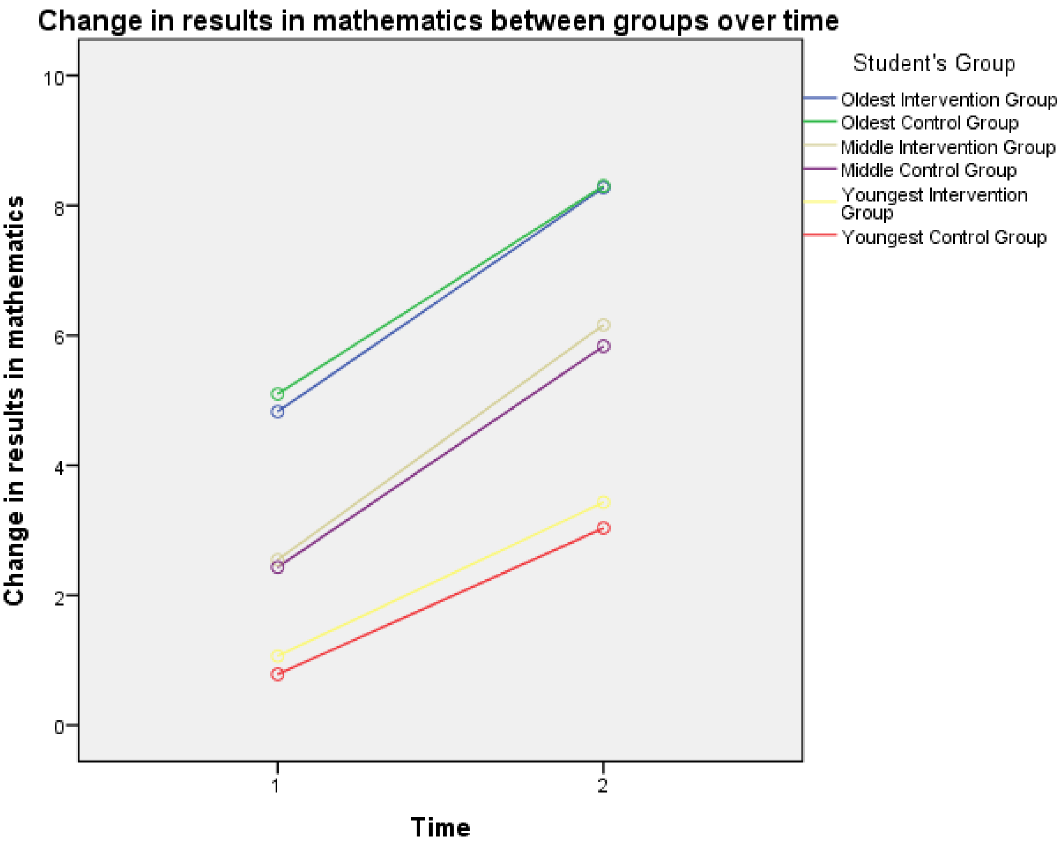
Figure 5.2 sets out the outcomes for writing in all groups. The oldest groups (***music 1*** and ***control 1***) started with the same scores. The music intervention group achieved higher scores at the end of the year. Both middle groups (***music 2*** and ***control 2***) performed almost identically. The youngest groups (***music 3*** and ***control 3***) had a parallel progression pattern with ***music 3*** starting and finishing the year slightly better than ***control 3*** (p = .0001 in all cases). The difference in progression between music and control groups in writing was **0.46** for ***music 1*** and ***control 1*** (the oldest groups), **0.25** for ***music 2*** and ***control 2*** (the middle groups), and **0.13** for ***music 3*** and ***control 3*** (the youngest groups).

Figure 5.2: Change in results in writing for the intervention and control groups over two periods of time



In mathematics, as showed in Figure 5.3, the oldest group ***music 1*** started the year slightly below their peers but had matched their performance in the end of year results. There were very slight differences in performance in the middle groups with ***music 2*** achieving slightly higher than ***control 2***. As in previous assessments, the youngest groups performed similarly with ***music 3*** starting and finishing the year with slightly higher scores. All scores were statistically significant with p = .0001. The difference in progression between music and control groups in mathematics was **0.22** for ***music 1*** and ***control 1*** (the oldest groups), **0.21** for ***music 2*** and ***control 2*** (the middle groups), and **0.11** for ***music 3*** and ***control 3*** (the youngest groups).

Figure 5.3: Change in results in mathematics for the intervention and control groups over two periods of time



The results of the picture test, presented in Figure 5.4, show that both of the older groups (***music 1*** and ***control 1***) had nearly the same starting point at the beginning of the year. ***Music 1*** achieved lower than their peers towards the end of the year however that result was not statistically significant. Performance in this and in the puzzle test was measured in the time which the children took to complete a spatial-temporal task so the less time taken, the better the achievement. In the middle groups (***music 2*** and ***control 2***) there was a difference between the groups at the beginning of the year. This difference remained the same throughout the year with the same level of progression in both groups (p = .0001). In the youngest groups, ***music 3*** performed worse than ***control 3*** at the beginning of the year but by the end of the year, the children in ***music 3*** outperformed their peers (p = .0001). The difference in progression between music and control groups in the picture test was **– 0.95** for ***music 1*** and ***control 1*** (the oldest groups), 0.17 for ***music 2*** and ***control 2*** (the middle groups) and **– 2.29** for ***music 3*** and ***control 3*** (the youngest groups). As the picture and the puzzle test were constructed in such a way that the less time taken to finish the task the better the result, the music group progressing better than their peers would be illustrated by a negative number.

Figure 5.4: Change in results in the picture test for the intervention and control groups over two periods of time

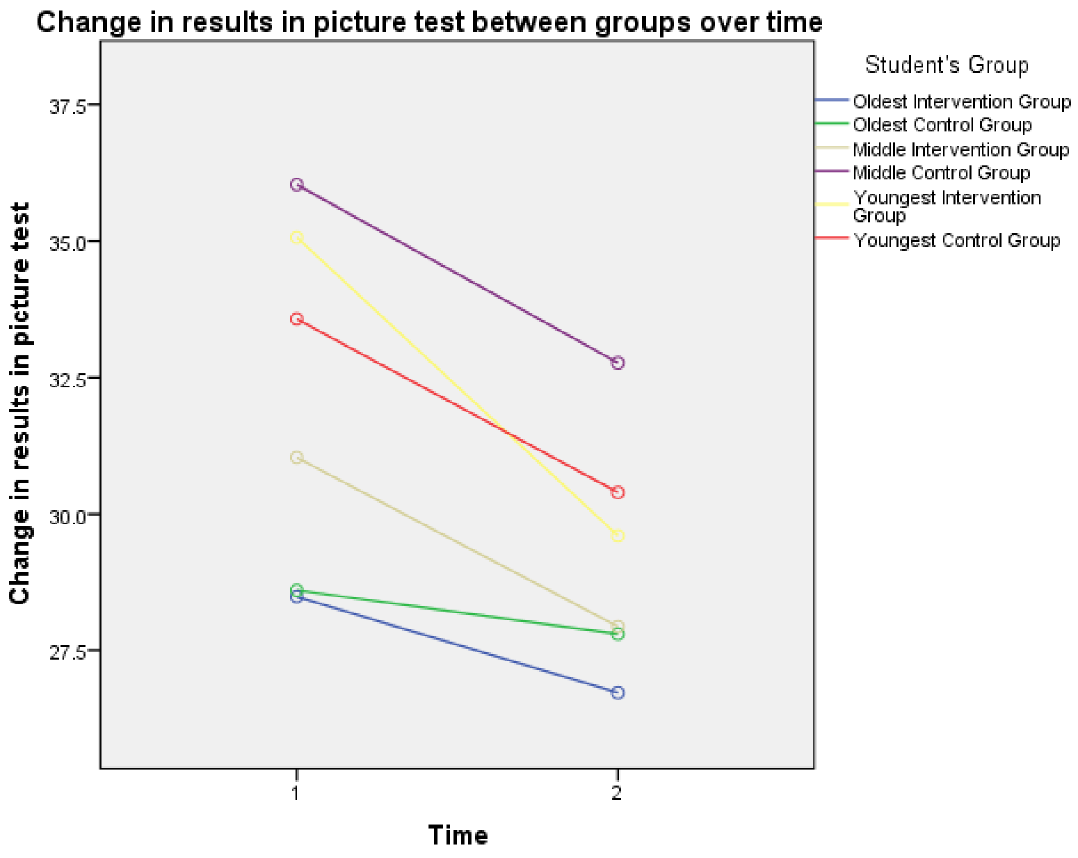
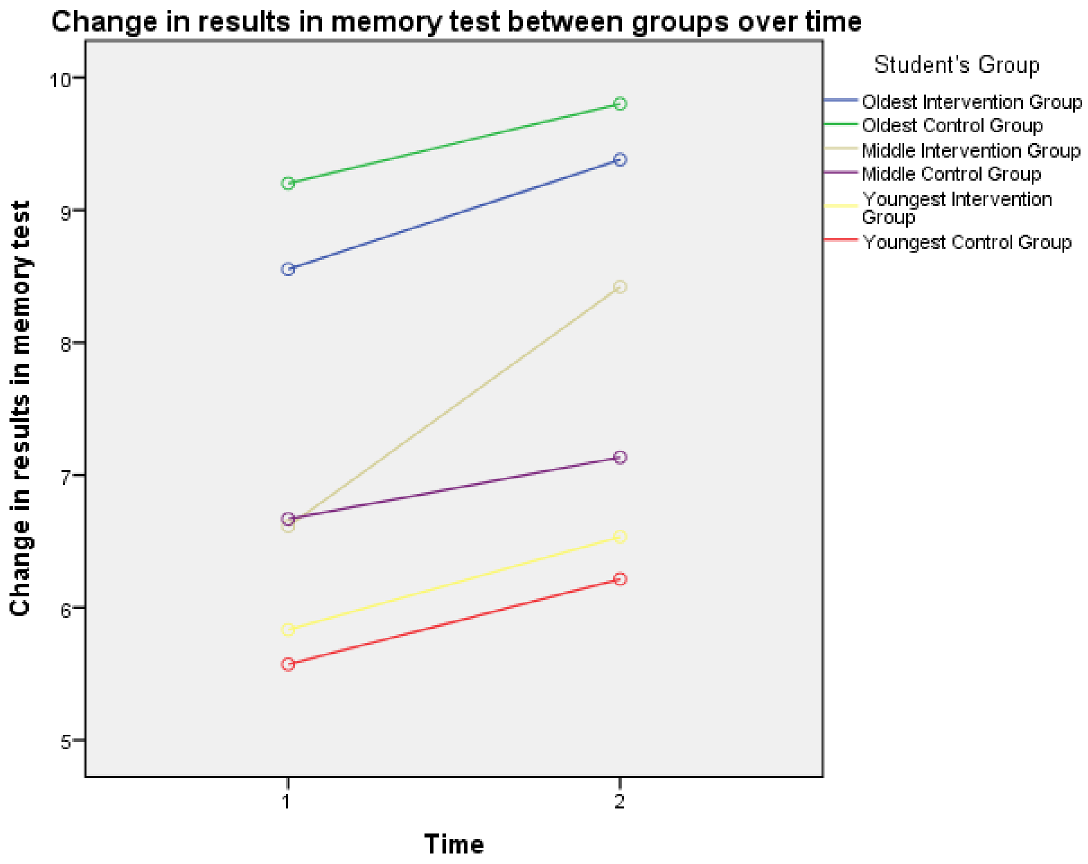


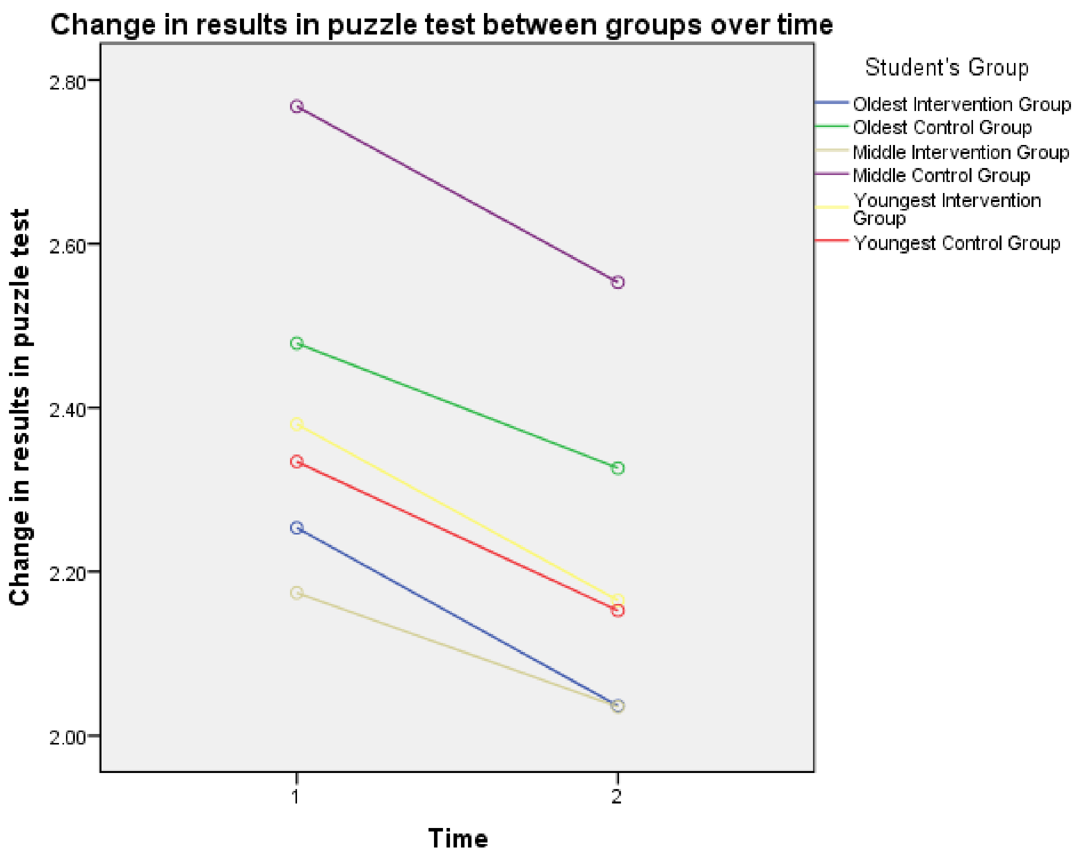
Figure 5.5 presents the children's performance on the memory tests. The oldest groups (***music 1*** and ***control 1)*** progressed very similarly with the control group starting and finishing the year with slightly higher scores. Both of the middle groups (***music 2 and control 2***) started the year with similar results but during the year ***music 2*** outperformed their peers. In the youngest groups, ***music 3*** started marginally higher than ***control 3*** and the groups progressed similarly over the year. All results were statistically significant apart from ***control 2***. The difference in progression between music and control groups in the memory test was **0.22** for ***music 1*** and ***control 1*** (the oldest groups), **1.22** for ***music 2*** and ***control 2*** (the middle groups), and **0.06** for ***music 3*** and ***control 3*** (the youngest groups).

Figure 5.5: Change in results in the memory test for the intervention and control groups over two periods of time



In the puzzle test, as presented in Figure 5.6, the oldest group ***music 1*** started the year with better results (less time needed to perform the task) and over the year progressed more rapidly than ***control 1.*** There was a statistically significant difference in scores between the middle groups (***music 2*** and ***control 2***) at the beginning of the year and in ***control 2*** a greater change over the period of time was observed. Within the youngest groups, ***music 3*** started with slightly lower scores than ***control 3*** but by the end of the year the results of both groups were similar (p = .0001 in all cases). The difference in progression between music and control groups in the puzzle test was **– 0.06** for ***music 1*** and ***control 1*** (the oldest groups), 0.08 for ***music 2*** and ***control 2*** (the middle groups), and **- 0.03** for ***music 3*** and ***control 3*** (the youngest groups). Similar to the picture test, the negative results show that the music groups progressed more than their peers.

Figure 5.6: Change in results in the puzzle test for the intervention and control groups over two periods of time



5.4 Chapter summary

The hypothesis of this study assumed that participation in the music programme created for the purposes of this research would have an impact on children's spatial-temporal skills which might transfer to learning in mathematics. The analyses in this chapter aimed to explore whether children who took part in the intervention in the main study had achieved higher scores than the children from the control groups in the picture and puzzle tests assessing spatial temporal skills, and possibly in mathematics.

The findings showed a number of relationships:

- In mathematics, the progression achieved by the youngest music group was statistically significantly greater than that of their peers from the control group suggesting a positive influence of the intervention on the learning of mathematics.
- The older music groups also showed a greater change in scores over time in mathematics but these results were not statistically significant. This finding confirms the proposition from previous studies that the younger the children when they participate in music instruction the greater the impact on other skills.
- In the spatial-temporal measurements, progression was greater for both younger music groups. The youngest intervention group outperformed their peers in the picture test while the middle group did so in the puzzle test. These differences were statistically significant. This confirms the impact of the music programme on the enhancement of spatial-temporal skills and points to the it being greater the younger the age of the children.
- In performance on the memory test, there were no statistically significant differences between the intervention and control groups for the oldest and youngest groups. There was a statistically significant difference between the groups for the middle group.

Table 5.6 presents which groups performed better in pre- and post- intervention testing and in which groups the progression at the two times of testing was greater. The highlighted differences were statistically significant.

Table 5.6: Higher achieving groups in pre- and post- testing and the progression over the time of the intervention

	Oldest group			Middle group			Youngest group		
	Pre-	Post-	Change	Pre-	Post-	Change	Pre-	Post-	Change
Reading	*control1*	*music1*	***music1**** η_p^2 **= .092** ***p = .019***	***music2 t(59)=2.13 p = .037***	*music2*	*control2*	*music3*	*music3*	*music3*
Writing	*music1*	*music1*	*music1*	*even*	*music2*	*music2*	*music3*	*music3*	*music3*
Mathematics	*control1*	*even*	*music1*	*even*	*music2*	*music2*	*music3*	***music3 t(56)=2.16 p = .036***	***music3*** η_p^2 **= .079** ***p = .032***
Picture test	*even*	*music1*	*music1*	*music2*	*music2*	*control2*	*control3*	*music3*	***music3*** η_p^2 **= .144** ***p = .003***
Memory test	*control1*	*control1*	*music1*	*even*	***music2 t(59)=3.13 p = 018***	***music2*** η_p^2 **= .229** ***p = .000***	*music3*	*music3*	*music3*
Puzzle test	*music1*	*music1*	*music1*	***music2 t(59)=2.68 p = .01***	***music2 t(59)=2.43 p = .018***	***control2*** η_p^2 **= .103** ***p = .00***	*control3*	*even*	*music3*

*groups highlighted in bold showed statistically significant result

To enable more robust analyses, the results of all the children who throughout the programme were in Year 1 and in Foundation Stage were considered together as combined Yr1 and FS groups. These findings are presented in chapter 6.

Chapter 6: Relationships between groups: Analysis of all Year1 and Foundation Stage data throughout the period of intervention

6.1 Introduction

Throughout the period of the intervention there were four groups of children who attended Year 1 classes in two different academic years and a further four groups who attended FS classes. These children were taught by different teachers in different environments and although they followed the same curricular specifications it is likely that the way they were taught was different. To minimise the effects of such differences the data from the different classes were analysed together according to the school year that the children were in. This created data from four groups to be analysed. There were two older groups: the ***Yr1 Music*** group with 60 children and ***Yr1 Control*** group with 60 children, and two younger groups: the ***FS Music*** group (61) and ***FS Control*** group (58). The substantial size of each of the groups with an overall total of 239 facilitated robust analysis whilst still taking account of the differences in the assessment between the more formal testing in Year1 and the more observation based evaluation in the Foundation Stage (Reception class).

The research questions considered in this chapter are:

- How, if at all, does participation in music influence learning in mathematics?
- Does participation in music improve spatial-temporal skills? What is the relationship between the development of these abilities and learning in mathematics?

6.2 Results

6.2.1 Pre-intervention testing

At the start of the intervention there were some differences between the music and control groups. The ***Yr1 Music*** group had slightly higher scores in reading (mean difference [MD] = 0.13), the picture test (MD = - 1.73) and the puzzle test (MD = - 0.36), whilst the control group had better results in mathematics (MD = 0.1) and the memory test (MD = 0.26). Some of the mean differences were negative as they were the result of subtracting the scores of the ***Yr1 Control*** group from the ***Yr1 Music*** group. An independent-samples test was conducted to establish whether these differences were statistically significant. Out of the six assessments only the difference in the puzzle test was statistically significant (t (118) = - 2.190, p = .031 (two-tailed)). In all of the other assessments the differences were not statistically significant.

Of younger groups, the ***FS Music*** group achieved higher scores in all tests but reading where both sets of scores were very similar. The mean differences were as follows: writing (MD = 0.05), mathematics (MD = 0.15), picture test (MD = - 1.48), memory test (MD = 0.34), and puzzle test (MD = - 0.21). These differences were very small and the independent-samples t-test established that none of them were statistically significant.

6.2.2 Post-intervention testing

Comparison of the means of the scores achieved by the Yr1 groups at the end of the intervention revealed that the ***Yr1 Music*** group was better than the control group in all areas of assessment with differences respectively: writing (MD = 0.17), picture test (MD = - 1.6), memory test (MD = 0.31), and puzzle test (MD = - 0.63) whilst differences in reading and mathematics were minimal. The only statistically significant difference was in the puzzle test (t (118) = - 2. 473, p = .015).

Between the FS groups the results of the ***FS Music*** group were higher than the control group. The mean differences were: reading (MD = 0.33), writing (MD = 0.16), mathematics (MD = 0.26), picture test (MD = - 2.98), memory test (MD = 0.12), and puzzle test (MD = - 0.31). An independent-samples t-test showed that there were statistically significant differences in reading (t (117) = 2.208, p = .029), and in the puzzle test (t (117) = - 2.052, p = .042).

6.2.3 Change of scores over the period of the intervention

A paired-samples t-test was used to establish how the scores changed over time in each group in each of the assessment areas. In all cases the changes were statistically significant. Table 6.1 presents the values of t, the difference in means and Pearson's correlation coefficient. With one exception, in all cases the significance value for the Pearson's correlation was .0001.

In the older groups, the ***Yr1 Music*** group outperformed the control group in writing, mathematics, and the picture, memory and puzzle tests. For the ***Yr1 Music*** group reading, writing and mathematics had a moderate correlation with previous scores whilst for the spatial-temporal and memory tests the correlation was strong. For the control group these relationships were strong apart from mathematics where the strength of correlation was very small. In the FS groups, the ***FS Music*** group outperformed their peers in reading, writing, mathematics, and spatial-temporal tests. The ***FS Control*** group achieved better scores in the memory test. All of the correlations between the scores at the two points in time were moderate or strong apart from the result in mathematics in the control group where the correlation was small.

Table 6.1: Changes in scores in different groups in all areas of assessment over the time of the intervention

	reading	writing	Mathematics	picture test	memory test	puzzle test
Yr1 Music Group	t(59)= 16.0 MD = 2.45 r = .517	t(59)= 15.8 **MD = 2.48** r = .417	t(59)= 18.4 **MD = 2.73** r = .320	t(59)= -7.0 **MD = -3.61** r = .996	t(59)= 9.8 **MD = 1.41** r = .883	t(59)= -7.8 **MD = -.23** r = .959
Yr1 Control Group	t(59)= 17.0 **MD = 2.55** r = .497	t(59)= 16.2 MD = 2.33 r = .544	t(59)= 18.0 MD = 2.58 r = .086	t(59)= -7.5 MD = -2.86 r = .974	t(59)= 4.5 MD = .833 r = .744	t(59)= -7.7 MD = -.21 r = .976
Music 2 Group	t(60)= 23.1 MD = **1.88** r = .715	t(60)= 15.6 **MD = 1.63** r = .550	t(60)= 21.9 **MD = 1.9** r = .588	t(60)= -12.1 **MD = -5.55** r = .963	T(60)=3.4 MD = .44 r = .844 p = .001	t(60)= -8.6 **MD = -.27** r = .947
Control 2 Group	t(57)= 16.3 MD = 1.51 r = .455	t(57)= 14.4 MD = 1.51 r = .322	t(57)= 20.4 MD = 1.79 r = .147	t(57)= -8.8 MD = -3.1 r = .976	t(57)= 5.6 MD = **.65** r = .806	t(57)= -6.2 MD = -.18 r = .973

value of p = .0001 in all unmarked cases

6.2.4 Interactions between the outcomes for the control and the intervention groups pre- and post-intervention

The second part of the analysis examined the impact of the intervention in contrast to the control group over time. A repeated measures analysis of variance was undertaken to investigate the impact of the music intervention on the two age groups in all areas of assessments over two periods of time. Before proceeding with the analyses descriptive statistics and several assumptions were checked (Gravetter and Wallnau, 2004; Pallant, 2007). Tables 11 and 13 present the descriptive statistics for the younger and the older groups. The Levene's test of equality of error variances was calculated and at no point was the assumption of the homogeneity of variance violated (as presented in tables 12 and 14, Appendix 2). The assumption of the homogeneity of inter-correlations was not violated as shown in the results from the Box's test of equality of covariance matrices presented in tables 12 and 14 in Appendix 2.

No statistically significant interactions were found between belonging to an intervention or control group and the assessment measure outcomes at the two times of testing in reading, writing, mathematics, and the picture and puzzle tests for the older children. Analysis of the memory test data (p = .013, partial eta squared .051) indicated a moderate relationship with the control group achieving higher scores. Unsurprisingly there was a statistically significant effect for time in all areas of testing with partial eta squared at a level above .14 in all cases indicating a large effect size. The main effect comparing participation in the intervention versus belonging to a control group was statistically significant for the puzzle test (p = .021, partial eta squared .045). This indicated a small effect with higher achievement in the intervention group. Table 6.2 presents the results for the Yr1 children.

Table 6.2: The impact of the intervention compared with the control over two time periods in the Yr1 groups (Yr1 Music and Yr1 Control)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	P	Partial Eta Squared
Reading	.998	.64	.002	**.177**	**.000**	**.823**	.628	.002
Writing	.996	.48	.004	**.187**	**.000**	**.813**	.596	.002
Mathematics	.996	.46	.004	**.151**	**.000**	**.849**	.841	.000
Picture test	.989	.24	.011	**.536**	**.000**	**.464**	.313	.009
Memory test	**.949**	**.013**	**.051**	**.554**	**.000**	**.446**	.946	.000
Puzzle test	.998	.63	.002	**.490**	**.000**	**.510**	**.021**	**.045**

In the younger groups, there was statistically significant interaction between participation in the music programme compared with the control group and time in two assessment areas. These were the picture and the puzzle test with p = .0001 (partial eta squared = .132, a moderate effect size), and p = .037 (partial eta squared = .037, a small effect size) respectively. In both of these tests the results of the intervention group were greater than these of the control group. All six areas of assessment were statistically significantly different related to time with p < .05. The main effect comparing the intervention and the control groups was statistically significant in mathematics (p = .035, partial eta squared = .035) and the puzzle test (p = .041, partial eta squared = .031). In both cases the effect size was small. Also in these two cases the intervention group achieved higher scores. Table 6.3 presents the results of an analysis of variance for the FS groups.

Table 6.3: The impact of the intervention compared with the control over two time periods in the FS groups (FS Music and FS Control 1)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	P	Partial Eta Squared
Reading	.929	.003	.071	**.133**	**.000**	**.867**	.181	.015
Writing	.994	.412	.006	**.205**	**.000**	**.765**	.358	.007
Mathematics	.993	.381	.007	**.115**	**.000**	**.885**	**.035**	**.037**
Picture test	**.868**	**.000**	**.132**	**.345**	**.000**	**.655**	.413	.006
Memory test	.987	.222	.013	**.744**	**.000**	**.256**	.393	.006
Puzzle test	**.963**	**.037**	**.037**	**.511**	**.000**	**.489**	**.041**	**.031**

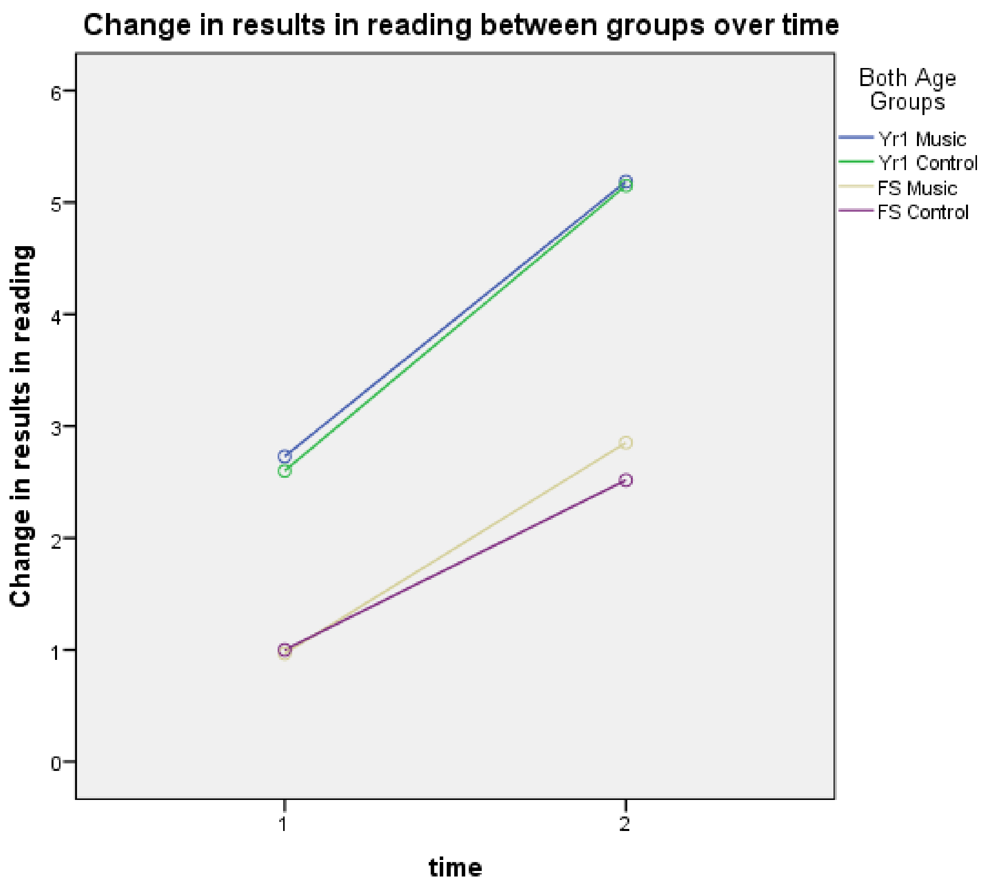
When both ages of children were considered, a repeated measures analysis of variance revealed that only for the picture test was the interaction between belonging to a group and time statistically significant (Wilks Lambda = .947, p = .0001, partial eta squared = .053). The main effect for the two conditions was statistically significant for the puzzle test with p = .004 (partial eta squared = .034, a small effect size). In both these assessments higher scores were achieved by the intervention group.

6.2.5 Comparison of the intervention and the control groups by changes over time in each measurement area

Further analysis considered changes in measures in all areas of testing for the Yr1 and the FS intervention and control groups over the two periods of time. Data were collected pre- and post- intervention over the length of a school year when the older groups were in year one and the younger children were in foundation stage.

Figure 6.1 presents the change in results in reading. Within the Yr1 groups, the control group started marginally lower and finished the year with results equal to the music group. The progression level, measured as a subtraction of the mean difference in scores achieved by the control group from the mean difference of the intervention group was - 0.1. Both FS groups began the year at the same level of attainment but the intervention group's progression was greater than for the control group by 0.37.

Figure 6.1: Change in results in reading for the intervention and control groups over two periods of time



In writing both of the older groups started with the similar scores but the intervention group progressed more than the control group by 0.15. The ***FS Music*** group also started from a similar point to the ***FS Control*** group but outperformed their peers towards the end of the year by 0.12 as presented in Figure 6.2.

Figure 6.2: Change in results in writing for the intervention and control groups over two periods of time

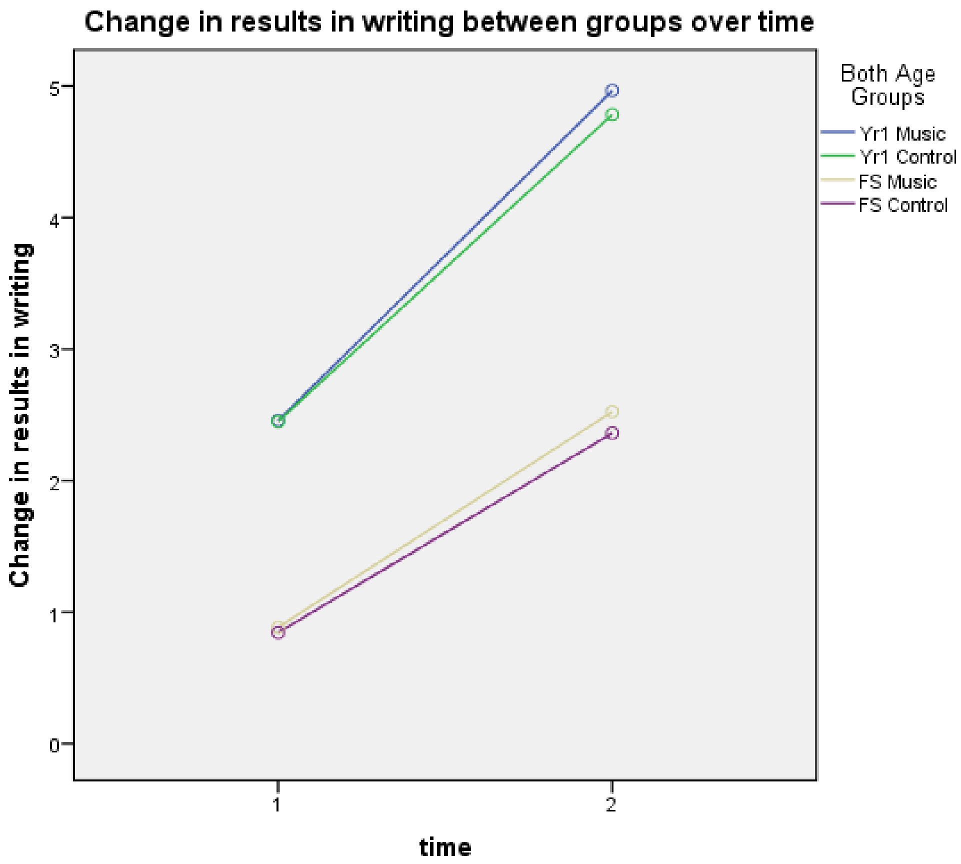
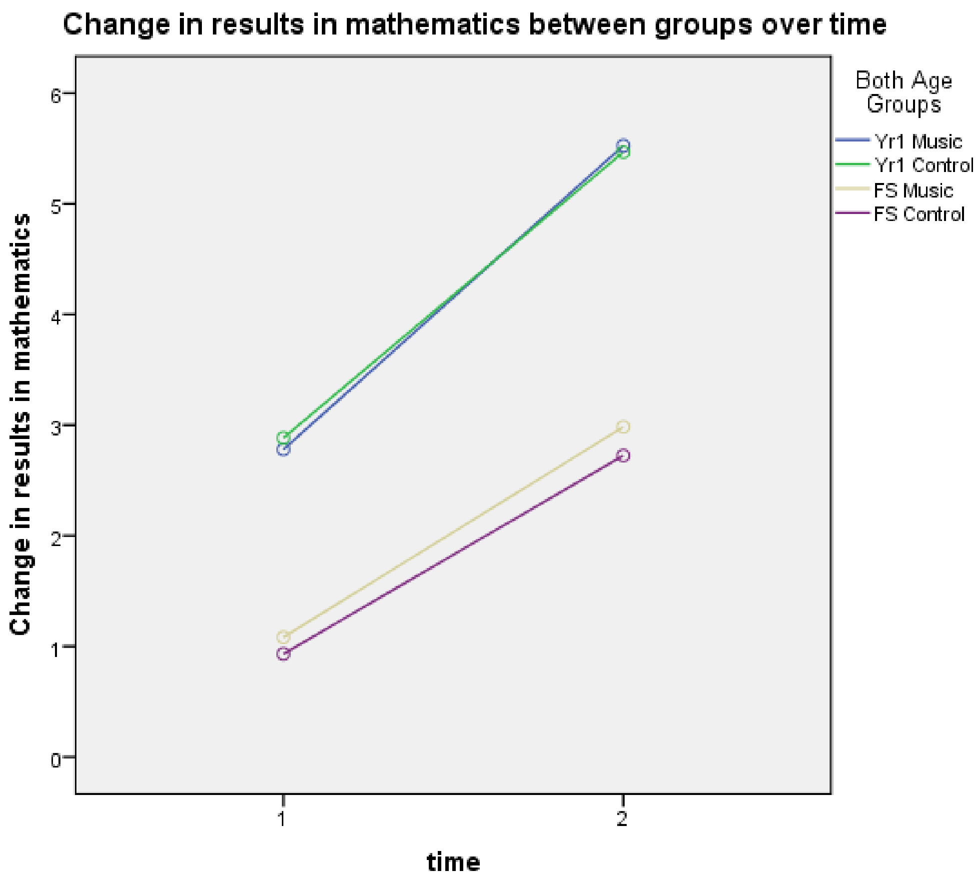


Figure 6.3 shows the changes in results in mathematics. Of the older groups, the intervention group started slightly lower than the control group and achieved higher gains by 0.15. The ***FS Music*** group scored higher at the beginning of the year and at the end of the year the gap between the two groups increased to 0.11.

Figure 6.3: Change in results in mathematics for the intervention and control groups over two periods of time



Changes in achievement in the picture test are presented in Figure 6.4. The ***Yr1 Music*** group progressed more than the control group with a difference of 0.75. The difference in change in the results between the younger groups was 2.45. The intervention group made the greatest progress.

Figure 6.4: Change in results in the picture test for the intervention and control groups over two periods of time

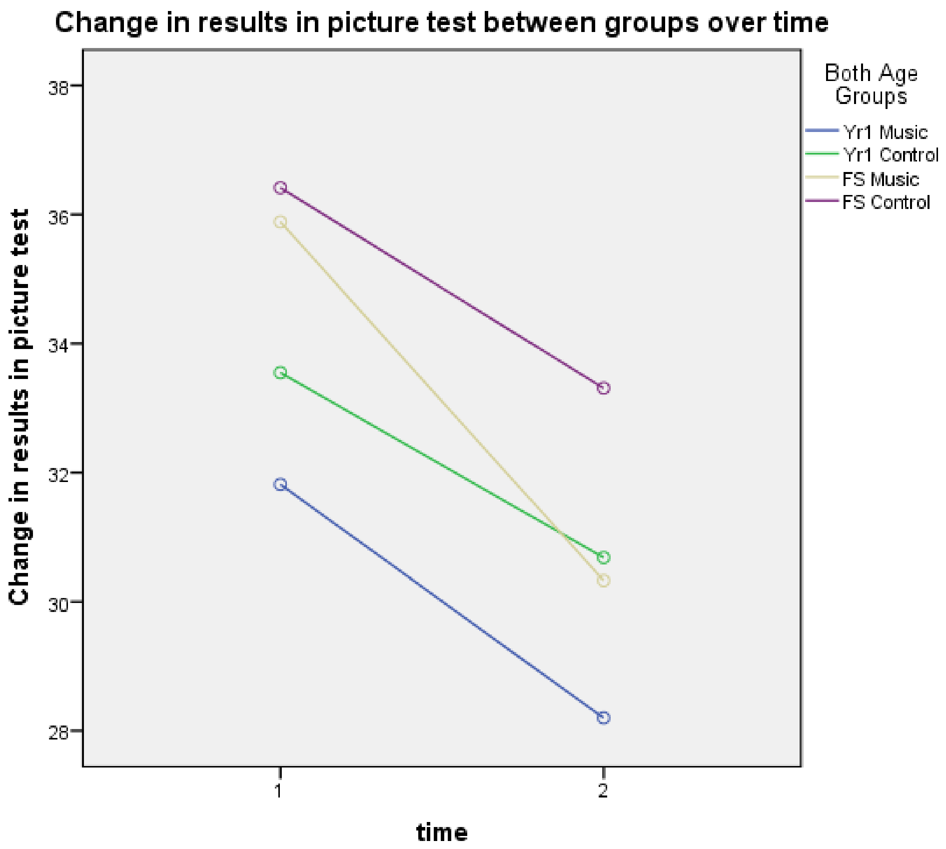
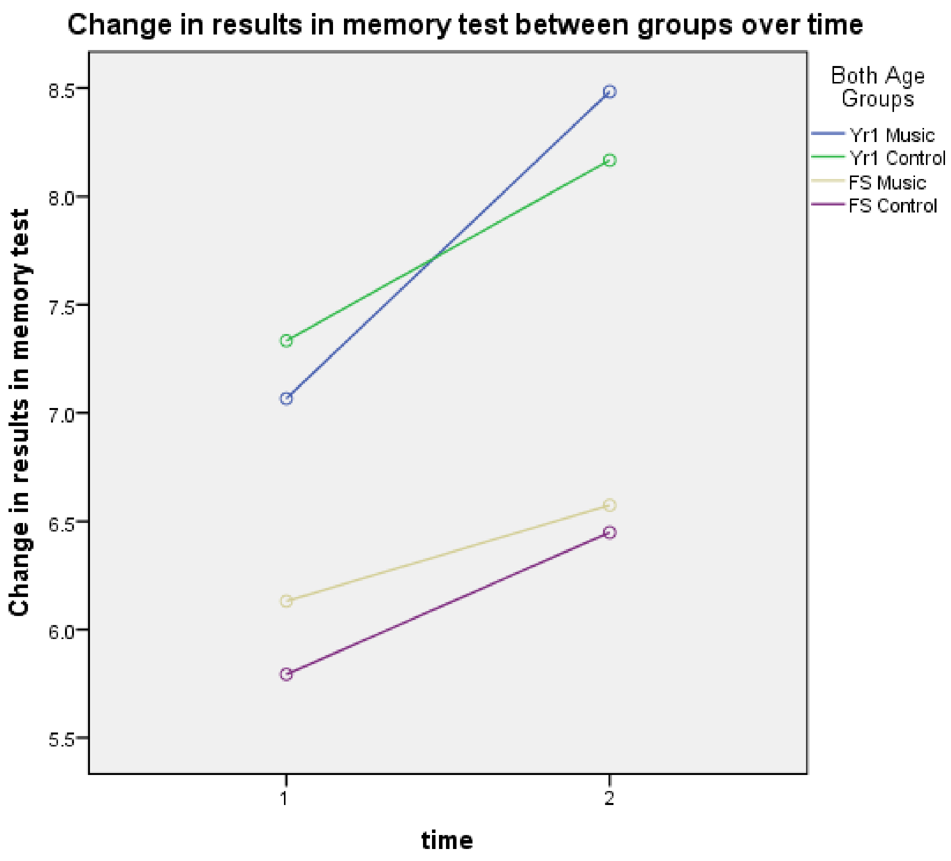


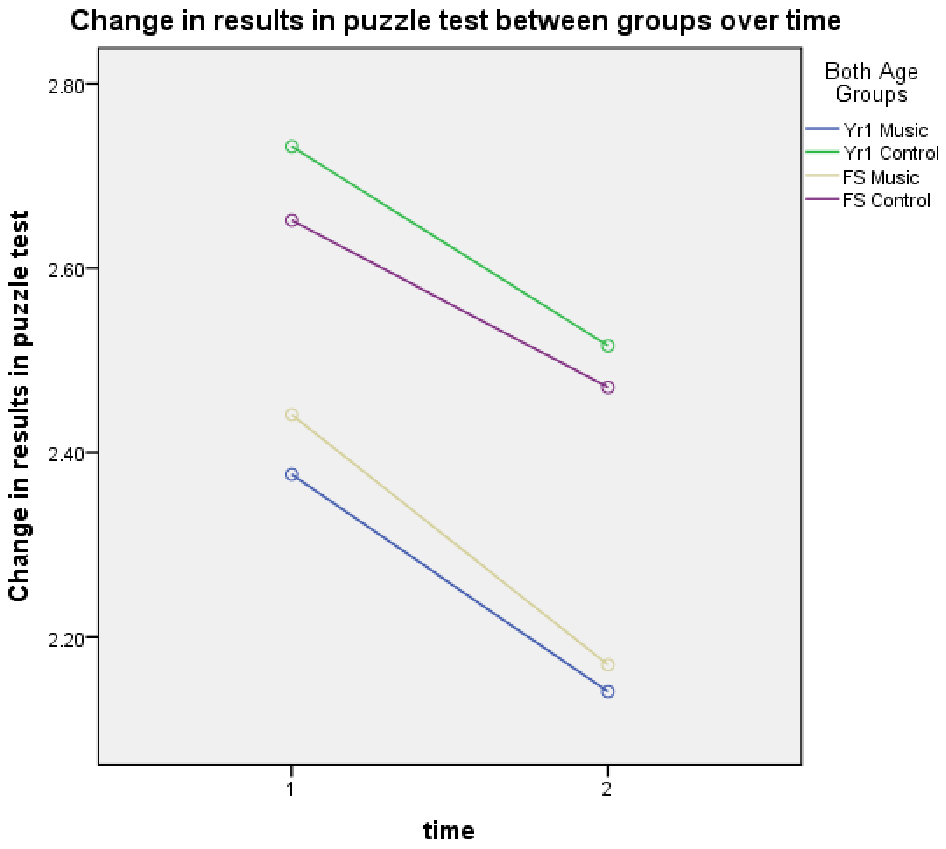
Figure 6.5 presents the changes in the scores in the memory test. Between the older groups, the ***Yr1 Music*** group progressed more by 0.58. For the younger groups the difference was - 0.21 indicating that the control group made the greatest progress.

Figure 6.5: Change in results in the memory test for the intervention and control groups over two periods of time



All four groups progressed very similarly in the puzzle test as presented in Figure 6.6. Both older and younger intervention groups achieving slightly higher, 0.02 and 0.09 respectively.

Figure 6.6: Change in results in the puzzle test for the intervention and control groups over two periods of time



6.3 Chapter summary

The data from all of the classes in each year group were combined to enable more robust statistical analyses with larger sample sizes. As the children in the different classes were taught by different teachers using different pedagogical approaches, combining the data minimised possible confounding differences between classes. The analyses set out to investigate the differences in performance in spatial-temporal and mathematical tests between the intervention and the control groups using data collected throughout the study in two age groups - Yr1 and in FS classes. Overall the sample included 239 children.

The results of the analyses highlighted several statistically significant differences between the intervention and the control groups as follows:

- In mathematics, the younger children who participated in the music programme achieved statistically significant change of scores over the time of the intervention. This confirms the findings from the main part of the study and suggests that rhythmic instruction has a positive impact on learning mathematics with a more pronounced effect in younger children.

- In the spatial-temporal measurements, both, younger and older music groups outperformed their peers in the puzzle test. These differences were statistically significant. The younger music group recorded statistically significantly greater progression in the picture test. These findings confirm the impact of the music programme on pupils' spatial-temporal reasoning, particularly as they are supported by the results from the pilot and the main study.

- In reading, the younger music group showed statistically significantly higher scores than their peers from the control group. Although reading was not a primary focus of this study, this outcome confirms findings from other studies in this field (see Overy, 2000; Corrigall and Trainor, 2011; Long, 2014; Hallam, 2015) and indicates possible directions for further research.

In table 6.4, groups which achieved higher scores in pre- and post- intervention testing and a greater change in scores over time are presented. The cases highlighted in bold were statistically significant.

Table 6.4: Higher achieving groups in pre- and post- testing and progression over the period of the intervention

	Older groups Yr1 Music and Yr1 Control			Younger groups FS Music and FS Control		
	Pre-	Post-	Change	Pre-	Post-	Change
Reading	*Yr1 Music*	*Yr1 Music*	*Yr1 Control*	*FS Control*	***FS Music t(117)=2.2 p = .029***	*FS Music*
Writing	*Yr1 Music*	*Yr1 Music*	*Yr1 Music*	*FS Music*	*FS Music*	*FS Music*
Mathematics	*Yr1 Control*	*Yr1 Music*	*Yr1 Music*	*FS Music*	*FS Music*	***FS Music*** η_p^2 ***= .144 p = .003***
Picture test	*Yr1 Music*	*Yr1 Music*	*Yr1 Music*	*FS Music*	*FS Music*	***FS Music*** η_p^2 ***= .144 p = .003***
Memory test	*Yr1 Control*	*Yr1 Music*	***Yr1 Music*** η_p^2 ***= .144 p = .003***	*FS Music*	*FS Music*	*FS Control*
Puzzle test	*Yr1 Music*	***Yr1 Music* t(118) = 2.4 p = .015***	***Yr1 Music*** η_p^2 ***= .144 p = .003***	*FS Music*	***FS Music t(117)=2.0 p = .042***	***FS Music*** η_p^2 ***= .144 p = .003***

*groups highlighted in bold showed statistically significant result

Chapter 7 considers the sustainability of the impact of the music programme on academic achievement.

Chapter 7: Relationships between groups after the programme was ended

7.1 Introduction

The results of this research confirm the existing evidence that pupils who participate in music programmes achieve higher scores in spatial-temporal tests and also score higher in other related assessments. This raises question as to whether such enhancements in performance are sustainable. Literature considering this issue is very limited, although there seems to be agreement that the longer the training the longer lasting effects it will bring. The only clear statement comes from Rauscher (2002) who suggested that at least two years of instruction were needed for sustained enhancement in spatial-temporal skills. The current study set out to examine whether there was any impact on children's school attainment. To additionally address the issue of sustainability, the timescale of this research was constructed to take account of Rauscher's suggestion with two years of the children's active participation in the music programme and further data collection after the instruction was ended. What happens when the music instruction is withdrawn? Does performance differ between intervention and control groups a year after the end of the music instruction? To answer such questions data from assessments in reading, writing and mathematics were collected one academic year after the music programme was withdrawn. This chapter summarises the analysis of these data and addresses the following research question:

- What are the long-term relationships between music and mathematics and is the impact sustainable?

7.2 Results

The results of the tests in reading, writing and mathematics were compared for the music and control groups at the end of the intervention. An independent-samples t-test showed that in all three assessments the music groups outperformed control groups with mean differences of MD = .231 in reading, MD = .284 in writing, and MD = .149 in mathematics. None of these differences were statistically significant.

The intervention was withdrawn in July 2013 and at the end of the academic year 2013/2014 another set of data was collected. Assessments in reading, writing, and mathematics are regularly recorded by the school so collection of these data did not add any additional workload for the teachers. It was considered unethical to disturb children's learning yet again to perform the spatial-temporal and memory tests.

The results of the music groups were still slightly higher than those of the control groups but the mean differences were smaller than before. In reading MD = .165, in writing MD = .185, and in mathematics MD = .076. These scores were not statistically significant.

A paired-samples t-test was used to explore how the data had changed between the withdrawal of the music programme and the end of following academic year. The results are presented in Table 7.1. Not surprisingly all of the changes over time were statistically significant (p = .0001, two tailed). However, in all three areas of assessment the control groups made better progress than their peers. These differences were very small.

Table 7.1: Changes in scores in different groups in reading, writing and mathematics over the time of the intervention

	Reading	writing	mathematics
Music groups	t(89) = 31.9 MD = 2.42 r = .972	t(89) = 27.9 MD = 2.34 r = .964	t(89) = 37.9 MD = 2.22 r = .974
Control groups	t(87) = 37.8 MD = 2.48 r = .967	t(87) = 34.8 MD = 2.44 r = .962	t(87) = 44.5 MD = 2.29 r = .979

value of p = .0001 in all unmarked cases

In assessing the impact of belonging to the intervention versus the control group over the period of time since the intervention ended, a repeated measures analysis was used. In neither of the assessment areas was there a significant interaction between belonging to the intervention or control group and time. There was also no significant main effect for the two conditions as shown in Table 7.2. In all three cases the main effect for time was statistically significant as might have been expected taking account of general educational progression.

Table 7.2: The impact of belonging to the intervention versus control groups over the period of an academic year after the end of the music programme

	Interaction between belonging to the intervention against the control group and time			Main effect for time			Main effect for belonging to the intervention against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	P	Partial Eta Squared
Reading	.998	.512	.002	**.069**	**.000**	**.931**	.612	.001
Writing	.995	.369	.005	**.084**	**.000**	**.916**	.531	.002
Mathematics	.995	.350	.005	**.050**	**.000**	**.950**	.746	.001

The performance of the intervention against control groups in all three areas of assessment over the two periods of time is presented in Figures 7.1, 7.2, and 7.3.

Figure 7.1 illustrates nearly the same progression in reading for both groups with the control group achieving marginally greater change.

Figure 7.1: Change in results in reading in intervention and control groups over the period of an academic year after withdrawal of the music programme

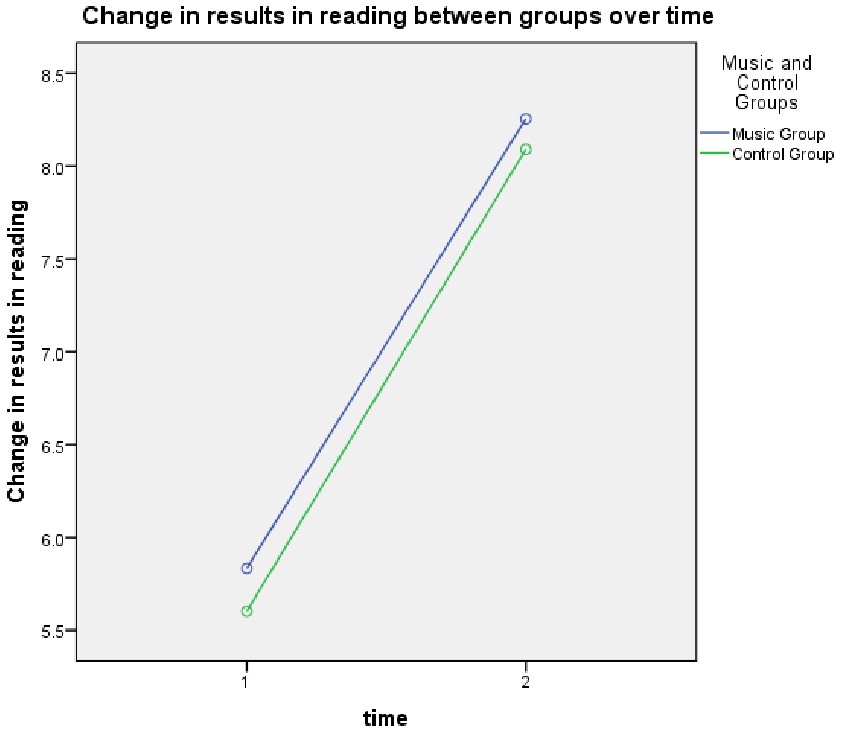
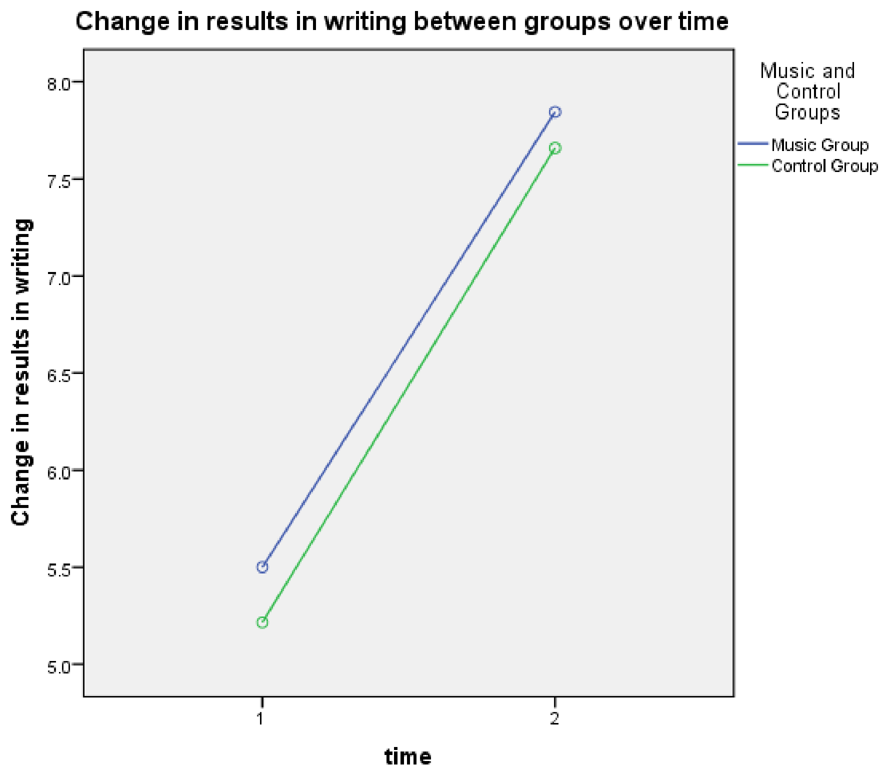


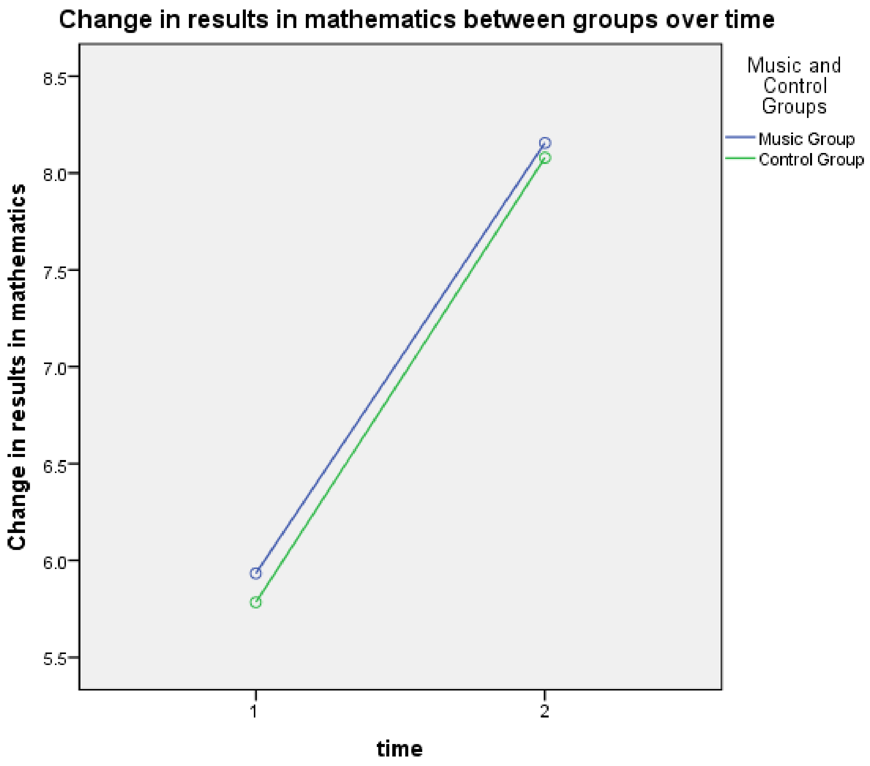
Figure 7.2 shows that in writing both, intervention and control groups progressed similarly.

Figure 7.2: Change in results in writing in intervention and control groups over the period of an academic year after withdrawal of the music programme



Also in mathematics, progression recorded for the intervention and control groups was similar as presented in Figure 7.3. The control group slightly outperformed their peers.

Figure 7.3: Change in results in mathematics in intervention and control groups over the period of an academic year after withdrawal of the music programme



7.3 Chapter summary

The issues considered in this chapter concerned what happened once the music intervention was withdrawn and whether any differences between groups which might have been observed whilst the children were actively involved in music activities were still present once the programme had ended.

Comparison of the results of the music and control groups at the end of the year following the completion of the programme showed marginal differences none of which were statistically significant. In terms of progression over time, children in both groups performed similarly with the performance of the control groups slightly greater than intervention groups. In neither of the assessment areas was there a significant interaction between belonging to the intervention or control group and time or a significant main effect for the two conditions. In view of these findings it is questionable whether the impact of the music programme was sustainable and would continue once the programme was withdrawn.

Chapter 8: Relationships between school attainment and performance on the spatial –temporal, memory and music tests: Analysis of data from the pilot study

8.1 Introduction

Throughout the intervention, the specific mathematical skills of the children were assessed by the teachers and their specific musical skills were assessed by the researcher. Three levels of measurement were used for testing these competencies – *'no understanding of concept'*, *'beginning to understand the concept'*, and *'fully understands the concept'*. This form of assessment was widely used by the teachers in the school at the time of the study and was adapted by the researcher for testing the children's skills in music. As there was no baseline assessment for these skills most analyses reported in this chapter are based on correlations.

The research questions considered in this chapter are:

- In which mathematical abilities can the change be observed? Which mathematical skills, if any, might be developed in a more significant way by a music intervention?
- What are the relationships between specific mathematical skills and achievement in music? Which particular musical activities might have the strongest impact?

8.2 Relationships between the results in mathematics and other areas of school, and study specific, measurements

Further analysis was focused on investigating the relationships between participating in the music programme and performance on different tests against performance in such tests without taking part in music lessons. This also led to an exploration of the possible reasons for some of the differences between the intervention and control groups.

8.2.1 Relationships between mathematics and measures of reading, writing, spatial reasoning, memory and musical skills for the intervention and the control groups

As the main aim of the study was to focus on the possible impact of participation in the music programme on achievement in mathematics, correlations between the results in different areas of assessment were analysed for the intervention and the control groups. The forms of assessment included: results in mathematics in September (just before the programme started) and results in mathematics, writing, reading, spatial – temporal tests – the picture, puzzle and memory tests in July (at the end of the intervention).

Table 8.1 presents the Pearson correlations between achievement in mathematics and other assessments for the intervention and control groups. Apart from the marked cases, the significance level in all cases was p = .0001. These results present the strongest correlations between the results in mathematics at the end of the year and the results in mathematics at the beginning of the year, and in reading and writing at the end of the year. For the intervention group the correlation was slightly smaller than for the control group in mathematics in September and stronger when reading and writing were considered.

Apart from the school assessments, the correlations between children's results in mathematics at the end of the year and spatial-temporal and memory test results were stronger for the control group and present a stronger relationship between mathematics and the memory test than mathematics and spatial-temporal skills.

These analyses explored relationships between different areas of measurement for the intervention and control groups with a view of repeating similar analyses for the main study. This enabled investigating whether the strength of these correlations changed over the second year of the intervention for both the music and control groups. The results of such comparison are presented in table 9.2 in chapter 9.

Table 8.1: Pearson correlations between achievement in mathematics and other assessments for the intervention and control groups

Intervention Group	Mathematics Sept	Reading July	Writing July	Picture test July	Memory test July	Puzzle test July
Mathematics July	.915**	.946**	.956**	-.367**	.664**	-.295* p = .022
Mathematics Sept		.849**	.887**	-.221	.578**	-.132
Reading July			.926**	-.408**	.721**	-.390**
Writing July				-.464**	.686**	-.358**
Picture test July					-.421**	.621**
Memory test July						-.521**

Control Group	Mathematics Sept	Reading July	Writing July	Picture test July	Memory test July	Puzzle test July
Mathematics July	.922**	.887**	.858**	-.500**	.690**	-.430**
Mathematics Sept		.871**	.835**	-.388**	.621**	-.308* p = .017
Reading July			.941**	-.592**	.671**	-.585**
Writing July				-.566**	.567**	-.612**
Picture test July					-.643**	.775**
Memory test July						-.468**

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed)
Negative correlations suggest that the increase in one variable was proportional to the decrease in other variable (in this case, less time needed to complete spatial-temporal and memory tests, which is a positive development).

8.2.2 Relationships between variables for the intervention and the control groups split into year one and reception class

Considering the differences in the assessment measures for the children in FS and Year 1 with a more formal approach in the latter, a review of the correlation between results in mathematics and other assessments within each of the four groups was performed.

Table 8.2 presents the Pearson correlations between the results in mathematics at the end of the year and other assessments for each of the intervention and control groups. These results present a rather different picture, especially for the older groups. There was a strong correlation between the results in mathematics and all the assessments, including the picture (r = -.782), memory (r = .690) and puzzle (r = -.758) tests. In ***music 1***, the strength of correlation with the spatial – temporal tests was greater than the memory test. The younger groups' results in mathematics were less strongly correlated with achievement in mathematics at the beginning of the year and reading and writing, not significantly correlated with the picture test and fairly strongly with the puzzle test (r = -571). There was a significant difference between the groups in the results in the memory test – the correlation in the intervention group was strong (r = .519) whilst in the control group it was not statistically significant.

Table 8.2: Pearson correlations between the results in mathematics at the end of the year and other assessments for each of the intervention and control groups

		Mathematics Sept	Reading July	Writing July	Picture test July	Memory test July	Puzzle test July
Mathematics July	Music 1 Group	.835**	.931**	.941**	-.782**	.690**	-.758**
	Control 1 Group	.766**	.702**	.648**	-.670**	.612**	-.668**
	Music 2 Group	.533** p = .002	.783**	.704**	-.307 p = .093	.519** p = .003	-.479** p = .006
	Control 2 Group	.271 p = .147	.598**	.653**	-.358 p = .052	.233 p = .215	-.571** p = .001

** Correlation significant at the 0.01 level (2-tailed)
value of p = .0001 in all unmarked cases

8.2.3 Exploration of spatial-temporal and memory variables as predictors of results in mathematics

Having established the correlation between the results in mathematics and the spatial – temporal and memory test scores it was logical to ask how well do spatial – temporal and memory results predict achievement in mathematics. How much of the variance of the results in mathematics can be explained by the scores in the spatial – temporal and memory tests and which of those three independent variables is the best predictor of scores in mathematics? To answer those questions a multiple regression analysis with those four variables was used. A number of assumptions had to be checked prior to the analysis. The sample size of 120 was considerably above that recommended by Tabachnick and Fidell (2001, p. 117) (N = 50 + 8m =

74 with m being a number of independent variables). Considering the skewness of the dependent variable a greater number of cases was needed to ensure that that the results could be generalised. The independent variables were not correlated with each other above r = .9 and there were no outliers in the sample. Table 8.3 presents the results.

All three independent variables correlated substantially with the outcomes in mathematics with r = -.444 for the picture test, r = .683 for the memory test, and r = -.375 for the puzzle test. The correlation between the picture test and the puzzle test was just above r = .7 so all three variables were kept in the model. To confirm that the independent variables were not multicollinear, the tolerance and the Variance Inflation Factor values were considered. In neither case was the value of tolerance smaller than .10 or the value of VIF bigger than 10 so the variables did not violate the multicollinearity assumption. The Normal P – P Plot showed normal distribution and the scatterplot confirmed that there were no outliers.

The value of the adjusted R square was .464 which indicated that this model of regression explained 46% of the variance of the results in mathematics at the end of the year (p = .0001).

Of the three independent variables, the memory test contributed the most to the prediction of scores in mathematics with a beta coefficient of .619 (p = .0001). Neither the picture nor the puzzle test made a statistically significant unique contribution. The part correlation coefficient of .523 for the memory test indicated that it uniquely explained 27% of the variance in scores in mathematics.

Table 8.3: Multiple regression analysis for pupils' scores in the picture, memory, puzzle test and mathematics for the whole sample (N = 120)

Variable	**B**	**SE(B)**	**β**	***t***	**Sig. (p)**	**R^2**
Picture test	-.015	.013	-.119	-1.186	.238	.006
Memory test	.403	.052	.619	7.788	.000	.273
Puzzle test	-.011	.169	-.006	-.065	.947	.000

Adjusted R^2 = .464

There may have been differences in the ways that the music programme impacted on the learning of the older and younger groups. A similar multiple regression for each of these groups might have provided more detailed insights but the sample of 60 was too small to perform such analyses.

To explore the possible contribution of overall music scores to the results in mathematics a model of standard multiple regression which included three independent variables – the picture test, memory test and music score from the intervention group was considered. However, the sample of 60 children was lower than the required 74 (for three variables).

The correlation coefficient between the scores in mathematics and music at the end of the year was r = .418, p = .001 which suggests a moderate strength of this relationship.

8.2.4 Summary of the analysis of the relationships between the results in mathematics and other areas of measurement

With the possible impact that music might have on learning mathematics being the dominant interest of this study, an exploration of correlations between results in mathematics and other factors which might have contributed to those scores was performed.

A correlation matrix for all the four groups showed high correlations between achievement in mathematics at the end of the year and the results in mathematics at the beginning of the year and writing and reading at the end of the programme. This relationship was expected. In the intervention groups, there was a moderate correlation with the outcomes of the spatial – temporal tests and a large effect correlation with the memory test confirming that all three components had a relationship with learning mathematics. The control group's results were moderately correlated with the puzzle test and strongly with the picture test. The level of correlation with the memory test was very similar to that for the intervention group.

Once the groups were considered separately according to their age, the correlation matrix showed a large difference between the older and the younger groups. In both older groups the relationship between scores in mathematics at the end of the year and the memory test were similar with a large effect. Also, the correlation with the results in spatial – temporal tests was large in both groups with a slightly stronger interaction in the intervention group. These results suggest that whilst participating in the music programme, children's spatial – temporal skills progressed more than their peers and that that had an impact on their learning mathematics.

The findings from the analysis of data from the younger groups do not support this. In the intervention group, all the areas of school assessment and the memory test were correlated with mathematics and only the more difficult of the spatial – temporal tests – the puzzle test was moderately related. The result for the picture test was not statistically significant. Within the control group, the matrix was surprising with a strong relationship between mathematics and reading, writing and the puzzle test, whilst the correlation between scores in mathematics at the beginning of the year and at the end of the year did not reach statistical significance. Similarly, also in the picture and memory tests the value of p was greater than .05. These data question the coherence of the assessment process within the foundation stage class. This has already been raised in relation to the interpretation of the results from group comparisons and might potentially confound the findings of this study.

One of this research aims was to establish whether the development of spatial – temporal skills had a direct impact on learning mathematics. Three independent variables: the picture, memory and puzzle tests were included in a multiple regression model. Although this model explained 45% of variability in results in mathematics, only the memory test reached statistical significance with a large effect size. With the differences in the assessment criteria between the two ages, checking the regression for just the older children would have been advisable at this point but the pilot study involved only 60 older children which was too small a number for that analysis to be undertaken. This issue will be reconsidered with the larger sample from the next part of the intervention.

Within the elements which might have been related with achievement in mathematics, the overall score in the music test was also considered in relation to the intervention groups. The correlation was of a moderate effect with $r = .421$ ($p = .0001$). To gain a deeper understanding of the links and interactions in the learning pattern further, analyses of specific skills in all three areas of music, mathematics, and spatial – temporal reasoning were undertaken.

8.3 Exploration of the relationships between specific mathematical, musical and spatial – temporal skills

In this study the interaction of two processes was explored. The impact that learning music can have on spatial – temporal skills and the benefit that spatial – temporal advancement might bring to learning mathematics. It was also possible that participation in the music programme might have a direct connection with learning mathematics is some other ways apart from the impact of enhanced spatial – temporal skills. A correlation matrix between the picture, memory and puzzle tests and music scores was developed to assess possible relationships amongst those variables.

Table 8.4 shows that scores in the overall music test were strongly correlated with the results in both spatial – temporal tests and the memory test with the relationship with the puzzle test being the strongest with r = -.711, p = .000.

Table 8.4: Pearson correlations between the overall music score and spatial – temporal and memory tests for the intervention groups

	Picture test score	Memory test score	Puzzle test score
Music test	-.632** p = .000	.649** p = .000	-.711** p = .000
Picture test		-.421** p = .001	.621** p = .000
Memory test			-.521** p = .000

** correlation significant at the 0.01 level (2-tailed)

8.3.1 Relationships between music, spatial-temporal and memory variables and specific mathematical skills

With such strong correlations between scores in music and spatial – temporal tests and as noted previously with the assessments in reading, writing and mathematics, a question arose as to whether these results might indicate that some children just perform better than others in school and also did so on the tests designed specifically for this study. In other words, a possibility that participation in the music programme was irrelevant needed to be considered. This is a serious issue taking into account that this study aimed to explore not only the relationships between the different areas of learning but also to investigate the possibility of causation. If some children perform better overall, the correlations between music, picture, memory and puzzle tests and specific mathematical skills should be at similar level. To explore this, a correlation matrix was created. This could be only undertaken for the older intervention group, because only the older groups were assessed in relation to specific mathematical skills. That meant that the sample size was only 30. Table 8.5 sets out the Pearson correlations between music, spatial – temporal reasoning and memory scores and specific mathematical skills for the older intervention group.

From these results, it is clear that all of the tests were correlated with some mathematical skills rather than all of them. If some children's attainment was better than that of their peers throughout, it is most likely that all of the correlations with specific mathematical skills would be at about the same level. Distinct differences between these correlations for the intervention group, as well as dissimilarity of correlation patterns between the intervention and control groups, suggest that these outcomes resulted from participation in the intervention programme. The strongest correlations for the four tests were with the skills entitled 2D shapes, 3D shapes and practical addition and subtraction. Apart from this, the music, picture and memory tests were strongly correlated with number recognition up to 20 and moderately correlated with counting to 10 and counting to 20 with the picture test being also correlated with number recognition to 10.

Table 8.5: Pearson correlations between music, spatial – temporal and memory scores and specific mathematical skills for the older intervention group

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Music score	.334	.618** p = .000	.381* p = .041	.422* p = .023	.911** p = .000	.908** p = .000	.908** p = .000
Picture test	-.430* p = .018	-.512** p = .004	-.388* p = .034	-.378* p = .039	-.768** p = .000	-.742** p = .000	-.754** p = .000
Memory test	.180	.480** p = .007	.363* p = .049	.429* p = .018	.687** p = .000	.667** p = .000	.780** p = .000
Puzzle test	-.221	-.424* p = .020	-.326	-.300	-.692** p = .000	-.735** p = .000	-.709** p = .000

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)

For the older control group, the results in the spatial – temporal tests were strongly correlated with all but one mathematical skill (number recognition up to 10). The memory test scores were only related to counting to 20 and 3D shapes as presented in Table 8.6.

Table 8.6: Pearson correlations between music, spatial – temporal and memory scores and specific mathematical skills for the older control group

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Picture test	*n.s.*	-.671** p = .0001	-.650** p = .0001	-.816** p = .0001	-.701** p = .0001	-.813** p = .0001	-.726** p = .0001
Memory test	*n.s.*	*n.s.*	*n.s.*	.523** p = .003	*n.s.*	.402* p = .028	*n.s.*
Puzzle test	*n.s.*	-.584** p = .001	-.577** p = .001	-.893** p = .0001	-.542** p = .002	-.867** p = .0001	-.821** p = .0001

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed)

As both learning mathematics and learning music are very complex activities, it was conjectured that a search for possible relationships between specific mathematical and specific musical skills might provide a better understanding of both processes. The correlations between achievement in mathematics at the end of the year and specific musical skills for the older and younger groups and all four groups together are presented in Table 8.7. The strongest correlations were observed in the older group (***music 1***) with all of the coefficients above .50 suggesting a strong relationship. In the younger group (***music 2***), singing and clapping the beat, repeating the rhythm and the overall score were strongly correlated. For the other skills, the interaction was moderate. When both groups were considered, all of the correlation coefficients dropped to moderate levels and for keeping with the beat with the group and individually the correlation was significant at the .05 level.

Table 8.7: Pearson correlations between results in mathematics and specific musical skills for younger and older intervention groups

	Keeping beat with the group	Keeping beat individually	Singing and clapping the beat	Singing and clapping the rhythm	Walking to the beat	Repeating one bar of a 4-beat rhythm	Overall music score
Mathematics	.728**	.737**	.728**	.797**	.665**	.834**	.844**
music 1	p = .0001	p = .0001	p = .0001	p = .0001	p = .0001	p = .0001	p = .0001
Mathematics	.535**	.457*	.648**	.518**	.461*	.665**	.620**
music 2	p = .002	p = .011	p = .0001	p = .003	p = .010	p = .0001	p = .0001
Mathematics	.287*	.293*	.414**	.402**	.465**	.331**	.421**
both groups	p = .026	p = .023	p = .001	p = .001	p = .0001	p = .010	p = .001

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed)

8.3.2 Exploration of the relationships between specific mathematical and specific musical skills

Since all of the musical skills were correlated with the results in mathematics, a further investigation into which mathematical skills might be related more strongly with the musical skills was performed. The results are set out in Table 8.8.

There was a strong correlation between all of the musical skills and number recognition up to 20, 2D shape, 3D shape and practical addition and subtraction. Additionally, strong relationships were observed between repeating the rhythm and counting up to 10 and between singing and clapping the rhythm and counting to 20. Two more moderate correlations were between repeating the rhythm and counting to 20 and walking to the beat and counting to 20. For all the coefficients without an asterisk the significance level was above .05.

Table 8.8: Pearson correlations between specific musical skills and specific mathematical skills for the music 1

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Keeping beat with the group	.306	.553** p = .002	.297	.253	.879** p = .0001	.894** p = .0001	.866** p = .0001
Keeping beat individually	.293	.535** p = .003	.208	.307	.725** p = .0001	.750** p = .0001	.718** p = .0001
Singing and clapping the beat	.306	.553** p = .002	.297	.253	.879** p = .0001	.894** p = .0001	.866** p = .0001
Singing and clapping the rhythm	.274	.535** p = .003	.360	.537** p = .003	.833** p = .0001	.812** p = .0001	.841** p = .0001
Walking to the beat	.320	.502** p = .005	.257	.404* p = .030	.734** p = .0001	.764** p = .0001	.696** p = .0001
Repeating one bar of a 4-beat rhythm	.308	.633** p = .0001	.553** p = .002	.388* p = .037	.877** p = .0001	.823** p = .0001	.908** p = .0001

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)

8.3.3 Summary of the relationships between specific mathematical, musical and spatial – temporal skills

The analyses reported here examined the interactions between mathematical, musical, memory and spatial - temporal skills considering whether those skills were more likely to relate to some overarching cognitive capacity or could possibly be nurtured and developed whilst learning music. Considering that not all mathematical skills were correlated with either spatial-temporal or specific musical skills, the assumption that some were developed through participation in the music programme seemed plausible.

The strong correlation between the understanding of 2D and 3D shapes and spatial – temporal reasoning was hardly surprising. Spatial – temporal reasoning was also strongly correlated with practical addition and subtraction which is not only the most complex of the measured mathematical skills but is also assessed with physical objects as props and as such is related with spatial awareness. The strong correlations between similar areas of the curriculum and musical skills suggests that there is an association between the development of spatial – temporal skills and participation in the music programme. Another mathematical skill strongly related with spatial – temporal and musical skills was number recognition up to 20. This unforeseen relationship will be returned to later.

8.4 Chapter Summary

The theoretical framework for this study suggested that through participation in a music programme, children were likely to enhance their spatial – temporal skills when compared with non-participating peers. This in turn might positively influence learning in mathematics. Comparisons of the results between the intervention and control groups indicated differences between them and suggested the need for further analysis of the relationships between the variables to establish the nature of any interactions.

The correlational analyses indicated a strong relationship between music and performance on the spatial – temporal and memory tests. This together with the observed earlier differences between the intervention and the control groups in the spatial – temporal tests but not in the memory tests, suggested that taking part in a music programme helped develop spatial – temporal reasoning. Whether those skills were then used further in enhancing learning mathematics was unclear considering that neither the picture nor the puzzle test made a substantial contribution to the prediction of scores in mathematics at the end of the year as demonstrated in the multiple regression model. Further analysis showed that there was a strong relation between spatial – temporal and musical skills and some mathematical skills including: counting to 20, understanding of 2D and 3D shapes and practical addition and subtraction. This suggests that the spatial – temporal skills may only be useful in learning in specific areas of mathematics and that is why their contribution to the overall mathematical scores in the multiple regression was not statistically significant.

The following chapter sets out the analysis of data relating to the first year of the main study with a larger group of children.

Chapter 9: Relationships between school attainment and performance on the spatial – temporal, memory and music tests: Analysis of data from the first year of the main study

9.1 Introduction

This chapter reports further analysis investigating the relationships between children's performance in mathematics and measures of spatial reasoning, memory and musical skills and their membership of the intervention or the control group in the first year in the main study. The research questions addressed in this chapter are:

- In which mathematical abilities can any change be observed? Which mathematical skills, if any, might be developed in a more significant way by a music intervention?
- What are the relationships between specific mathematical skills and achievement in music? Which particular musical activities might have the strongest impact?

9.2 Relationships between the results in mathematics and other areas of school, and study specific, measurements

The sample for the analyses described in this chapter included all 120 children who took part in the pilot study and 58 new participants making the total number of participants 178. There were 59 children from Year 2, 61 children from Year 1 and the new pupils from the Reception class. In each of these cohorts, half of the children were randomly assigned to the intervention and the other half to the control group.

9.2.1 Relationships between mathematics and measures of reading, writing, spatial reasoning, memory and musical skills for the intervention and the control groups

With the main purpose of the study to investigate the impact which participation in the music programme might have on achievement in mathematics, correlations between the results in the different tests were calculated for the intervention and control groups. The measurements were: mathematics, reading, writing, the picture test, the memory test and the puzzle test.

Table 9.1 presents Pearson correlations between achievement in mathematics and other assessments for the intervention and control groups. Apart from the marked cases, the significance level in all cases was $p = .0001$. The strongest correlations were between achievement in mathematics at the end of the year and the results in mathematics at the beginning of the year, and in reading and writing at the end of the year. For the intervention group these correlations were slightly smaller than the control group in mathematics in September and stronger when reading and writing were considered.

The correlations between children's results in mathematics at the end of the year and spatial-temporal tests were stronger in the intervention group. For the control groups the relationship was stronger in the memory test. For both groups the relationship between mathematics and memory was stronger than for mathematics and spatial-temporal skills. For the control groups the correlation between mathematics at the end of the year and the picture test was small (Pallant, 2007) and only significant at the .05 level. The correlations between the puzzle test and mathematics for the same group were not statistically significant.

Table 9.1: Pearson correlations between achievement in mathematics and other assessments for the intervention and control groups

Intervention Group	Mathematics Sept	Reading July	Writing July	Picture test July	Memory test July	Puzzle test July
Mathematics July	.914**	.926**	.929**	-.429**	.699**	-.427**
Mathematics Sept		.933**	.920**	-.356** p = .001	.675**	-.339** p = .001
Reading July			.970**	-.431**	.726*	-.422**
Writing July				-.465**	.703**	-.434**
Picture test July					-.386**	.768**
Memory test July						-.423**

Control Group	Mathematics Sept	Reading July	Writing July	Picture test July	Memory test July	Puzzle test July
Mathematics July	.939**	.923**	.907**	-.244* p = .022	.749**	-.132 p = .220
Mathematics Sept		926**	.904**	-.286** p = .007	.784**	-.160 p = .137
Reading July			.960**	-.356** p = .001	.749**	-.240* p = .025
Writing July				-.382**	.744**	-.292** p = .006
Picture test July					-.460**	.731**
Memory test July						-.246* p = .021

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed) value of p = .0001 in all unmarked cases
Negative correlations suggest that the increase in one variable was proportional to the decrease in other variable (in this case, less time needed to complete spatial-temporal and memory tests, which is a positive development).

Comparing these results with the similar analyses from the pilot study, for the intervention groups, the correlations between the picture and the puzzle test and all other assessments were stronger in the second year of the study than in the pilot year apart from the results in the memory test where the relationships were less strong. Correlations between the memory test and mathematics, reading and writing were also stronger in the second year. For the control groups, correlations between the spatial-temporal tests and other assessments were smaller in the second year of the study. In the same groups, correlations between results in the memory test and mathematics at the beginning and at the end of the year, reading and writing were stronger in the second year than in the pilot. These differences were greater than in the intervention groups apart from mathematics at the beginning of the year as shown in Table 9.2. The correlations support the assumption that spatial-temporal skills contribute to learning in mathematics.

Table 9.2: Pearson correlations between spatial-temporal and memory tests and other assessments at the end of the pilot study and at the end of the second year of the study

Intervention Group	Picture test pilot	Picture test second year	Memory test pilot	Memory test second year	Puzzle test pilot	Puzzle test Second year
Mathematics July	-.367**	-.429**	.664**	.699**	-.295* p = .022	-.427**
Mathematics Sept	-.221	-.356** p = .001	.578**	.675**	-.132	-.339** p = .001
Reading July	-.408**	-.431**	.721**	.726*	-.390**	-.422**
Writing July	-.464**	-.465**	.686**	.703**	-.358**	-.434**
Picture test July			-.421**	-.386**	.621**	.768**
Memory test July					-.521**	-.423**

Control Group	Picture test pilot	Picture test second year	Memory test pilot	Memory test second year	Puzzle test pilot	Puzzle test Second year
Mathematics July	-.500**	-.244* p = .022	.690**	.749**	-.430**	-.132 p = .220
Mathematics Sept	-.388**	-.286** p = .007	.621**	.784**	-.308* p = .017	-.160 p = .137
Reading July	-.592**	-.356** p = .001	.671**	.749**	-.585**	-.240* p = .025
Writing July	-.566**	-.382**	.567**	.744**	-.612**	-.292** p = .006
Picture test July			-.643**	-.460**	.775**	.731**
Memory test July					-.468**	-.246* p = .021

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed) value of p = .0001 in all unmarked cases
Negative correlations suggest that the increase in one variable was proportional to the decrease in other variable (in this case, less time needed to complete spatial-temporal and memory tests, which is a positive development).

9.2.2 Exploration of spatial-temporal and memory variables as predictors of results in mathematics in all age groups

A multiple regression analysis was used to ascertain whether results in the picture, memory and puzzle tests predicted achievement in mathematics and to explore how much variance of the scores in mathematics could be explained be the scores in the spatial-temporal and memory tests. The results are presented in table 9.3. A number of assumptions needed to be checked before the regression could be undertaken. The independent variables were not correlated with each other above r = .9, the sample size of 178 was greater than that recommended (N = 50 + 8m with m = 3) (Tabachnick and Fidell, 2001) and there were no outliers.

All three independent variables were correlated with the scores in mathematics with r = -.339 for the picture test, r = .723 for the memory test, and r = -.268 for the puzzle test. To ensure that none of the independent variables violated the multicollinearity assumption, the tolerance and the Variance Inflation Factor values were calculated and in no case was the value of tolerance smaller than .10 or the value of VIF bigger than 10. P – P Plot showed normal distribution and the scatterplot confirmed no outliers.

The value of the adjusted R square was .516 explaining 51% of the variance in results in mathematics at the end of the year (p = .0001). Of the three independent variables, the memory test contributed the most to the prediction of scores in mathematics with a beta coefficient of .708 (p = .0001). Neither the picture nor the puzzle test made a statistically significant unique contribution. The part correlation coefficient of .640 for the memory test indicated that it uniquely explained 41% of the variance in scores in mathematics.

Table 9.3: Multiple regression analysis for pupils' scores in the picture, memory, puzzle test and mathematics for the whole sample (N = 178)

Variable	**B**	**SE(B)**	**β**	***t***	**Sig. (p)**	**R^2**
Picture test	-.006	.020	-.025	-.308	.759	.025
Memory test	.768	.065	.708	12.238	.000	.409
Puzzle test	-.038	.238	-.013	-.161	.875	.000

Adjusted R^2 = .516

9.2.3 Exploration of spatial-temporal and memory variables as predictors of results in mathematics in the two older age groups

There were differences in the ways the older and the youngest groups were assessed in mathematics. The results of a similar multiple regression undertaken for the four oldest groups are shown in table 9.4. All three independent variables were correlated with the scores in mathematics with r = -.473 for the picture test, r = .632 for the memory test, and r = -.494 for the puzzle test. The results showed that the memory test contributed the most to the prediction of results in mathematics, with a beta coefficient of .504 (p = .0001). The beta coefficient of .214 (p = .046) for the puzzle test was statistically significant at the 0.05 level. The part correlation coefficient for the memory test was .422 uniquely explaining 18% of the variance in scores in mathematics. It was the best predictor of the three independent variables. The part correlation coefficient for the puzzle test was .14 explaining 2% of the variance in these results.

Table 9.4: Multiple regression analysis for pupils' scores in the picture, memory, puzzle test and mathematics for four oldest groups (N = 120)

Variable	**B**	**SE(B)**	**β**	***t***	**Sig. (p)**	**R^2**
Picture test	-.008	.018	-.046	-.421	.675	.000
Memory test	.424	.069	.504	6.102	.000	.178
Puzzle test	-.444	.220	-.214	-2.021	.046	.019

Adjusted R^2 = .432

9.2.4 Exploration of spatial-temporal, memory and music variables as predictors of results in mathematics in the three intervention groups

The possible contribution of overall music scores to the results in mathematics was explored using a multiple regression which included four independent variables – the picture test, memory test, puzzle test, and total music score for the intervention group. The sample size was 90. The results are presented in table 9.5. All three independent variables were correlated with the scores in mathematics with r = -.429 for the picture test, r = .699 for the memory test, r = -.427 for the puzzle test, and r = .582 for the overall music score. The only statistically significant predictor of scores in mathematics was the memory test with a part correlation coefficient of .438 explaining 19% of the variance in scores in mathematics. The adjusted R squared for this model was .503 explaining 50% of variation in results in mathematics at the end of the year (p = .0001).

When the relationship between the scores in mathematics and in music at the end of the year was considered, the correlation coefficient was r = .582 (p = .0001). In the linear regression, the adjusted R square for music was .017, so about 2% of variability in scores in mathematics was explained by the scores in music.

Table 9.5: Multiple regression analysis for pupils' scores in the picture, memory, puzzle test and mathematics for the music groups (N = 90)

Variable	**B**	**SE(B)**	**β**	***t***	**Sig. (p)**	**R^2**
Picture test	-.029	.037	-.114	-.781	.438	.005
Memory test	.624	.131	.545	4.770	.000	.191
Puzzle test	.268	.581	.078	.462	.646	.001
Music score	.189	.130	.242	1.460	.150	.017

Adjusted R^2 = .503

9.2.5 Summary of the analysis of the relationships between the results in mathematics and all other areas of measurement

An investigation of correlations between results in mathematics and other areas of assessment was performed to explore the possible impact that learning music might have on learning mathematics.

A correlation matrix for the intervention and control groups showed strong correlations between the results in mathematics at the end of the year and achievement in mathematics at the beginning of the year and reading and writing at the end of the year. These relationships were similar to those observed in the pilot study. In the intervention groups, similarly to the pilot study, there was a moderate correlation with the spatial – temporal tests and a large correlation with the memory test. These findings confirmed that all of the three components had a relationship with learning mathematics. For the control groups correlations with the spatial – temporal and memory tests were different from those in the pilot study as there was a small correlation between the achievement in mathematics and in the picture test, a large correlation with the memory test, while the relationship with the puzzle test was not statistically significant.

For the intervention groups, the correlations between the picture and the puzzle tests and all other assessments were stronger in the second year of the study than in the pilot year, apart from the results in the memory test where the relationships were smaller. For the control groups, the correlations between spatial-temporal tests and other assessments were smaller in the second year of the study apart from the memory test.

The differences in these correlations between the more formally assessed older groups and the younger groups were much smaller than those observed in the pilot study.

One of the aims of this study was to establish whether the development of spatial – temporal skills had a direct impact on learning mathematics. The multiple regression model used to explore that included three independent variables: picture, memory and puzzle tests. Although the model explained 51% of variability in results in mathematics, only the memory test reached statistical significance with a large effect. With the differences between the more formal assessment in the older groups and the less prescribed assessment in the youngest classes, a regression for the 120 oldest children was performed. The results showed that both the memory test and the puzzle test made a unique contribution to the total variance in the scores in mathematics.

The correlation between achievement in mathematics and the overall score in the music test was also considered for the intervention groups. The relationship was strong ($r = .582$, $p = .0001$). To examine these correlations further an analysis of specific skills in all three areas of music, mathematics and the spatial – temporal reasoning were undertaken.

9.3 Exploration of the relationships between specific mathematical, musical and spatial – temporal skills

Previous research into the impact that actively participating in making music has on other cognitive skills has suggested that such participation develops spatial – temporal skills. It is also acknowledged that spatial skills are used whilst learning mathematics. This research aimed to investigate the impact that learning music might have on spatial – temporal skills and how that might benefit the learning of mathematics. Another possibility which was considered was that active participation in making music might be related to learning mathematics in some other way than through the development of spatial – temporal abilities. To examine such possibility a correlation matrix was calculated between the picture, memory and puzzle tests and the overall score in music for the intervention groups. The results are presented in Table 9.6. Scores in the music test were strongly correlated with the results in all three tests with the puzzle test being the strongest (r = -.773). In all cases the value of p was .0001.

Table 9.6: Pearson correlations between the overall music score and spatial – temporal and memory tests for the intervention groups

	Picture test score	Memory test score	Puzzle test score
Music test	-.678**	.593**	-.773**
Picture test		-.386**	.768**
Memory test			-.423**

** correlation significant at the 0.01 level (2-tailed)

9.3.1 Relationships between music, spatial-temporal and memory variables and specific mathematical skills

With the correlations between the results in music and in the spatial – temporal tests and assessments in reading, writing and mathematics being high in both the pilot and the main study a question emerged as to whether this simply reflected that fact that some children perform better in school than others regardless of participation in the music programme. As this study aimed to explore not only the relationships between the different areas of learning but also to investigate the possibility of causation between these areas this was an important issue to consider.

If this assumption was correct the correlations between music, picture, memory and puzzle tests and specific mathematical skills should be at similar levels and the patterns should be similar in both intervention, and control groups. To explore this, correlation matrixes were created for the intervention and the control groups including the same variables apart from the overall music score and compared within year groups. This analysis was undertaken for the two older age groups as the assessment in the reception classes was less formal and did not include specific mathematical skills. Table 9.7 sets out the Pearson correlations between music, spatial – temporal and memory scores, and specific mathematical skills for the oldest intervention group. Although many of the correlations with specific mathematical skills were of a similar level for the spatial – temporal, memory and music scores some were less strong, for instance, the relationship between the puzzle test and counting to 100. This suggests that children did not perform at the same high standard in all assessment areas. Additionally, it is noticeable that within the intervention group the correlations between scores in the memory test and three of the mathematical skills were only significant at the .05 level and were of moderate strength. In all cases, apart from those marked, the significance level was p = .0001.

Table 9.7: Pearson correlations between music, spatial – temporal and memory scores and specific mathematical skills for the oldest intervention group: music 1

	Counting to 100	Counting back from 20	Counting objects accurately	Using number line	Attributes of shapes	Symmetry patterns	Problem solving
Music score	.553** p = .002	.678**	.620**	.791* *	.696**	.649**	.810**
Picture test	-.563** p = .001	-.729**	-.642**	-.887**	-.699**	-.679**	-.833**
Memory test	.403* p = .030	.492** p = .007	.467* p = .011	.706**	.698**	.394* p = .034	.671**
Puzzle test	-.388* p = .038	-.727**	-.653**	-.842**	-.648**	-.640**	-.823**

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2- tailed)
value of p = .0001 in all unmarked cases

Table 9.8 presents the Pearson correlations between the spatial – temporal and memory scores and specific mathematical skills for the oldest control group. In all but two cases, the memory and puzzle tests and counting to 100, correlations within this group were less strong than in the intervention group. None of the correlations between counting back from 20 and other variables were statistically significant. The variety of strengths of the correlations between the spatial – temporal and memory results and the mathematical skills supported the assumption that different mathematical abilities are correlated with spatial – temporal and memory skills at different levels or not at all.

Table 9.8: Pearson correlations between spatial – temporal and memory scores and specific mathematical skills for the oldest control group: control 1

	Counting to 100	Counting back from 20	Counting objects accurately	Using number line	Attributes of shapes	Symmetry patterns	Problem solving
Picture test	-.401* p = .028	*n.s.*	-.514** p = .004	-.598**	-.362* p = .049	-.574** p = .001	-.585** p = .001
Memory test	.517** p = .003	*n.s.*	.514** p = .004	.530** p = .003	.564** p = .001	.623**	.631**
Puzzle test	-.421* p = .020	*n.s.*	-.489** p = .006	-.670**	-.497** p = .005	-.634**	-.617**

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)
value of p = .0001 in all unmarked cases

A similar correlation matrix was also created for the middle age group ***music 2*** to examine the relationships between the results on the spatial – temporal, memory and music tests and mathematical skills specifically for Year 1 children.

Table 9.9 presents the correlations within the intervention group. There was variability in the strength of the relationships and some were not statistically significant. This suggests that it cannot be assumed that some children perform better in all tasks. There were no statistically significant correlations between any of the four tests and number recognition to 10. The same result was observed in a matrix calculated for the same age group in the pilot study. Apart from that, some relationships between the scores in the memory tests and mathematical abilities were not statistically significant – number recognition to 20 and problem solving. Others were only significant at the 0.05 level – counting to 10 and 2D shapes. These results differ from the parallel group in the pilot study, where number recognition, 2D shapes and problem solving, were strongly correlated with scores in the memory test. The greatest contrast with the results in the pilot study was in correlations between scores in the picture test and scores in mathematical skills. Very small correlations or correlations which were not statistically significant contrast with the mostly strong correlations in the pilot study for the same age group.

Table 9.9: Pearson correlations between music, spatial – temporal and memory scores and specific mathematical skills for the middle intervention group: music 2

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Music score	*n.s.*	.468** p = .008	.538** p = .002	. 550** p = .001	.517** p = .003	.647**	.615**
Picture test	*n.s.*	-.404* p = .024	*n.s.*	*n.s.*	*n.s.*	-.410* p = .022	-.400* p = .026
Memory test	*n.s.*	*n.s.*	.358* p = .048	.519** p = .003	.416* p = .020	.488** p = .005	*n.s.*
Puzzle test	*n.s.*	-.569** p = .001	-.617**	-.550** p = .001	-.534** p = .002	-.534** p = .002	-.454** p = .01

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)
value of p = .0001 in all unmarked cases

For the control group of the same age, most of the results in specific mathematical skills were not related with the picture, memory and puzzle test scores as shown in table 9.10. There were moderate correlations between number recognition up to 20 and both of the spatial – temporal tests. The same tests were also strongly related with counting to 20. The scores in the puzzle test were strongly related with geometrical abilities. All of these relationships were also present in the pilot study for the same age group with the addition of strong correlations between the picture and the puzzle test and all mathematical skills apart from number recognition to 10. The memory test was correlated with counting to 20 and 3D shapes.

Table 9.10: Pearson correlations between music, spatial – temporal and memory scores and specific mathematical skills for the middle control group: control 2

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Picture test	*n.s.*	-.373* p = .042	*n.s.*	-.492** p = .006	*n.s.*	*n.s.*	*n.s.*
Memory test	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Puzzle test	*n.s.*	-.408* p = .025	*n.s.*	-.487** p = .006	-.586** p = .001	-.552** p = .002	*n.s.*

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed) value of p = .0001 in all unmarked cases

By this year of the study there were two intervention and two control groups which had taken part in the programme whilst being in year 1 so the scores were combined to form a bigger sample. The results were similar to those in the pilot study. For the intervention group, all but one mathematical skill was strongly correlated with both spatial-temporal tests and with the memory test. Only the most basic skill – number recognition to 10 was not correlated as presented in table 9.11. Additionally, similarly to the results in the pilot study, it was the most complicated skills like counting to 20 and practical addition and subtraction (apart from 2D and 3D shapes) where the strongest correlations were observed. No such relationship was observed for the control group. For the control groups, all mathematical skills apart from number recognition to 10 were strongly correlated with the picture and the puzzle test but only one – practical addition and subtraction - with the memory test – table 9.12.

Table 9.11: Pearson correlations between music, spatial – temporal and memory scores and specific mathematical skills for the combined year 1 intervention groups

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Music score	.307* p = .017	.547**	.443**	. 473**	.749**	.808**	.797**
Picture test	*n.s.*	-.460**	-.369** p = .004	-.331** p = .001	-.500**	-.584**	-.580**
Memory test	*n.s.*	.379** p = .003	.358** p = .005	.445**	.588**	.601**	-.606**
Puzzle test	*n.s.*	-.512**	-.472**	-.422** p = .001	-.681**	-.698**	-.631**

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed) value of p = .0001 in all unmarked cases

Table 9.12: Pearson correlations between music, spatial – temporal and memory scores and specific mathematical skills for the combined year 1 control groups

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Picture test	*n.s.*	-.515**	-.446**	-.539**	-.476**	-.578**	-.421** p = .001
Memory test	*n.s.*	.264* p = .042	*n.s.*	*n.s.*	*n.s.*	*n.s.*	-.338** p = .008
Puzzle Test	*n.s.*	-.494**	-.425**	-.632**	-.561**	-.701**	-.503**

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed) value of p = .0001 in all unmarked cases

9.3.2 Exploration of the relationships between specific mathematical and specific musical skills

Data related to the assessment of specific musical skills were also collected to investigate the possible relationships between these skills and results in mathematics and specific mathematical skills. This enabled further analysis of the relationships occurring in these two areas of learning. Table 9.13 shows the correlations between achievement in mathematics at the end of the year and specific musical skills in the second year of the programme for the older and middle groups: ***music 1*** and ***music 2***. These data confirmed that some musical skills were more strongly correlated with performance in mathematics than others and that there were differences between the two groups. When both groups were considered together the correlations were less strong but still statistically significant for all musical skills.

Table 9.13: Pearson correlations between results in mathematics and specific musical skills for older and middle intervention groups (music 1 and music 2)

	Clapping a strong beat in 4-count bar	Clapping a strong beat in 3-count bar	Repeating 2 bars of 4-count rhythm	Imitating a rhythm for 4 bars	Playing a bar of rhythm from notation	Improvising a bar of a 4-count rhythm	Overall music score
Mathematics ***music 1***	.696**	.788**	.461* p = .012	*n.s.*	.684**	.407* p = .028	.729** p = .0001
Mathematics ***music 2***	.708**	. 681**	.570** p = .001	.700**	. 677**	.487** p = .005	.782**
Mathematics both groups	. 354** p = .005	.495 **	.364** p = .004	.426** p = .001	.576**	.501**	.582**

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)
value of p = .0001 in all unmarked cases

As the youngest group started their music programme a year later, their musical assessment was based around a different range of skills and is presented in Table 9.14. For this group. all correlations were strong and statistically significant.

Table 9.14: Pearson correlations between results in mathematics and specific musical skills for the youngest intervention group (music 3)

	Keeping beat with the group	Keeping beat individually	Singing and clapping the beat	Singing and clapping the rhythm	Walking to the beat	Repeating one bar of a 4-beat rhythm	Overall music score
Mathematics ***music 3***	.608** p = .0001	.500** p = .005	.603** p = .0001	.546** p = .002	.560** p = .001	.523** p = .003	.715** p = .001

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)

The collection of data assessing specific mathematical and specific musical skills enabled further investigation into which mathematical skills might be more strongly related with specific musical skills. Such data could only be collected in the two older groups: ***music 1*** and ***music 2*** because the assessment in mathematics in the youngest group ***music 3*** was less formal and did not include specific mathematical skills. Because the assessment in mathematics specified different skills in different year groups, there was a need to create two separate matrixes, one for each year group.

Table 9.15 shows Pearson's correlations between specific musical skills and specific mathematical skills for the oldest intervention group ***music 1***. There was a strong correlation between all the musical skills, using the number line and problem solving. Also, the skills related to geometry, for instance, attributes of shapes and symmetry were strongly correlated with most musical skills apart from imitating the rhythm for 4 bars and improvising a bar of a 4-count which were only correlated at the p = .05 level. The correlation between symmetry and improvising the rhythm was not statistically significant. Out of the musical skills, clapping a strong beat in a 4-count and 3-count bar and playing a bar of rhythm from notation were most strongly correlated with mathematical skills.

Table 9.15: Pearson correlations between specific musical skills and specific mathematical skills for the music 1

	Counting to 100	Counting back from 20	Counting objects accurately	Using number line	Attributes of shapes	Symmetry patterns	Problem solving
Clapping a strong beat in 4-count bar	.616 **	.720 **	.546** p = .002	.761 **	.621**	.612 **	.726 **
Clapping a strong beat in 3-count bar	.578** p = .001	.718**	.724**	.716**	.689**	.653**	.702 **
Repeating 2 bars of 4-count rhythm	*n.s.*	*n.s.*	.369* p = .049	.535**	.483**	.524**	.695**
Imitating a rhythm for 4 bars	*n.s.*	.390* p = .036	*n.s.*	.563**	.468* p = .010	.399* p = .032	.604** p = .001
Playing a bar of rhythm from notation	.451* p = .014	.600** p = .001	.613**	.703**	.725**	.560** p = .002	.722**
Improvising a bar of a 4-count rhythm	*n.s.*	.374* p = .046	*n.s.*	.556** p = .002	.391* p = .036	*n.s.*	.569** p = .001

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed)
value of p = .0001 in all unmarked cases

Table 9.16 presents Pearson's correlations between specific musical skills and specific mathematical skills for the ***music 2*** group. Like in the pilot study, correlations between number recognition to 10 and the musical skills were mostly not statistically significant, whilst number recognition to 20 and counting to 10 were moderately correlated with musical skills. Practical addition and subtraction was a mathematical skill most strongly correlated with musical skills. There were strong relationships between geometry and most musical skills apart from 2D shapes and repeating 2 bars of 4-count rhythm, and 2D shapes and improvising a bar of a 4-count rhythm. Improvising a bar of a 4-count rhythm was only correlated strongly with 3D shapes and moderately with practical addition and subtraction, whilst all the other correlations were not statistically significant. These findings are similar to the correlations between the same musical mathematical skills for the older group ***music 1***. Another similarity with the older group was a strong correlation between all but one mathematical skill and playing a bar of rhythm from notation. Also, clapping a strong beat in a 4-count bar was strongly correlated with mathematical skills in both age groups. The biggest differences between these two groups were in imitating a rhythm for 4 bars which was strongly related with mathematical skills for the younger group ***music 2***, whilst for the older group, ***music 1,*** the relationship was less strong.

Table 9.16: Pearson correlations between specific musical skills and specific mathematical skills for the music 2

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Clapping a strong beat in 4-count bar	.373* p = .039	.517** p = .003	.536** p = .002	.517** p = .003	.542** p = .002	.599**	.427* p = .017
Clapping a strong beat in 3-count bar	*n.s.*	.441* p = .013	.453* p = .010	*n.s.*	.542** p = .002	.541** p = .002	.488** p = .005
Repeating 2 bars of 4-count rhythm	*n.s.*	.440* p = .013	.358* p = .048	.589**	*n.s.*	.432* p = .015	.435* p = .015
Imitating a rhythm for 4 bars	*n.s.*	.398* p = .027	.581** p = .001	.543** p = .002	.490** p = .005	.545** p = .002	.461** p = .009
Playing bar of rhythm from notation	*n.s.*	.496** p = .005	.422* p = .018	.496** p = .005	.464** p = .009	.585** p = .001	.693**
Improvising a bar of a 4-count rhythm	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	.459** p = .009	.449* p = .011

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)
value of p = .0001 in all unmarked cases

9.3.3 Summary of the relationships between specific mathematical, musical and spatial – temporal skills

This part of the analysis investigated specific skills in all three areas of music, mathematics and spatial – temporal reasoning and the relationships between them. Scores in music tests were strongly correlated with the picture, memory, and puzzle tests.

The fact that not all mathematical skills were correlated with spatial-temporal abilities challenged the proposition that some children simply perform better than others in all areas of learning with or without participation in active music making. For the oldest groups, all but one correlation between the results in the spatial – temporal tests and specific mathematical skills were stronger for the intervention group. Such correlations with the memory test were stronger for the control group in skills related to counting and stronger for the intervention groups in geometry and problem solving. Counting back from 20 did not have statistically significant relationship with spatial – temporal or memory tests for the control group.

For the middle groups (***music 2***), the results in music and in the puzzle test were strongly related to all but one mathematical skill for the intervention group. The exception was number recognition up to 10. These results were the same as in the pilot study. For the control group, the results in the puzzle test were correlated only with geometrical skills and counting to 20. The scores in the picture test were moderately related to number recognition up to 20 for the both groups, and with 3D shapes and practical addition and subtraction for the music group and counting to 20 for the control group.

In terms of specific musical skills, most were strongly correlated with the results in mathematics in all three intervention groups apart from imitating a rhythm from notation for the oldest group (***music 1***) which was not statistically significant. Further analyses showed that the relationship between improvising and specific mathematical skills was generally not statistically significant. Also, some mathematical skills, for instance, number recognition up to 10 and counting to 100 were not correlated with most musical skills. These results were very similar to the pilot study where the correlations between number recognition and counting to 10 and specific musical skills were not statistically significant.

9.4 Chapter Summary

This chapter examined the relationships between attainment in mathematics and in the other tests undertaken either by the teachers as part of regular school assessment or by the researcher in areas specific to the study. Moderate correlations with the spatial – temporal measurements and strong relationship with the memory tests confirmed that all three components had relationships with learning mathematics.

Additional strong relationships with attainment in reading and writing observed in the analyses, posed the question as to whether some children are predisposed to higher achievement independently of their engagement with music. If this was the case better performance should be observed throughout a wide range of skills. The analyses in this chapter suggested that only some specific mathematical skills were correlated with the results in the spatial – temporal tests and with only some musical skills. As such associations were consistent in both the pilot and the main study the evidence provides a robust representation of the impact of the music programme.

Chapter 10: Long-term relationships between the variables and the sustainability of impact after the conclusion of the music programme

10.1 Introduction

After the programme had been running for two years, the intervention was withdrawn and another set of data relating to performance in mathematics was collected. The longitudinal character of this enabled investigation into how participation in the music programme impacted on pupils' spatial-temporal skills and their learning in mathematics over two years of running of the programme but also allowed the examination of how such a relationship changed over that period of time. Collecting students' attainment data a year after the programme was withdrawn, facilitated exploration of the possible long term benefits of learning music. This chapter describes data analysis related to these issues and addresses the following research question:

- What are the long-term relationships between active engagement in making music and mathematics and is the impact sustainable?

10.2 Relationships between variables and results in mathematics

10.2.1 Relationships between mathematics and other variables after termination of the music programme

Within the academic literature there is limited support for the notion that learning music might have an impact on spatial-temporal abilities beyond the time of actual participation in music (Rauscher and Zupan, 2000; Rauscher 2002). However, whether there is a relationship between improved spatial-temporal skills and learning mathematics has not yet been explored. Data collected in this study throughout the intervention and a year after it was terminated allowed exploration of this issue.

The was a strong correlation between results in the picture, puzzle, and memory tests at the end of the intervention and the results in mathematics a year after the programme was withdrawn for the intervention groups as presented in Table 10.1. For the control groups the relationship between the picture test and mathematics was statistically significant but of relatively small strength, while the puzzle test was not correlated with $p > .05$. A similar correlation with the memory test was stronger for the control groups.

Table 10.1: Pearson correlations between achievement in mathematics and other assessments for the intervention and control groups

Intervention Group	Picture test end of intervention	Memory test end of intervention	Puzzle test end of intervention
Mathematics after withdrawal	-.512**	.681**	-.510**
Picture test end of intervention		-.386**	.768**
Memory test end of intervention			-.423**

Control Group	Picture test end of intervention	Memory test end of intervention	Puzzle test end of intervention
Mathematics after withdrawal	-.272* p = .010	.721**	-.187 p = .080
Picture test end of intervention		-.460**	.731**
Memory test end of intervention			-.246* p = .021

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)
Negative correlations suggest that the increase in one variable was proportional to the decrease in other variable (in this case, less time needed to complete spatial-temporal and memory tests, which is a positive development).

10.2.2 Relationships between mathematics and other variables over the three-year period of the study

To examine how the relationship between results in spatial-temporal and memory tests and mathematics developed over the three-years of the study, correlations between these variables at different points in the programme were calculated. Table 10.2 presents these correlations for the intervention groups. At the beginning of the study there was a small strength relationship between the picture test and mathematics which by the end of the pilot study and the end of the main study had increased to moderate strength. Once the intervention was withdrawn, the correlation became even stronger a year after termination of the music programme. The relationship between the memory test and mathematics was strong throughout the study with the last three measurements being at a very similar level. At the beginning of the study, the relationship between the results in the puzzle test and mathematics was not statistically significant. At the end of the pilot study and the end of the main study it had become statistically significant and of moderate strength. After the music programme had stopped it became even stronger.

Table 10.2: Comparison of correlations between results in mathematics and in spatial-temporal and memory tests throughout the period of study for the intervention groups

Intervention Group	Mathematics beginning of the study	Mathematics end of pilot study	Mathematics end of main study	Mathematics after intervention withdrawal
Picture test	-.280* p = .031	-.367**	-.429**	-.512**
Memory test	.441**	.664**	.699**	.681**
Puzzle test	-.181 p = .167	-.295**	-.427**	-.510**

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)

Correlations obtained for the control groups are presented in the Table 10.3. The association between the results of the picture test and mathematics was moderate at the beginning of the study; it became strong at the end of the pilot study but then weakened by the end of the main study. It then stayed at a similar level for the last measurement a year later. The correlation between the memory test and mathematics was strong at the beginning of the study and gained in strength throughout the period of three years. The relationship between the puzzle test and mathematics was of small strength at the beginning of the pilot study, became moderate at the end of the pilot study after which time it stopped being statistically significant.

Table 10.3: Comparison of correlations between results in mathematics and in spatial-temporal and memory tests throughout the period of study for the control groups

Control Group	Mathematics beginning of the study	Mathematics end of pilot study	Mathematics end of main study	Mathematics after intervention withdrawal
Picture test	-.401** p = .002	-.500**	-.244**	-.272**
Memory test	.561**	.690**	.749**	.721**
Puzzle test	-.278* p = .032	-.430**	-.132 p = .220	-.187 p =.08

** correlation significant at the 0.01 level (2-tailed)* correlation significant at the 0.05 level (2-tailed)

As this research set out to explore the impact that participation in music had on learning mathematics, the next analysis focused on the relationship between the results in music and in mathematics over the period of the study. As presented in Table 10.4 at the end of the pilot study the correlation was moderate, it became stronger at the end of the main study and even stronger a year after the music programme was ended.

Table 10.4: Comparison of correlations between results in music and mathematics throughout the period of study for the intervention group

Intervention Group	Mathematics end of pilot study	Mathematics end of main study	Mathematics after intervention withdrawal
Overall score in music	-.354** p = .001	-.582**	-.635**

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed)

10.3 Chapter summary

A year after the musical programme was terminated data in mathematics was collected. A range of analyses showed that the relationship of the mathematical data with children's scores in the picture, memory and puzzle tests was strong even then for the intervention groups. For the control groups these correlations were relatively weaker or statistically non-significant for the spatial-temporal tests and strong on the memory test.

Investigation of the relationships between the results in mathematics at different points of the study and the picture and the puzzle tests showed differences between the intervention and the control groups. For the music groups the correlation strengthened throughout the process, including the year after the programme ended. As for the control group, after the initial assessment of the relationship, it became weaker or even statistically non-significant in terms of the puzzle test. Correlations between mathematics and the memory test were strong for both groups from the beginning and became even stronger throughout the study. That suggests that spatial-temporal abilities were related to active participation in music which is why the relationships recorded for the intervention groups became stronger than for the control group. Concurrently, relationships with the memory test became stronger for both groups suggesting that their development was determined by other than participation in the musical programme and was similar for all of the children.

The relationship between the results in music and mathematics developed over the period of three years being of moderate strength at the end of the pilot study, gradually increasing by the end of the main study and continuing to become stronger a year after the programme ended. This might suggest that some children simply perform better in both subjects, however, as set out in Chapter 8 and Chapter 9, this association was not the same across a variety of mathematical skills which suggests that such a proposition is not likely. A more likely explanation is that the musical programme impacts on some, rather than all mathematical skills.

Chapter 11: Impact of the music programme on different groups of children

11.1 Introduction

A limited number of studies in this area have investigated the interaction between music and academic achievement and the development of spatial-temporal reasoning in children taking account of differences between groups, for instance, from low-income families (Neville et al., 2008), and children who do not perform well academically (Rauscher, 2003b). Similarly, there has been no research into the impact of active engagement with music on groups of children with Special Educational Needs and Disabilities (SEND) or with English as an Additional Language (EAL). The current study was able to collect data relating to such groups enabling analysis to be undertaken to gain in depth understanding of the impact of participation in the music programme on these different groups of children. Additionally, gender differences have rarely been examined. The analysis of the data collected in this project provided some insights into possible gender differences. This chapter describes findings from such analyses and addresses the following question:

- What is the impact of the programme on different groups of children (SEND, FSM, EAL, male/female)?

11.2 The impact of the programme on children with Special Educational Needs and Disabilities

Within the whole sample, 21% of children had SEND. Schools support SEND children on several levels depending on the severity of the assessed difficulties in learning of each child. An appropriately graded and focused support ranges from 'school action', through 'school action plus,' to a 'special educational needs statement' for pupils with most acute learning difficulties. The greatest proportion of children with SEND have moderate learning difficulties and are supported by a process of 'school action' which might constitute: additional support from teaching assistants; differentiated work in the classroom; or some lessons in smaller groups. 'School action plus' assists children with more acute difficulties with more individual support from teachers and teaching assistants. Some children might benefit from individual lessons which support their specific needs and be granted additional time to access the requirements of the National Curriculum. In some cases, these efforts might be combined with bodies from outside of the school like school-home worker, speech therapist etc. Most severe difficulties require very specific assistance and the 'SEND statement', which comes with an additional budget, enable the school to employ a teaching assistant who works individually with each child, provide learning structures prepared precisely for the needs of the child and often cooperate with a range of out of school agencies.

In the sample in the current study, moderate learning difficulties were the most frequent. 20 pupils were assessed to have such needs. Another 13 children had speech, language and communication difficulties. Behavioural, emotional and social difficulties were noted in two children, and there were singular cases of autistic spectrum disorder and hearing impairment. Within the intervention group there were 22 pupils with SEND, out of whom 17 required additional support in the form of 'school action'. Four needed 'school action plus', and there was one child with a 'SEND statement'. There were 15 children with SEND in the control group. One required 'school action plus', the remainder were supported by 'school action'.

11.2.1 Analyses of the changes in scores between the SEND music and the SEND control groups

Paired samples t-test between the SEND music and SEND control groups provided insight into changes of scores over the period of intervention. Values of t, differences in means and the Pearson's correlation coefficients are presented in table 11.1. In all cases the significance value for the Pearson's correlation was $p = .0001$. Greater values of difference in means between the groups are highlighted in bold. Children from the SEND music group made greater progress than their peers in writing and the picture, memory and puzzle tests. In reading and mathematics children from the SEND control groups made greater gains. However, as table 11.2 shows none of these differences were statistically significant.

Repeated measures mixed between-within analysis of variance was used in all six areas of assessment pre- and post-intervention to further examine change in scores over the two periods of time and the impact of belonging to the intervention versus the control group. Table 11.2 presents these differences in change in scores. In both groups in all assessments there was a statistically significant effect for time but no other significant differences between groups were recorded.

Table 11.1: Changes in scores for the SEND music and control groups in all areas of assessment over the time of the intervention

	reading	writing	mathematics	picture test	memory test	puzzle test
Music SEND group	t(21)= 10.27 MD = 3.09 r = .795	t(21)= 10.78 **MD = 2.86** r = .799	t(21)= 9.72 MD = 3.27 r = .766	t(21)=- 5.71 **MD = -6.77** r = .875	t(21)= 7.24 **MD = -1.86** r = .587	t(21)= -6.43 **MD = -.52** r = .925
Control SEND group	t(14)= 9.32 **MD = 3.13** r = .869	t(14)= 10.21 MD = 2.60 r = .863	t(14)= 11.22 **MD = 3.60** r = .858	t(14)= -5.20 MD = -6.26 r = .944	t(14)= 3.10 MD = 1.26 r = .531	t(14)= -3.95 MD = -.36 r = .954

value of p = .0001 in all unmarked cases

Table 11.2: The impact of the intervention on the children from the SEND music and the SEND control groups over two time periods

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	1.00	.927	.000	**.159**	**.000**	**.841**	.771	.002
Writing	.987	.498	.013	**.148**	**.000**	**.852**	.507	.013
Mathematics	.987	.506	.013	**.149**	**.000**	**.851**	.583	.009
Picture test	.998	.774	.002	**.386**	**.000**	**.614**	.453	.016
Memory test	.954	.201	.046	**.428**	**.000**	**.572**	.512	.012
Puzzle test	.952	.191	.048	**.408**	**.000**	**.592**	.483	.014

The lack of difference between children with SEND from the intervention and the control groups might be related to the fact that within the music group there were more children with more complex educational needs. That these pupils performed on a par with children who required less additional support might suggest that taking part in the music programme had a positive impact on their learning. When the scores of the children whose educational needs were supported only by school action were considered, the differences between the music and the control group were slightly greater but still not statistically significant.

11.2.2 Analyses of the changes in scores between the music SEND and the music non-SEND groups

In the group of children who took part in the music lessons there were 22 diagnosed with SEND and 68 overall who made up the non-SEND group. When compared with children without SEND within the intervention group, progression in the SEND music group was less in academic measurements like reading, writing and mathematics as reported in table 11.3. In the picture test, the memory test, and the puzzle test, the SEND group achieved better scores. All these differences in scores were statistically significant as presented in table 11.4.

Analysis of variance was undertaken to examine whether these differences were statistically significant. Descriptive statistics for these analyses are showed in table 15, Appendix 2. The Levene's test of equality of error variances was calculated and at no point was the assumption of the homogeneity of variance violated (as presented in table 16, Appendix 2). The assumption of the homogeneity of inter-correlations was not violated as shown by the Box's test of equality of covariance matrices presented in table 16, Appendix 2. All of these differences were statistically significant with the non-SEND group achieving greater progression in reading ($p = .004$, partial eta squared = .092), writing ($p = .007$, partial eta squared = .081) and mathematics ($p = .010$, partial eta squared = .074). However, on the spatial-temporal and memory tests the results were the opposite with the SEND group showing greater progression. The main effect for the difference in progression between these two groups was statistically significant in the picture test ($p = .001$, partial eta squared = .113), the memory test ($p = .000$, partial eta squared = .198), and the puzzle test ($p = .0001$, partial eta squared = .263). Results of these analyses are presented in table 11.4.

Table 11.3: Changes in scores in different groups in all areas of assessment over the time of the intervention for the music SEND and music non-SEND groups

	reading	writing	mathematics	picture test	memory test	puzzle test
Music SEN group	t(21)= 10.27 MD = 3.09 r = .795	t(21)= 10.7 MD = 2.86 r = .799	t(21)= 9.72 MD = 3.27 r = .766	t(21)=- 5.71 **MD = -6.77** r = .875	t(21)= 7.24 **MD = 1.86** r = .587	t(21)= -6.43 **MD = -.52** r = .925
Music non-SEN group	t(67)= 20.59 **MD = 4.57** r = .794	t(67)= 21.4 **MD = 4.27** r = .833	t(67)= 23.38 **MD = 4.52** r = .764	t(67)= -11.09 MD = -6.73 r = .914	t(67)= 8.07 MD = 1.39 r = .778	t(67)= -10.7 MD = -.37 r = .859

value of p = .0001 in all unmarked cases

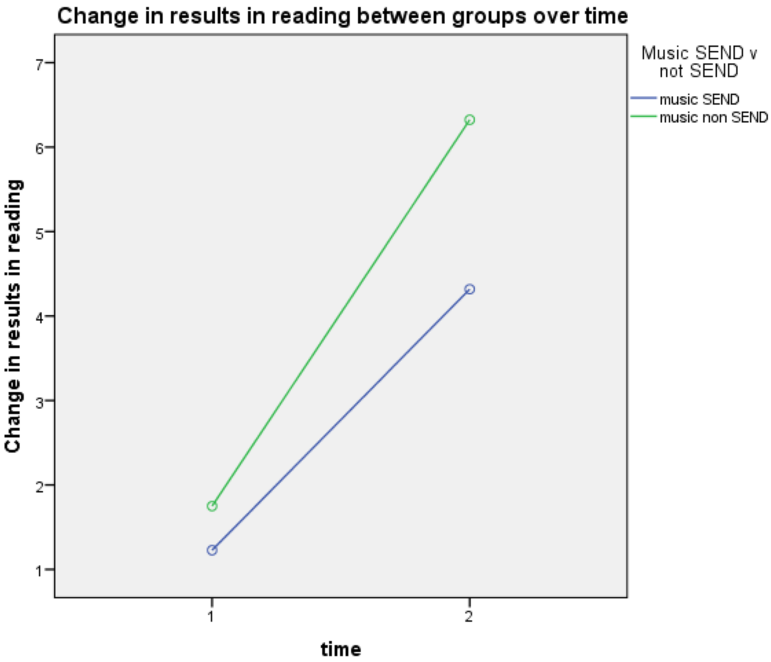
Table 11.4: The impact of the intervention on the SEND and non-SEND children over two time periods for the music group

	Interaction between the participation in the music programme against the control group and time			Main effect for time			Main effect for participation in the music programme against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	**.879**	**.001**	**.121**	**.214**	**.000**	**.786**	**.004**	**.092**
Writing	**.865**	**.000**	**.135**	**.202**	**.000**	**.786**	**.007**	**.081**
Mathematics	**.895**	**.002**	**.105**	**.181**	**.000**	**.819**	**.010**	**.074**
Picture test	1.0	.976	.000	**.434**	**.000**	**.566**	**.001**	**.113**
Memory test	.979	.171	.021	**.486**	**.000**	**.514**	**.000**	**.198**
Puzzle test	.955	.044	.045	**.390**	**.000**	**.610**	**.000**	**.263**

Figures 11.1, 11.2, 11.3, 11.4, 11.5, and 11.6 present the differences in change scores. On the spatial-temporal and memory tests progression was greater for the SEND group, although the results for the SEND group started and ended lower than for the non-SEND group.

Figure 11.1 sets out the outcomes of the assessment in reading. The non-SEND music group achieved greater progression than their peers from the SEND group.

Figure 11.1: Change in results in reading for the SEND music and the non-SEND music groups over two periods of time



As presented in figure 11.2, the non-SEND music group outperformed their SEND peers in writing.

Figure 11.2: Change in results in writing for the SEND music and the non-SEND music groups over two periods of time

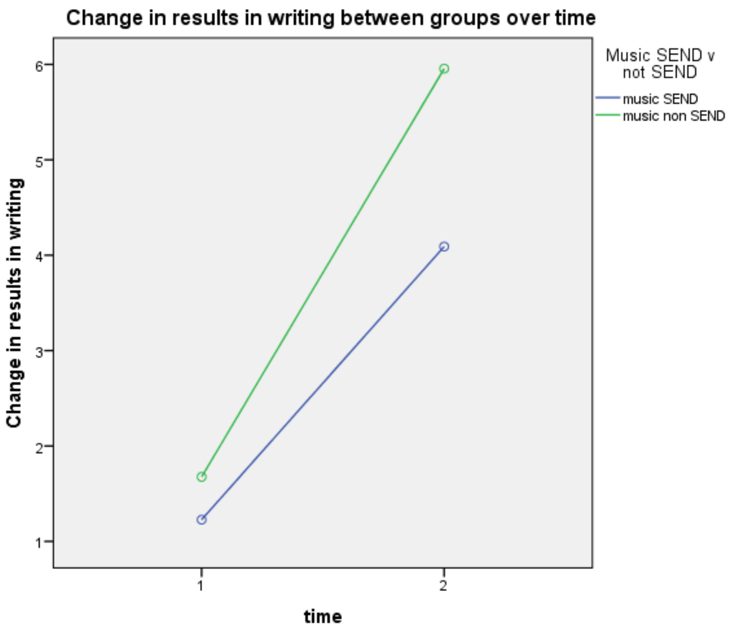
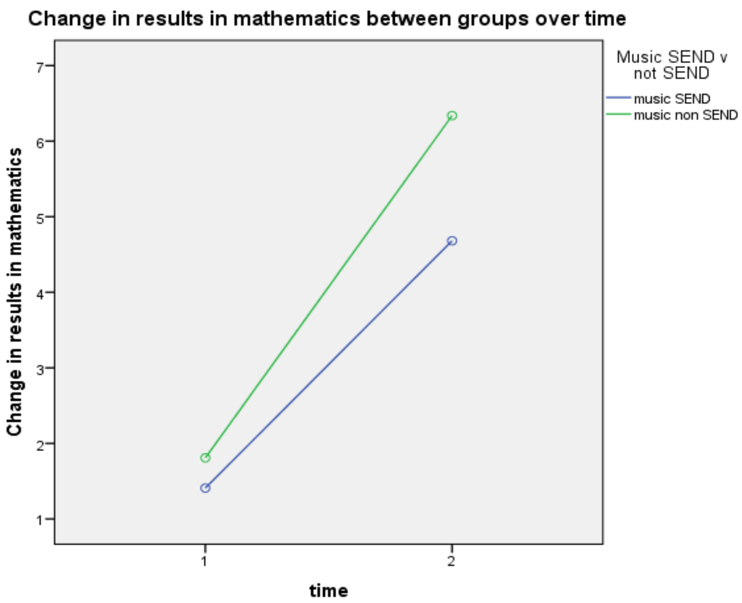


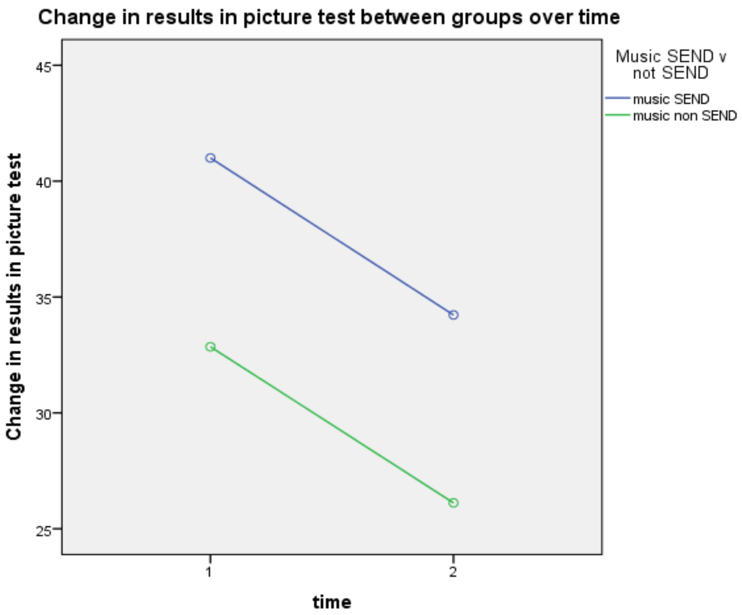
Figure 11.3 shows the progression in mathematics with the non-SEND music group achieving greater gains than the SEND group.

Figure 11.3: Change in results in mathematics for the SEND music and the non-SEND music groups over two periods of time



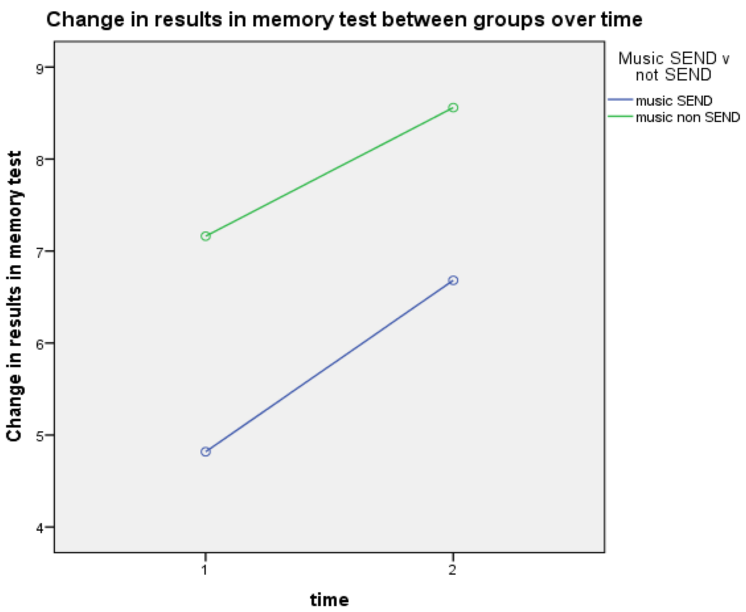
In the picture test children from the SEND music group made greater progress than the non-SEND group as illustrated in Fig. 11.4.

Figure 11.4: Change in results in the picture test for the SEND music and the non-SEND music groups over two periods of time



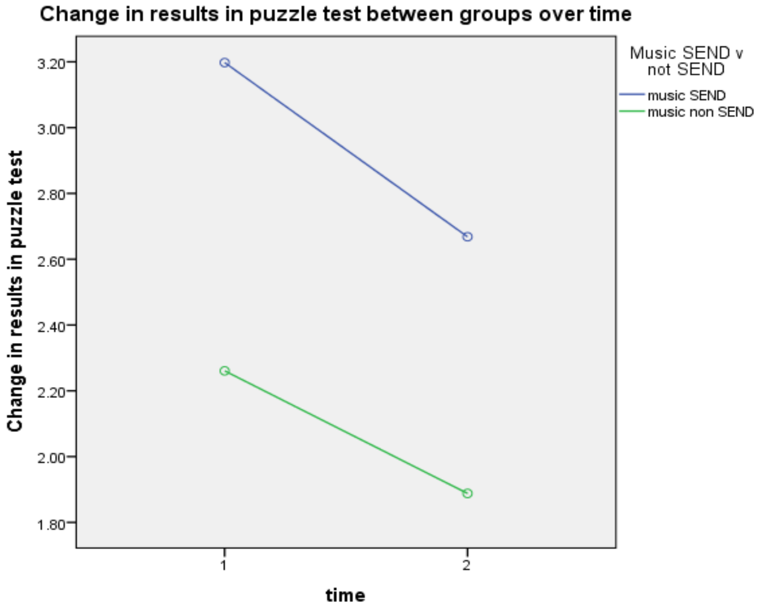
On the memory test pupils from the SEND group achieved greater progress than the children who did not have SEND as presented in figure 11.5.

Figure 11.5: Change in results in the memory test for the SEND music and the non-SEND music groups over two periods of time



Change of scores in the puzzle test was greater for the SEND children than for the non-SEND children as illustrated in figure 11.6.

Figure 11.6: Change in results in the puzzle test for the SEND music and the non-SEND music groups over two periods of time



11.2.3 Summary

The possible impact of music programmes on children with SEND has not been reported previously. The findings of the current study represent the first consideration of such a relationship. The results suggest that participation in the music programme had a more pronounce impact on the development of spatial-temporal and memory skills in the children with SEND than on other children from the intervention group (p = .001, partial eta squared = .113 for the picture test; p = .000, partial eta squared = .198 for the memory test; p = .000, partial eta squared = .263 for the puzzle test). It is possible that because of children's additional needs longer participation in music is required to achieve the development in academic areas of assessment. Once the progression for the SEND music and the SEND control groups was considered, there were no statistically significant differences between there groups. Further research is needed to examine these questions in more depth.

11.3 The impact of the programme on children for whom English is an Additional Language (EAL)

Within the group of 178 children who took part in the study, 23% of them were identified as pupils for whom English was not the first but an additional language. Out of these 41 students, 21 of them belonged to the intervention group and 20 to the control group.

11.3.1 Analyses of the changes in scores between the EAL music and the EAL control groups

Changes in scores in the different tests were considered for the children from the EAL group and compared for the intervention group and the control group. In all six areas of assessment children from the EAL music group achieved greater progress than their peers as shown in table 11.5. However, only the difference in the puzzle test was statistically significant as showed in table 11.6.

To investigate the impact of participation in the music programme on the change of scores and the statistical significance of these changes, results of the EAL music group were compared with the results of the EAL control group in an analysis of variance. This was undertaken in all six areas of assessment across two time periods pre- and post-intervention. The analyses were preceded by checking the relevant assumptions for the measurements which showed statistically significant differences and none of them were violated. This included the descriptive statistics (presented in table 17, Appendix 2), the Levene's test of equality of error variances, and the assumption of the homogeneity of inter-correlations (both presented in table 18, Appendix 2).

The main effect for time was statistically significant for all six areas of assessment. In the puzzle test the interaction between belonging to the music group versus the control group was statistically significant with the intervention group outperforming their peers. No other interactions were statistically significant These results are presented in table 11.6.

Table 11.5: Changes in scores in different groups in all areas of assessment over the time of the intervention for the EAL music and control groups

	reading	writing	mathematics	picture test	memory test	puzzle test
Music EAL group	t(20)= 8.82 **MD = 3.47** r = .829	t(20)= 8.82 **MD = 3.28** r = .846	t(20)= 9.63 **MD = 3.48** r = .768	t(20)=- 4.37 **MD = -5.85** r = .807	t(20)= 5.50 **MD = -1.33** r = .838	t(20)= -9.7 **MD = -.46** r = .961
Control EAL group	t(19)= 10.10 MD = 3.10 r = .681	t(19)= 11.71 MD = 2.70 r = .788	t(19)= 11.70 MD = 3.30 r = .647	t(19)= -4.57 MD = -4.25 r = .947	t(19)= 4.32 MD = 1.20 r = .739	t(19)= -4.2 MD = -.29 r = .970

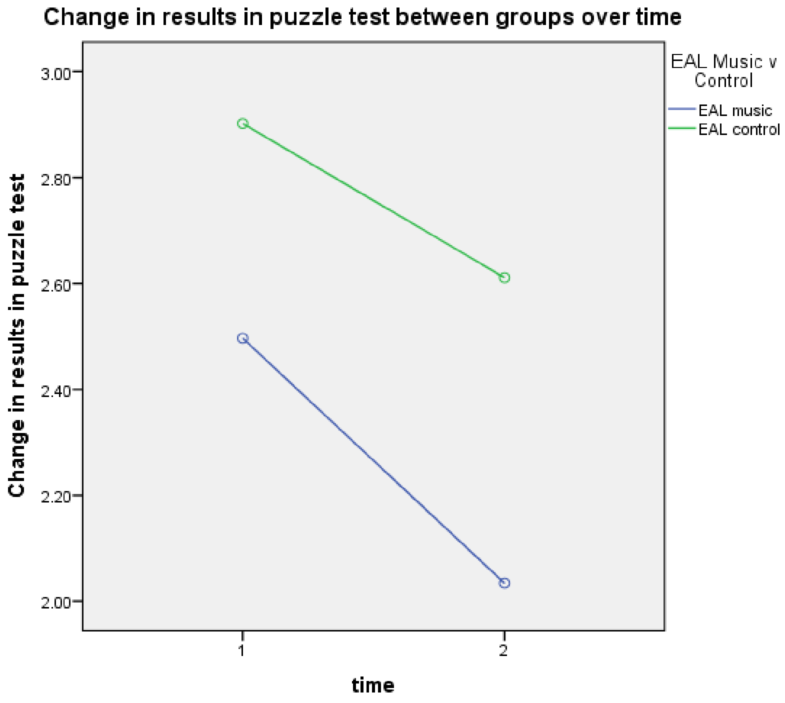
value of p = .0001 in all unmarked cases

Table 11.6: The impact of the intervention against the control over two time periods for the EAL groups (music and control)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	.986	.459	.014	**.18**	**.000**	**.81**	.354	.022
Writing	.957	.194	.043	**.17**	**.000**	**.82**	.117	.062
Mathematics	.998	.78	.002	**.15**	**.000**	**.84**	.648	.005
Picture test	.976	.335	.024	**.50**	**.000**	**.49**	.269	.031
Memory test	.997	.718	.003	**.45**	**.000**	**.55**	.489	.012
Puzzle test	**.902**	**.046**	**.098**	**.32**	**.000**	**.67**	.096	.068

Figure 11.7 shows how the EAL music and the EAL control groups performed in the puzzle test. The music group required less time to complete the task initially than the control group. Their progression by the end of the intervention was more pronounced and children from this group were successful in finishing the puzzle in much less time than children who did not take part in the music lessons. These changes over time and differences between the changes of scores in each group were statistically significant.

Figure 11.7: Change in results in the puzzle test for the EAL music and the EAL control groups over two periods of time



11.3.2 Analyses of the changes in scores between the music EAL and the music non-EAL groups

To examine the possible differences in the impact of participation in the music programme on children for whom English was an additional language, children who took part in music lessons were divided into a music EAL group and a music non-EAL group. There were 21 pupils in the EAL group and 69 in the non-EAL group. Comparison of the change in scores for each group showed that the non-EAL group made greater progress in all but one test. The only assessment in which the EAL group outperformed their peers was the puzzle test. All these results are presented in table 11.7.

Table 11.7: Changes in scores in the music EAL and the music non-EAL groups in all areas of assessment over the time of the intervention

	reading	writing	mathematics	picture test	memory test	puzzle test
Music EAL group	t(20)= 8.82 MD = 3.47 r = .829	t(20)= 8.82 MD = 3.28 r = .846	t(20)= 9.63 MD = 3.48 r = .768	t(20)=- 4.37 MD = -5.85 r = .807	t(20)= 5.50 MD = -1.33 r = .838	t(20)= -9.71 **MD = -.46** r = .961
Music non EAL group	t(68)= 20.34 **MD = 4.43** r = .822	t(68) = 21.21 **MD = 4.13** r = .841	t(68)= 22.84 **MD = 4.46** r = .809	t(68)= -12.20 **MD = -7.01** r = .914	t(68)= 8.90 **MD = 1.56** r = .831	t(68)= -9.55 MD = -.39 r = .914

The repeated measures analyses were preceded by checking the relevant assumptions and none of them were violated. This included the descriptive statistics (presented in table 19, Appendix 2), the Levene's test of equality of error variances, and the assumption of the homogeneity of inter-correlations (both presented in table 20, Appendix 2). The results of the analyses confirmed that there were statistically significant relationships between belonging to the music EAL versus the music non-EAL group and progression over the period of the study in four areas of measurement. These assessments were: reading (p = .036, partial eta squared = .049), writing (p = .041, partial eta squared = .046), mathematics (p = .012, partial eta squared = .069), and the memory test (p = .025, partial eta squared = .65). In all of these tests children for whom English was the mother tongue achieved greater change in scores than pupils from the EAL group. This suggests that the impact of participation in the music intervention was less on the EAL children in comparison with the non-EAL group. In table 11.8 the results in bold highlight the statistically significant differences in reading, writing, mathematics, and the memory test.

Table 11.8: The impact of the intervention on children from the EAL music group against the non-EAL music group over two time periods

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	**.951**	**.036**	**.049**	**.22**	**.000**	**.77**	.136	.025
Writing	**.954**	**.041**	**.046**	**.21**	**.000**	**.78**	.219	.017
Mathematics	**.931**	**.012**	**.069**	**.18**	**.000**	**.81**	.062	.039
Picture test	.991	.367	.009	**.46**	**.000**	**.53**	.954	.000
Memory test	.995	.505	.005	**.55**	**.000**	**.44**	**.026**	**.055**
Puzzle test	.992	.401	.008	**.43**	**.000**	**.56**	.893	.000

Figures 11.8, 11.9, 11.10, and 11.11 present progression over time for the music EAL and the non EAL groups. In four areas of measurement: reading, writing, mathematics and the memory test children from the non-EAL music group achieved greater gains than their peers.

Figure 11.8: Change in results in reading for the EAL music and the non-EAL music groups over two periods of time

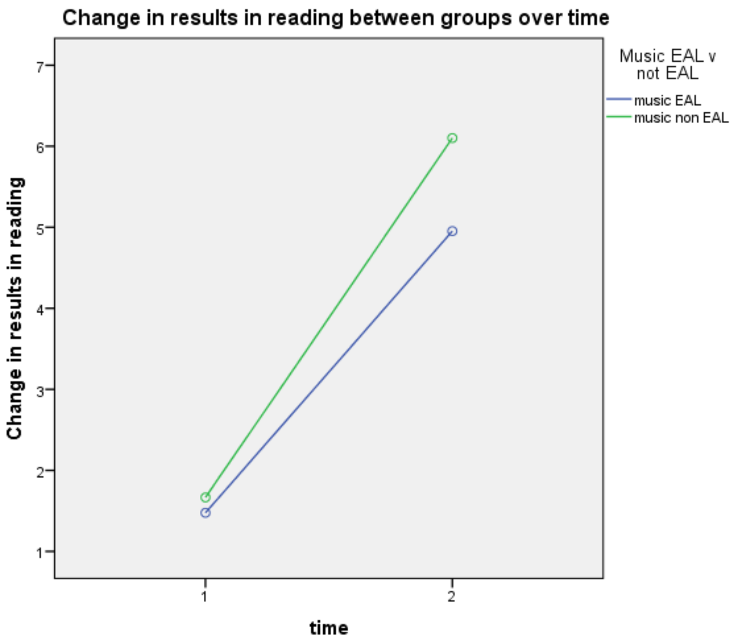


Figure 11.9: Change in results in writing for the EAL music and the non-EAL music groups over two periods of time

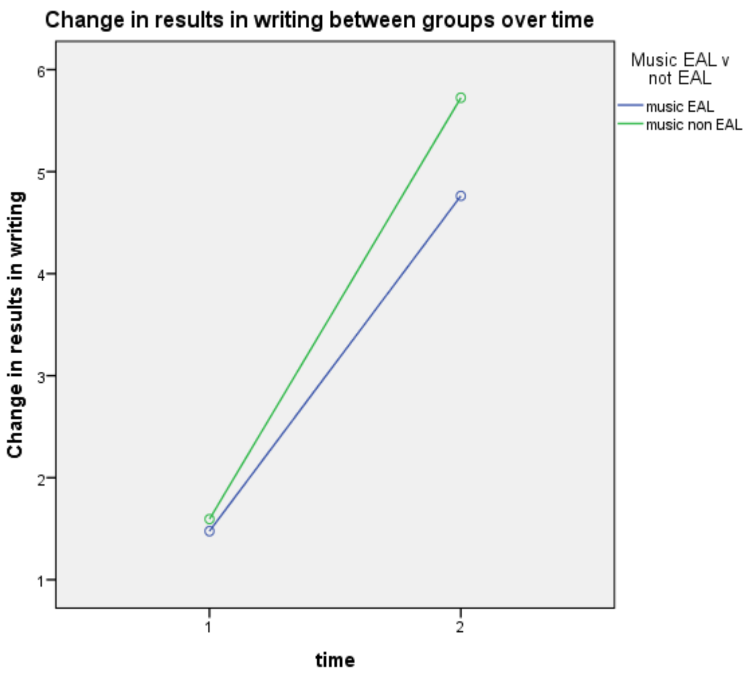


Figure 11.10: Change in results in mathematics for the EAL music and the non-EAL music groups over two periods of time

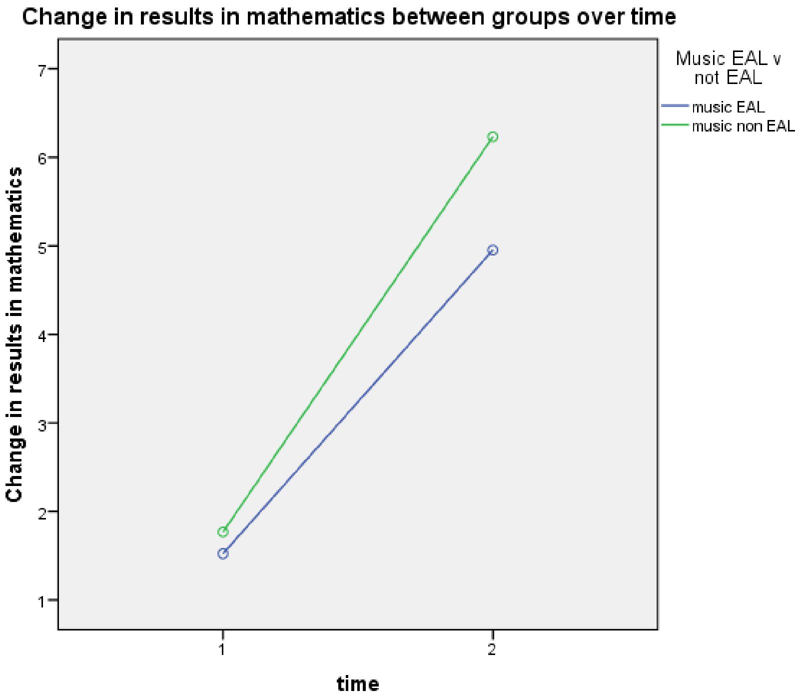
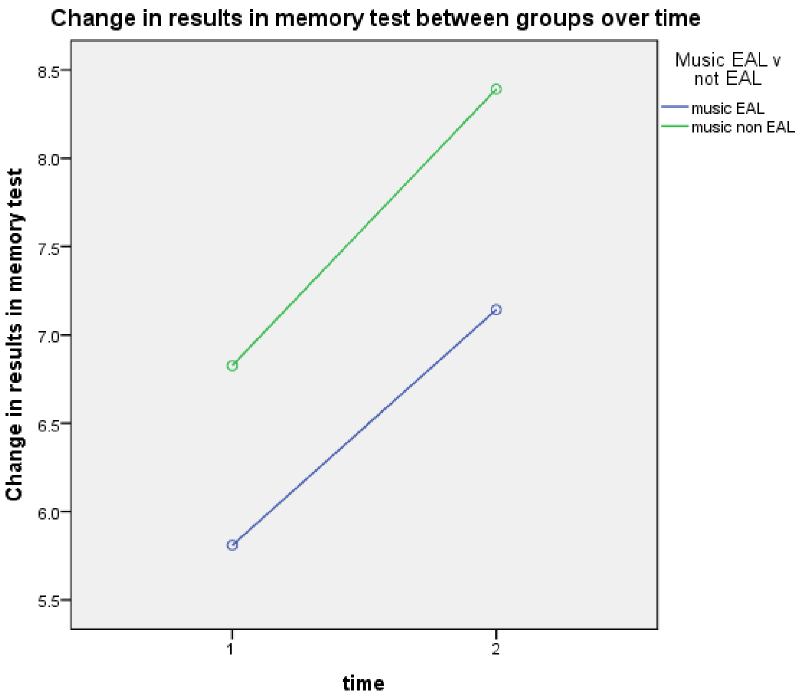


Figure 11.11: Change in results in the memory test for the EAL music and the non-EAL music groups over two periods of time



When attainment in music was considered, the non-EAL group showed greater change (mean difference = .337), but this difference was not statistically significant ($p = .648$).

11.3.4 Summary

The results presented here offer insight into how music programmes might impact on children for whom English is an additional language. This has not been researched or reported on before. The analyses of progression of children for whom English is an Additional Language showed that when the EAL children from the music group were compared with the EAL control group, children from the group who participated in the music lessons achieved greater change of scores. These were statistically significant for the puzzle test (p = .046, partial eta squared = .098).

Comparison within the group of children who took part in the music intervention showed that the non-EAL pupils had larger differences in means at the two times of assessment in all areas of measurement apart from the puzzle test. Some of these differences were statistically significant. They were: reading, writing, mathematics and the memory test (respectively p = .036, partial eta squared = .049; p = .041, partial eta squared = .046; p = .012, partial eta squared = .069; p = .026, partial eta squared = .055).

These findings suggest that participation in the music programme did not have a different impact on the EAL children as compared with the EAL control group or the non-EAL music group. These results are consistent with other findings that the attainment of the children whose first language is not English is often lower than their non-EAL peers as they have to acquire language skills to be able to access academic content. This usually continues until EAL pupils gain full command of the English language. The participants in this project were only in their first years of schooling. For this reason, the results relating to the EAL children are not surprising.

11.4 The impact of the programme on children eligible for Free School Meals

The location of the school where the intervention took place in a quite deprived area of the town meant that the percentage of children eligible for Free School Meals was quite high. Within the sample 24.2% of pupils belonged to the FSM group.

11.4.1 Analyses of the change in scores between the FSM music and the FSM control groups

Out of 43 of the FSM children, 22 participated in the music lessons and 21 made up the FSM control group. Paired samples t-tests were used to investigate changes of scores in all areas of measurement over the period of the intervention. Table 11.9 shows the results. The FSM music group made greater progress on the spatial-temporal tests whilst in all other assessments the FSM control group outperformed the intervention group. Differences in reading, writing and the picture test were statistically significant as showed in table 11.10.

Table 11.9: Changes in scores for the FSM music and the control groups in all areas of assessment over the time of the intervention

	reading	writing	mathematics	picture test	memory test	puzzle test
Music FSM group	t(21)= 11.4 MD = 3.50 r = .674	t(21)= 11.1 MD = 3.27 r = .723	t(21)= 9.72 MD = 3.81 r = .536	t(21)=- 6.19 **MD = -6.68** r = .899	t(21)= 3.35 MD = -1.04 r = .665	t(21)= -5.9 **MD = -.34** r = .929
Control FSM group	t(20)= 17.3 **MD = 4.38** r = .848	t(20)= 15.4 **MD = 4.09** r = .829	t(20)= 19.53 **MD = 4.33** r = .784	t(20)= -3.81 MD = -3.28 r = .935	t(20)= 3.79 **MD = 1.19** r = .715	t(20)= -4.8 MD = -.21 r = .958

value of p = .0001 in all unmarked cases

Analysis of variance was used to check whether these differences were statistically significant. The repeated measures analyses were preceded by checking the relevant assumptions for the measurements which showed statistically significant differences and none of them were violated. This included the descriptive statistics (presented in table 21, Appendix 2), the Levene's test of equality of error variances, and the assumption of the homogeneity of inter-correlations (both presented in table 22, Appendix 2).

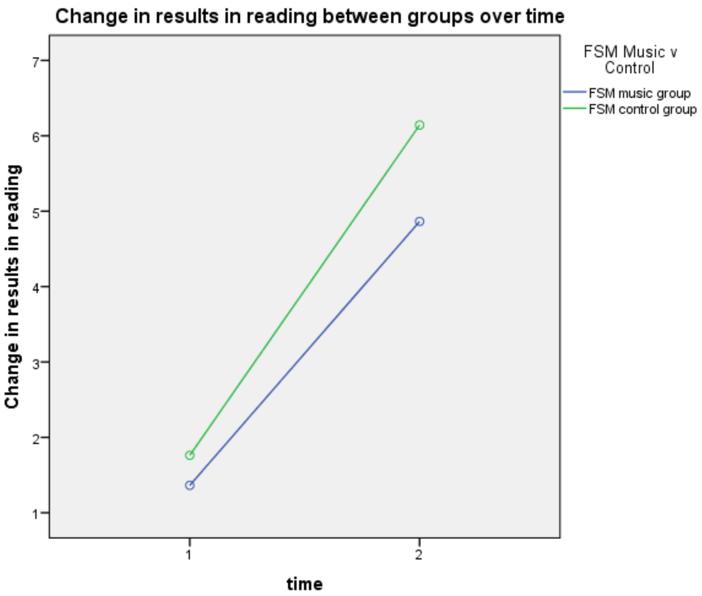
Table 11.10 shows that in three of the assessments statistically significant differences were observed. In reading (p = .033, partial eta squared = .106) and writing (p = .046, partial eta squared = .094). Children from the FSM control group achieved a greater change of scores. The FSM music group performed better in the picture test (p = .019, partial eta squared = .127).

Table 11.10: The impact of the intervention against the control over two time periods in the FSM groups (music and control)

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	**.894**	**.033**	**.106**	**.095**	**.000**	**.905**	.051	.090
Writing	**.906**	**.046**	**.094**	**.107**	**.000**	**.893**	.081	.072
Mathematics	.970	.266	.030	**.114**	**.000**	**.886**	.074	.076
Picture test	**.873**	**.019**	**.127**	**.444**	**.000**	**.557**	.991	.000
Memory test	.997	.745	.003	**.616**	**.000**	**.384**	.460	.013
Puzzle test	.926	.077	.074	**.418**	**.000**	**.582**	.619	.006

Figures 11.12, 11.13, and 11.14 show the differences in progression between the FSM groups which were statistically significant. In reading the control group achieved a greater change of scores as presented in fig. 11.12.

Figure 11.12: Change in results in reading for the FSM music and the FSM control groups over two periods of time



In writing the FSM control group achieved greater progression than their peers from the music group. Change of scores for both groups is presented in fig. 11.13.

Figure 11.13: Change in results in writing for the FSM music and the FSM control groups over two periods of time

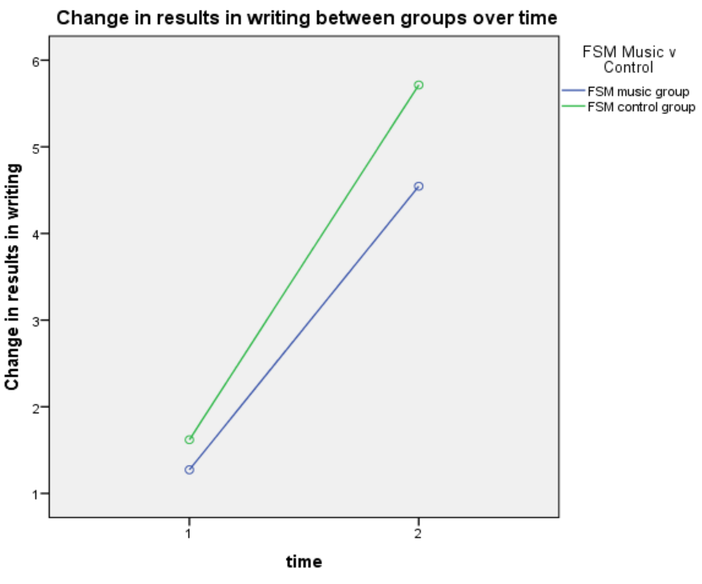
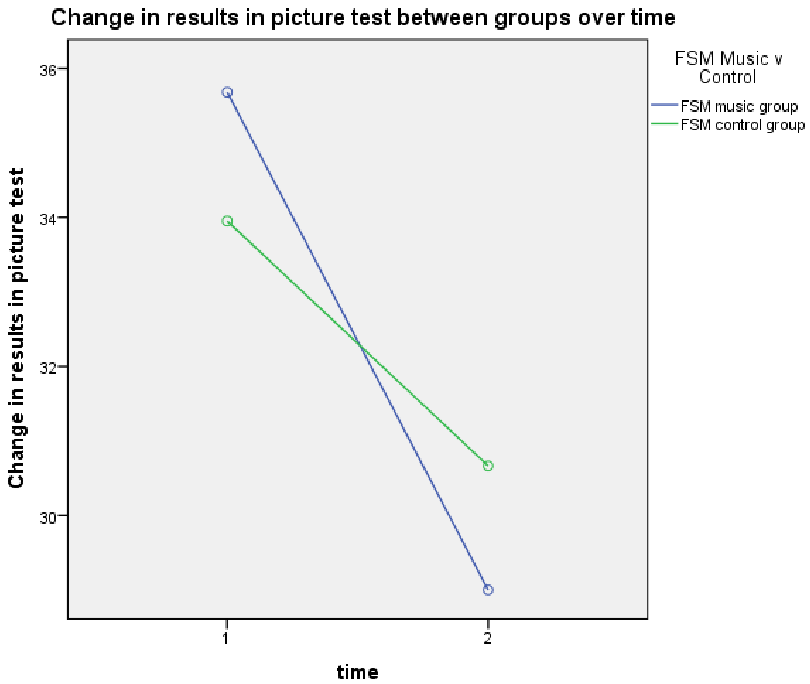


Figure 11.14 shows that in the picture test it was the children from the FSM music group who made greater progress.

Figure 11.14: Change in results in the picture test for the FSM music and the FSM control groups over two periods of time



These findings showed differences in progression between children eligible for Free School Meals who took part in the music intervention and the FSM children from the control group. In two of the measurements the FSM music group made greater progress than their peers. One of these differences was statistically significant. However, it is worth noting that the significant difference occurred in the picture test one of the areas which was predicted to not be affected by participation in the music lessons. Further research is required to investigate whether more intensive or more prolonged participation in the intervention might bring about more positive change.

11.4.2 Analyses of the changes in scores between the music FSM and the music non-FSM groups

The sample of children who took part in the music lessons was made up of 22 children eligible for Free School Meals and of 68 pupils from the non-FSM music group. Progression as measured in all testing areas for these two groups was greater for the non-FSM group across all six assessments. Table 11.11 presents the mean differences, values of t, and the Pearson's correlation coefficients for the music FSM and the music non-FSM groups. As the results of the repeated measures analyses showed, out of these differences only two were statistically significant. They were reading (p = .037, partial eta squared = .049), and writing (p = .032, partial eta squared = .051). All the results are presented in table 11.12. The analyses were preceded by checking the relevant assumptions for the measurements which showed statistically significant differences and none of them were violated. This included the descriptive statistics (presented in table 23, Appendix 2), the Levene's test of equality of error variances, and the assumption of the homogeneity of inter-correlations (both presented in table 24, Appendix 2). The differences between the FSM group and the non-FSM group in their music scores were not statistically significant (p = .195, MD = -.941).

Table 11.11: Changes in scores for the music FSM and the music non-FSM groups in all areas of assessment over the time of the intervention

	reading	writing	mathematics	picture test	memory test	puzzle test
Music FSM group	t(21)= 11.4 MD = 3.50 r = .674	t(21)= 11.07 MD = 3.27 r = .723	t(21)= 9.72 MD = 3.81 r = .536	t(21)=- 6.19 MD = -6.68 r = .899	t(21)= 3.35 MD = -1.04 r = .665	t(21)= -5.90 MD = -.34 r = .929
Music non-FSM group	t(67)= 19.2 **MD = 4.44** r = .822	t(67)= 20.1 **MD = 4.14** r = .841	t(67)= 22.30 **MD = 4.35** r = .809	t(67)= -10.79 **MD = -6.76** r = .914	t(67)= 10.27 **MD = 1.66** r = .831	t(67)= -10.7 **MD = -.43** r = .914

value of p = .0001 in all unmarked cases

Table 11.12: The impact of the intervention on the FSM and the non-FSM children over two time periods for the music group

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	**.951**	**.037**	**.049**	**.216**	**.000**	**.784**	.065	.038
Writing	**.942**	**.032**	**.051**	**.204**	**.000**	**.796**	.055	.041
Mathematics	.981	.195	.019	**.181**	**.000**	**.819**	.070	.037
Picture test	1.0	.948	.000	**.436**	**.000**	**.564**	.656	.002
Memory test	.963	.069	.037	**.574**	**.000**	**.426**	.279	.013
Puzzle test	.988	.295	.012	**.469**	**.000**	**.531**	.276	.013

11.4.3 Summary

These results suggest that participation in the music programme did not have a different impact on the children eligible for FSM as compared to children who were not eligible for Free School Meals. Both music groups achieved similar progression in most areas of assessment with the exception of reading and writing in which the non-FSM group had a greater change of scores ($p = .037$, partial eta squared = .049 for reading, and $p = .032$, partial eta squared = .051 for writing). When the progression of the FSM music group was compared with the FSM control group, children who took part in the intervention performed better than their peers in the picture test. This difference was statistically significant ($p = .019$, partial eta squared = .127).

11.5 The impact of the programme on children of different genders

The final issue considered in this chapter was whether the impact of the music programme depended on the gender of the participants. Out of the whole group of children who took part in the project, 47% were girls and 53% were boys. Three conditions were taken into account: differences between girls taking part in the music lessons and girls from the control group, differences between boys from the music group versus control boys, and a comparison between girls and boys who participated in the intervention.

11.5.1 Analyses of the changes in scores between the girls' music and the girls' control groups

A paired samples t-test between girls from the music group and girls from the control group revealed that girls who took part in music lessons achieved greater progression in all but one of the assessments. The control group outperformed their peers only in writing. Both groups were of a similar size with 41 girls in the music group and 42 in the control group. Table 11.13 shows values of t, mean differences and values of the Pearce's correlation coefficients. To investigate the statistical significance of the differences between the music and the control group an analysis of variance was used. The analyses were preceded by checking the relevant assumptions for the measurements which showed statistically significant differences and they were not violated. This included the descriptive statistics (presented in table 25, Appendix 2), the Levene's test of equality of error variances, and the assumption of the homogeneity of inter-correlations (both presented in table 26, Appendix 2). As presented in table 11.14 the only test in which there was a statistically significant difference was the picture test with the girls from the music group making greater progress than their peers (p = .009, partial eta squared = .918).

Table 11.13: Changes in scores for the girls' music and control groups in all areas of assessment over the time of the intervention

	reading	Writing	mathematics	picture test	memory test	puzzle test
Music girls' group	t(40)= 13.9 **MD = 4.24** r = .736	t(40)= 15.2 MD = 3.90 r = .768	t(40)= 16.37 **MD = 4.14** r = .759	t(40)=- 7.83 **MD = -6.73** r = .902	t(40)= 5.39 **MD = -1.19** r = .778	t(40)= -8.9 **MD = -.36** r = .932
Control girls' group	t(41)= 16.4 MD = 4.14 r = .804	t(41)= 18.3 **MD = 4.04** r = .827	t(41)= 18.60 MD = 4.11 r = .814	t(41)= -4.88 MD = -3.66 r = .933	t(41)= 5.03 MD = 1.00 r = .796	t(41)= -6.7 MD = -.28 r = .944

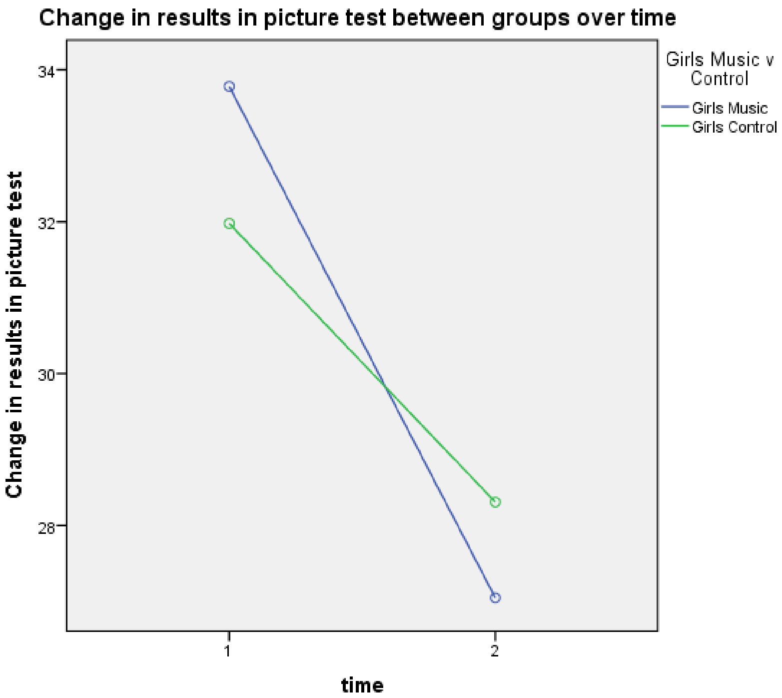
value of p = .0001 in all unmarked cases

Table 11.14: The impact of the intervention on the girls' music and control groups over two time periods

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	.999	.798	.001	**.152**	**.000**	**.848**	.507	.005
Writing	.998	.668	.002	**.127**	**.000**	**.873**	.612	.003
Mathematics	1.0	.935	.000	**.118**	**.000**	**.882**	.799	.001
Picture test	**.918**	**.009**	**.082**	**.493**	**.000**	**.507**	.899	.000
Memory test	.995	.513	.005	**.598**	**.000**	**.402**	.869	.000
Puzzle test	.977	.169	.023	**.397**	**.000**	**.603**	.974	.000

Fig. 11.15 presents the statistically significant difference in progression of both groups of girls for the puzzle test.

Figure 11.15: Change in results in the picture test for the girls' music and control groups over two periods of time



There were very few differences between the progression of the girls who took part in the music lessons and the control group. The only statistically significant difference in change of scores was in the picture test which supports the hypothesis of the music programme positively influencing the development of spatial-temporal reasoning. Results from the boys may shed more light on this finding.

11.5.2 Analyses of the changes in scores between the boys' music and the boys' control groups

95 boys took part in the current study. The first analyses considered performance of the intervention group versus the controls. 49 of them participated in music lessons and 46 were in the control group.

When mean differences were considered for the boys who participated in the intervention and control group, the music group achieved greater differences in means in all areas of measurement. These results are presented in table 11.15.

Table 11.15: Changes in scores for the boys' music and control groups in all areas of assessment over the time of the intervention

	reading	Writing	mathematics	picture test	memory test	puzzle test
Music boys' group	t(48)= 16.5 **MD = 4.18** r = .845	t(48)= 16.2 **MD = 3.95** r = .857	t(48)= 17.32 **MD = 4.28** r = .773	t(48)=- 9.81 **MD = -6.75** r = .922	t(48)= 9.47 **MD = -1.77** r = .828	t(48)= -8.8 **MD = -.44** r = .906
Control boys' Group	t(45)= 17.0 MD = 3.69 r = .848	t(45)= 15.9 MD = 3.32 r = .829	t(45)= 17.49 MD = 3.95 r = .784	t(45)= -8.21 MD = -4.82 r = .935	t(45)= 6.42 MD = 1.39 r = .715	t(45)= -7.5 MD = -.34 r = .958

value of p = .0001 in all unmarked cases

Of these differences in change scores between the two groups of boys, the repeated measures analyses showed that two were of statistical significance. The analyses were preceded by checking the relevant assumptions for the measurements which showed statistically significant differences and they were not violated. This included the descriptive statistics (presented in table 27, Appendix 2), the Levene's test of equality of error variances, and the assumption of the homogeneity of inter-correlations (both presented in table 28, Appendix 2).

The statistically significant differences were recorded for the picture test (p = .037, partial eta squared = .954) and the puzzle test (p = .015, partial eta squared = .588) as presented in table 11.16. In both these tests it was the boys from the music group who made greater progress than their peers. This finding is similar to that of the girls, although for the boys both spatial-temporal tests showed statistical significant differences as opposed to only one for the girls. The intervention may have had a greater effect on the boys.

Table 11.16: The impact of the intervention on the boys' music and control groups over two time periods

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	P	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	p	Partial Eta Squared
Reading	.978	.150	.022	**.142**	**.000**	**.855**	.331	.010
Writing	.960	.053	.040	**.154**	**.000**	**.846**	.228	.016
Mathematics	.990	.331	.010	**.134**	**.000**	**.866**	.616	.003
Picture test	**.954**	**.037**	**.046**	**.365**	**.000**	**.635**	.337	.010
Memory test	.981	.181	.019	**.430**	**.000**	**.570**	.443	.006
Puzzle test	.979	.157	.021	**.412**	**.000**	**.588**	**.015**	**.062**

Figures 11.16 and 11.7 show the level of progression achieved by both groups of boys over time in the picture and the puzzle test with the intervention groups achieving a greater change of scores in both measurements.

Figure 11.16: Change in results in the picture test for the boys' music and control groups over two periods of time

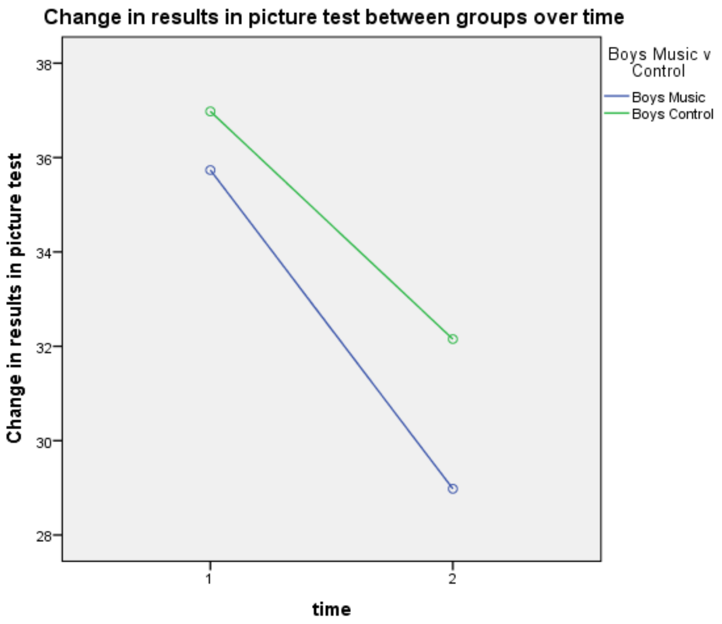
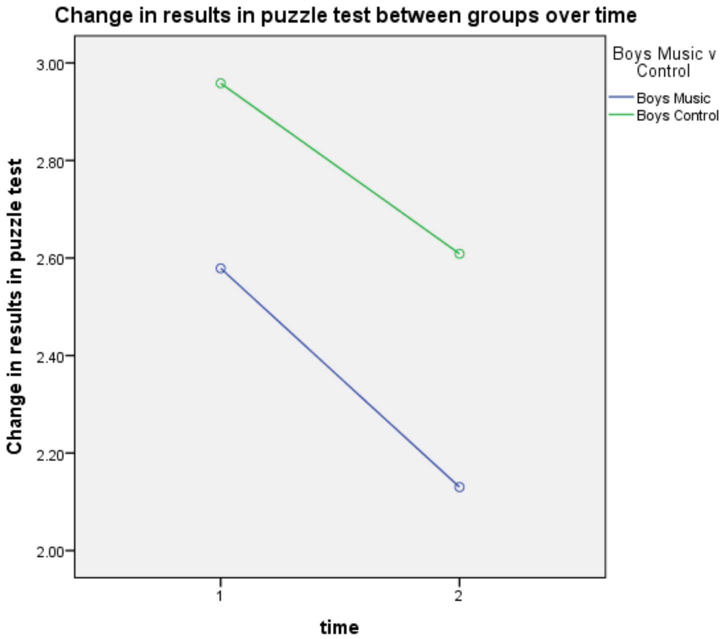


Figure 11.17: Change in results in the puzzle test for the boys' music and control groups over two periods of time



11.5.3 Analyses of the changes in scores between the music girls' and the music boys' groups

Results from the previous analyses showed that there were some differences between girls and boys depending on whether they were in the intervention or control groups. There were more differences for the boys compared to the girls' groups which might suggest a more pronounced impact of the music programme on the boys. Comparison between the girls' music group and the boys' music group was used to provide further insight into such a relationship.

In terms of differences in means achieved by the groups of girls and boys who participated in the music instruction, the progression of the girls in reading was greater than that of the boys while in all other assessments the change of scores in the boys were greater than girls as shown in table 11.17. However, the results of the analysis of variance showed that only one of these differences was statistically significant as table 11.18 presents. It was in the memory test in which the boys made greater progress ($p = .047$, partial eta squared = .044) than the girls. The analyses were preceded by checking the relevant assumptions for the memory test and they were not violated. This included the descriptive statistics (presented in table 29, Appendix 2), the Levene's test of equality of error variances, and the assumption of the homogeneity of inter-correlations (both presented in table 30, Appendix 2). In music, the girls' attainment was slightly greater than that of boys' with a mean difference of .732. However, this difference was not statistically significant ($p = .243$).

Table 11.17: Changes in scores for the music girls' and the music boys' groups in all areas of assessment over the time of the intervention

	reading	writing	mathematics	picture test	memory test	puzzle test
Music girls' group	t(40)= 13.9 **MD = 4.24** r = .736	t(40)= 15.2 MD = 3.90 r = .768	t(40)= 16.37 MD = 4.14 r = .759	t(40)=- 7.83 MD = -6.73 r = .902	t(40)= 5.39 MD = -1.19 r = .778	t(40)= -8.9 MD = -.36 r = .932
Music boys' Group	t(48)= 16.5 MD = 4.18 r = .845	t(48)= 16.2 **MD = 3.95** r = .857	t(48)= 17.32 **MD = 4.28** r = .773	t(48)=- 9.81 **MD = -6.75** r = .922	t(48)= 9.47 **MD = -1.77** r = .828	t(48)= -8.7 **MD = -.44** r = .906

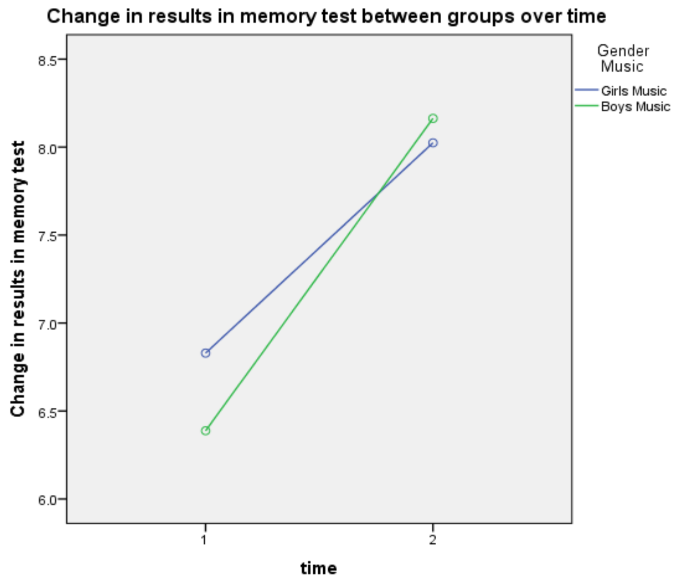
value of p = .0001 in all unmarked cases

Table 11.18: Impact of the intervention on the girls' and boys' music groups over two time periods

	Interaction between the participation in the music program against the control group and time			Main effect for time			Main effect for participation in the music program against the control group	
	Wilks Lambda	p	Partial Eta Squared	Wilks Lambda	p	Partial Eta Squared	P	Partial Eta Squared
Reading	1.0	.878	.000	**.160**	**.000**	**.840**	.654	.002
Writing	1.0	.873	.000	**.152**	**.000**	**.848**	.732	.001
Mathematics	.998	.696	.002	**.136**	**.000**	**.864**	.634	.003
Picture test	1.0	.983	.000	**.364**	**.000**	**.636**	.383	.009
Memory test	**.956**	**.047**	**.044**	**.453**	**.000**	**.547**	.729	.001
Puzzle test	.983	.222	.017	**.375**	**.000**	**.625**	.317	.011

Figure 11.18 shows how scores in the memory test changed over the period of the intervention for the girls and boys who took part in the music programme.

Figure 11.18: Change in results in the memory test for the girls' and boys' music groups over two periods of time



11.5.4 Summary

Possible gender differences in the impact that a music intervention might have on children's learning have not previously been investigated. This chapter addressed this issue. Both girls and boys from the music groups made greater progress than their peers in one or both spatial-temporal tests ($p = .009$, partial eta squared = .918 for girls in the picture test; $p = .037$, partial eta squared = .954 for boys in the picture test and $p = .015$, partial eta squared = .588 for boys in the puzzle test). This supports results from the analysis undertaken on mixed genders groups in the previous chapters. As there was only one statistically significant difference in progression (the memory test, $p = .047$, partial eta squared = .044) between girls and boys from the music group it seems that the impact of the music programme on both genders was similar, especially in the areas of spatial-temporal reasoning and mathematics.

11.6 Chapter summary

This chapter addressed the rarely researched differences between how a music programme might influence children from different groups. The groups considered were children with Special Educational Needs and Disabilities, children for whom English is an Additional Language, children eligible for Free School Meals which is often an indicator of social-economic status, and differences between girls and boys.

Overall, there were not many occasions where the differences between these groups were statistically significant, most such cases were related to spatial-temporal skills. Within the group of all children who took part in the music programme, pupils with SEND progressed statistically significantly greater than their peers in both, the picture and the puzzle test, and in the memory test. There were few differences within the music group between the EAL and the non-EAL children. Compared to the EAL control group, the EAL music group achieved greater results in the puzzle test and these differences were statistically significant There were no significant differences between the FSM and the non-FSM groups who participated in music lessons. The FSM music group recorded greater progression in the picture test than the FSM control group. This difference was statistically significant. The only statistically significant difference between boys and girls was recorded in the memory test.

These results shed some light on the impact that similar interventions may have on different groups of children and could inform strategies used in pedagogical practice in the classroom.

Chapter 12: Discussion

12.1 Introduction

Taking into account the long-researched links between music and mathematics and the positive relationship between music instruction and children's spatial-temporal skills, this research has focused on examining the possible impact of active participation in music on the learning of mathematics. In this study children who took part in a music programme were assessed on a variety of mathematical, spatial-temporal, and memory skills. Their results were compared with those from control groups made up of children who did not attend musical activities to investigate the relationships between specific musical, mathematical and spatial temporal competencies.

12.2 Research questions addressed in this study

The project investigated two main research questions:

- How, if at all, does participation in music influence learning in mathematics and learning in other academic areas?
- Can teaching which has led to the findings of this research be implemented in the primary classroom practice?

Five more detailed sub-questions were addressed:

- How, if at all, does participation in music influence learning in mathematics?
- Does participation in music improve spatial-temporal skills? What is the relationship between the development of these abilities and learning in mathematics?
- In which mathematical abilities can change be observed? Which mathematical skills, if any, might be developed in a more significant way by a music intervention?
- What are the relationships between specific mathematical skills and achievement in music? Which particular musical activities might have the strongest impact?
- What are the long-term relationships between music and mathematics and is the impact sustainable?
- What is the impact of the programme on different groups of children (SEND, FSM, EAL, gender differences)?

This chapter explores the findings and organises them into strands to relate them to the research questions with reference to the literature review. It also identifies and discusses the limitations of the study. Reflection on the implications of this project and its contribution to knowledge, will lead to suggestions about areas for further research.

12.3 How, if at all, does participation in music influence learning in mathematics?

Throughout the study the performance of groups of children who took part in the music programme and those who did not participate in such lessons was compared in the area of general mathematics, spatial-temporal abilities and on a memory test. Previous research has suggested that learning music, in particular rhythmic instruction leads to more notable development of spatial-temporal skills. As these skills are considered to be high mathematical abilities (Shaw, 1980), the current research set out to further examine the impact of music on spatial-temporal cognition and investigate its connection with the learning of mathematics. The possibility of the music programme affecting learning mathematics in other ways than through spatial-temporal context was also considered.

As the findings of the current study have suggested, in mathematics, the interaction between participation in the music programme and academic achievement was more complex than the relationship with spatial-temporal reasoning. Mathematics attainment was assessed based on teachers' assessment. The analysis of the overall scores showed that children from the youngest intervention groups achieved greater change than their peers in the control groups and that this difference was statistically significant. The effect was moderate for the youngest group and smaller for the combined group of all children who took part in music lessons. For the older groups the level of progression was also greater for the intervention groups but the magnitude of the difference was not substantial enough to make it statistically significant.

12.3.1 The pilot study

Throughout the pilot study, which took part in the first year of the programme, changes in scores, which provided a measurement of progression, were greater for both intervention groups with the control groups making less progress in all assessments apart from the memory test. However, the differences in changes of scores in mathematics between these groups were not large enough to be statistically significant (see section 4.3.4, chapter 4).

12.3.2 The main study

In the main study, in all three age groups, the intervention groups' progression in mathematics were greater than their peers. However, in the oldest and the middle groups these changes were not statistically significant. For the youngest groups the main effect emerging from comparing those participating in the music program with the control group was a statistically significant difference in mathematics with a moderate effect size ($p = .032$, partial eta squared = .079). More detailed analyses are set out in section 5.3.4, chapter 5.

12.3.3 The results from the combined groups

To enable more robust statistical analysis, the results of all of the children who participated in the research while in Year1 were combined to create a larger sample. This process was repeated for the children in the Foundation Stage. Four groups were established: ***Yr1 Music, Yr1 Control, FS Music,*** and ***FS Control.***

When changes in scores were considered, the level of progression was greater in the music groups for both ages with a statistically significant difference. No statistically significant interactions were found between belonging to an intervention or control group and the assessment measure outcomes at the two times of testing in mathematics for the older groups of children. For the younger groups, the main effect comparing participation in the intervention versus belonging to a control group was statistically significant for mathematics ($p = .035$, partial eta squared = .037). The intervention group achieved higher scores. Overall, there was a statistically significant difference in progression in mathematics for the younger children but not for the older pupils (see section 6.2.3, chapter 6).

Within the academic literature, several studies have reported the positive influence that learning music has had on learning mathematics (Graziano, Peterson and Shaw, 1999; Rauscher and LeMieux, 2003; Hannon and Trainor, 2007; Neville et al., 2008, Rauscher and Hinton, 2011; Wade, 2012; Yang et al., 2014; Hallam 2015 and McDonel, 2015). A meta-analysis of six studies by Vaughn (2000) concluded that music training had a positive impact on mathematical skills. The analysis which related to different musical interventions showed a clear relationship between musical training and mathematical skills. However, in some studies the music instruction was reported to have a small or no impact on achievement in mathematics (Rickard et al., 2012). Research by Costa-Giomi (2004) with children from disadvantaged families showed that music training did not affect children’s performance in mathematics, while Jaschke and colleagues (2013) reviewed several studies, including three linked to mathematics. Within this small sample, two of the studies supported the positive impact of music and one did not.

The results of the current research support the hypothesis that active participation in the music programme had a positive impact on learning in mathematics with the intervention groups consistently achieving greater progress than their peers, especially within the youngest groups. This effect was more marked in the younger children supporting the findings of Hetland (2000a), Rauscher and Zupan (2000), Rauscher (2003b), Rauscher and Hinton (2011), and McDonel (2015). As the differences between children from the intervention groups and children from the control groups in reading were much smaller and there were no differences in writing, it can be assumed that there was a causal relationship between the musical instruction and achievement in mathematics.

Table 12.1 sets out the different points in time of the study where the change in scores in mathematics was greater for the intervention groups than for the controls. These results were statistically significant. The most intense colour is used to mark the strongest relationships. Details of the statistical data can be found in table 11.3 in this chapter and in chapter 4, section 4.3.5, chapter 5, section 5.3.5, and chapter 6, section 6.2.4.

Table 12.1: Assessments in mathematics in which the change in scores over time for the intervention groups was statistically significantly greater than for the controls

	Pilot study		Main study			Combined classes	
	music 1 Yr1	***music 2 FS***	***music 1 Yr2***	***music 2 Yr1***	***music 3 FS***	***Y1 Music***	***FS Music***
Mathematics	✓				✓		✓

All presented relationships were statistically significant.

12.4 Does participation in music improve spatial-temporal skills and what is the relationship between the development of these abilities and learning in mathematics?

The results of the current study confirmed that participation in music has an impact on the development of spatial-temporal skills in young children aged 4 – 7. Children from all intervention groups throughout the two years of the research achieved a higher level of progression than their peers in the control group in one or both of the spatial-temporal tests. Most of the findings showed that there were statistically significant interactions between belonging to intervention groups versus control groups. The only group where such a relationship was not statistically significant was the oldest group in the main study, although this group progressed more than the control group. In all examples where the main effect for participation in the music programme against the control group was observed the results referred to the puzzle test.

Correlations between spatial-temporal reasoning and mathematical skills for the intervention group were moderate in the first year of the intervention and became stronger in the second year of the programme. The strong relationship between the memory test and mathematics was maintained at about the same level throughout the study. For the control group, correlations between scores in the picture and puzzle tests and mathematics were strong in the first year, and became less strong or even non-significant in the following year. The relationship of mathematics performance with the memory test for the control group was of a similar strength to that of the music group and became slightly stronger in the second year of the study. These results suggest that there is a strong interaction between mathematics and visual memory in all children. The relationship of mathematical skills with spatial-temporal reasoning became stronger over time which might suggest that greater development of spatial-temporal skills led to a closer relationship with mathematics.

12.4.1 The pilot study

Over the period of the pilot study, during the first year of the research, the progression of both music groups was greater than their peers in the spatial-temporal tests (the picture and the puzzle tests). These differences were statistically significant. Achievement in the memory test was similar between the groups with slightly better performance by the control groups. This suggests that it was the music intervention which led to the impact on spatial-temporal skills, rather than the learning occurring in the general school curriculum.

Belonging to the intervention versus control group for the older children had a statistically significant and a very large effect on scores on the picture test with a partial eta squared of .125 (p = .006), and a moderate effect in the puzzle test with partial eta squared of .071 (p = .041). In the younger groups, there was a statistically significant impact of the music intervention with a very large effect size in the picture test with a partial eta squared of .126 (p = .005). Also recorded was a moderate effect size in the memory and puzzle test (respectively p = .048 partial eta squared = .068; p = .026, partial eta squared = 081). The intervention group performed better in the spatial-temporal tests, whilst the control group performed better on the memory test (for further analyses see chapter 4, section 4.3.5.).

12.4.2 The main study

In the main study, progression was greater in the oldest and the youngest music groups in both spatial-temporal reasoning and the memory tests.

In the middle age groups, there was a statistically significant interaction between belonging to a group and the scores in the memory test with the music group achieving higher (p = .000, partial eta squared = .229). The main effect was statistically significant with a larger effect size in the puzzle test for the music group who showed greater gains with partial eta squared of .103 (p = .026). Within the youngest groups there was a statistically significant relationship with a very large effect size between participation in the music program in comparison with the control group in relation to pre- and post-test performance in the picture test with a partial eta squared of .144 (p = 003).

12.4.3 The results from the combined groups

This section describes results from all Yr1 and all FS groups combined. In terms of progression, both of the intervention groups achieved a greater change of scores in spatial-temporal tests than their peers from the control groups. In the memory test ***Yr1 Music*** and ***FS Control*** progressed more than corresponding groups.

Within the older groups, a statistically significant interaction between belonging to an intervention or control group and the assessment measure outcomes at the two times of testing was found in the memory test with a partial eta squared of .051, p = 013. It was the music group who achieved higher scores. The main effect comparing belonging to an intervention versus a control group was statistically significant for the puzzle test with higher results for the music group with a partial eta squared of .045, p = .021.

In the younger groups, there was a statistically significant interaction for belonging to a group over time in two assessment areas. These were the picture test with a partial eta squared of .132 (p = 000) and the puzzle test with a partial eta squared of .031 (p = .041). In both of these tests the results of the intervention group were greater than these of the control group (see chapter, section 6.2.4).

There is a strong body of evidence in the academic literature which suggests that actively making music develops spatial-temporal skills in children, particularly at a young age (Rauscher et al., 1995; Costa-Giomi, 1999; Graziano et al., 1999; Hallam 2000; Hetland 2000a; Hetland 2000b; Persellin, 2000; Rauscher and Zupan 2000; Shaw, 2000; Rauscher 2002; Rauscher, 2003a; Rauscher 2003b; Hannon and Trainor 2007; Spelke, 2008; Neville et al., 2008; Rauscher and Hinton 2011; Pietsch and Jansen, 2012; Jaschke et al., 2013; Yang et al., 2014; Hallam 2015). The music programmes used in these studies varied in many ways including different musical activities, different group sizes, different lengths of programmes, and different ages of participants. The music programme created for this study followed recommendations from the previous studies which pointed to the importance of rhythmic instruction, a length of programme of at least a year and a younger primary school age as the conditions enabling the strongest impact of music on the development of spatial-temporal skills. The suggestion that interventions with small groups had the greatest effect, with individual lessons being the ultimate choice could not be implemented in this research. Groups of 15 children were the best available option.

The results from this study support the hypothesis that actively learning music has a positive impact on the development of spatial-temporal skills. To control for a possible Hawthorn effect, a visual memory test was used with the underlying assumption that this should not be affected by the musical intervention. Throughout the study, the intervention groups had higher scores than their peers in one or both spatial-temporal tests in all but one assessment. The results on the memory test did not show such relationships and only twice did the children from the intervention groups outperform their peers on this test. While participation in the music intervention influenced scores in mathematics, it had a limited or no effect on other areas of measurement, suggesting that it was the music intervention and not general learning in or out of school which had an impact.

Table 12.2 summarises the outcomes of the scores on the picture, memory and puzzle tests at different points in the study in which the change in scores over time was greater for the intervention groups than for the control groups. All of the results were statistically significant. The intensity of the colour marks the strength of the relationship. Details of the statistical analysis can be found in table 11.3 in this chapter and in chapter 4 section 4.3.5, chapter 5 section 5.3.5, and chapter 6 section 6.2.4.

Table 12.2: Assessments in spatial-temporal and the memory tests in which the change in scores over time for the intervention groups was greater than for the controls

	Pilot study		Main study			Combined classes	
	music 1	***music 2***	***music 1***	***music 2***	***music 3***	***Y1 Music***	***FS Music***
Picture test	✓	✓			✓		✓
Memory test		✓		✓		✓	
Puzzle test	✓	✓		✓		✓	✓

All presented relationships were statistically significant.

Although spatial-temporal skills are sometimes presented as being related to the learning of mathematics (Graziano, Peterson, and Shaw 1999; Shaw, 2000; Rauscher and LeMieux, 2003), this relationship is rarely considered in literature. Only two studies have measured children's achievement in mathematics with standardized tests as in the current study. Rauscher and LeMieux (2003) observed that children who took part in a two-year long music programme with individual keyboard lessons scored higher on standardized arithmetic tests. In contrast, Costa-Giomi (2004) found that three years of individual piano instruction did not have an impact on results in mathematics. The current study set out, not only to explore these relationships, but to look for ways in which the process could be implemented into pedagogical practice if the findings should prove significant. For that reason, using testing driven by the National Curriculum was an important element of the project. If the music programme had an impact on the children's scores in teacher led assessment, it would make it easier to replicate such an intervention in other educational settings.

The progression of the intervention groups was compared with that of the control groups in the areas of mathematics, and picture, memory, and puzzle tests. The music groups outperformed the control groups in three instances in mathematics. In two of these cases statistically significantly greater results were also recorded in both spatial-temporal tests but not in the memory test as presented in Table 12.3. In the third case the results for the music group were greater in the picture test. Overall, these findings suggest that there is a relationship between better performance in mathematics and in spatial-temporal assessments. However, the findings also revealed occasions when the intervention groups were better than the controls in spatial-temporal tests but not in mathematics. This suggests that such a relationship is less strong than previously considered or that only considerable progression in spatial-temporal tests has an effect on results in mathematics. There is also the possibility that the development of spatial-temporal skills has an impact on specific mathematical skills rather than on general performance. This will be considered later in the chapter.

Table 12.3: Assessments in mathematics, spatial-temporal and the memory tests in which the change in scores over time for the intervention groups was greater than for the controls

	Pilot study		Main study			Combined classes	
	music 1	***music 2***	***music 1***	***music 2***	***music 3***	***Y1 Music***	***FS Music***
Mathematics	✓				✓ p = .032 η_p^2 = .079		✓ p = .035 η_p^2 = .037
Picture test	✓ p = .006 η_p^2 = .125	✓ p = .005 η_p^2 = .126			✓ p = .003 η_p^2 = .144		✓ p = .000 η_p^2 = .132
Memory test		✓ p = .048 η_p^2 = .068		✓ p = .000 η_p^2 = .229		✓ p = .013 η_p^2 = .051	
Puzzle test	✓ p = .041 η_p^2 = .071	✓ p = .026 η_p^2 = .081		✓ p = .012 η_p^2 = .103		✓ p = .021 η_p^2 = .045	✓ p = .041 η_p^2 = .031

12.5 In which mathematical abilities was change observed? Which mathematical skills, if any, might be developed in a more significant way by a music intervention?

The current study was uniquely focused on exploring the interactions between the music programme and the development of specific mathematical abilities. Table 12.4 presents the sets of mathematical skills assessed in each year group.

Table 12.4: Specific mathematical skills assessed in Year 1 and Year 2 classes

Year 1 assessments	Year 2 assessments
- number recognition to 10,	- counting to 100,
- number recognition to 20,	- counting back from 20,
- counting to 10,	- counting objects accurately,
- counting to 20,	- using number line,
- 2D shapes,	- attributes of shapes,
- 3D shapes,	- symmetry patterns,
- practical addition and subtraction.	- problem solving.

Once pupils were in Year 1, the following set of skills was assessed: number recognition to 10 and to 20, counting to 10 and to 20, 2D and 3D shapes and practical addition and subtraction. More complex skills were tested in year 2: counting to 100, counting back from 20, counting objects accurately, using the number line, attributes of shapes, symmetry patterns, and problem solving. The first set of abilities was assessed in both years of the study while the second set could only be assessed once in the second year of the project as only then did the oldest participants reach a Year 2 class. In assessing these competencies teachers focused on a set of skills and throughout the year they observed and recorded the level of competence of each child in relation to each specific skill. This approach to assessment did not allow for the analysis of change of scores as there was no baseline score. For this reason, only correlational relationships are reported.

In neither intervention nor control groups, was number recognition to 10 correlated with spatial-temporal abilities. For the music groups counting to 10 and to 20 were only correlated for some of the year groups and the relationships were not strong, although number recognition to 20 was moderately correlated. The academic literature suggests that of these skills, number recognition to 10, counting to 10, and to 20 depends less on spatial-temporal reasoning but more on memory (especially counting). These results confirm such a theoretical perspective. Not surprisingly geometrical skills, for instance, 2D and 3D shapes were strongly related to performance on both spatial tests. The strong interaction between spatial-temporal skills and practical addition and subtraction in children from the music group corresponded with previous research which pointed to a possible relationship between arithmetic calculation and problem solving and spatial-temporal reasoning (Gunderson et al., 2012, Van Nes and De Lange, 2007, Van Nes and Doorman 2011). The same pattern of relationships was observed between these mathematical skills and achievement on the music test. For the control groups, there were fewer statistically significant correlations between specific mathematical skills and the results on the picture and the puzzle tests and those present ones were low.

When the second set of specific mathematical skills was considered, the model of relationships observed in less complex abilities was repeated with counting to 100 being least strongly related with the spatial tests and assessment in music. Counting back from 20 and counting objects accurately were moderately correlated, while the relationship between geometrical abilities such as understanding of attributes of shapes and symmetry patterns and the picture, the puzzle, and the music tests was strong. Interestingly the strongest correlations with achievement in spatial-temporal tests and with assessment in music were observed for using number line and problem solving. These results differed for the control group where counting back from 20 was not correlated to either spatial or memory tests and all other relationships were of a similar moderate strength.

12.5.1 Mathematical skills assessed in Year 1 classes

In the pilot study, only the two older groups from Year 1 were formally assessed in mathematics. This assessment included general attainment and specific skills. Number recognition to 20, 2D and 3D shapes, and practical addition and subtraction were strongly correlated with results in music, the picture and the puzzle tests and the memory test. The moderate to strong correlations with the memory test, used in this study to control for a Hawthorn effect, suggests that it may not be as useful as an independent measure as initially proposed, although there were no statistically significant differences between music and control groups on this measure. Overall, the findings of the current study support the increasing body of research on the impact of musical engagement on visual memory which has had mixed results. The results on the memory test suggest that the effects of participation in the music programme might be wider than anticipated taking account of the previous research.

The correlations showed that for the control group all mathematical skills, apart from the most basic number recognition to 10, were strongly correlated with both spatial-temporal tests, whilst the memory test was only correlated with counting to 20. These scores suggest that there is a relationship between all mathematical skills and spatial-temporal skills in all children.

However, actively making music seems to further develop spatial-temporal skills which in turn impacts on some mathematical skills. However, this proposition was not confirmed by the findings from the second year of the study, although once the scores of all the children who attended the Year 1 class throughout the project were combined, the results were very similar to those of the pilot study. Additionally, in both sets of data, it was the most complicated skills, for instance, counting to 20 and practical addition and subtraction (apart from 2D and 3D shapes) where the strongest correlations were observed. All correlations presented in this section were statistically significant.

For the music group, correlations between spatial-temporal and mathematical skills were moderate in the first year of the intervention and became stronger in the second, main year of the study. The strong relationship between the memory test and mathematics was maintained throughout the study. For the control group, correlations between scores in the picture and puzzle tests and mathematics were strong in the first year, but much less strong or even non-significant in the second year. For this group, the relationship of mathematics with the memory test was very similar to the one recorded for the intervention group and stayed at about the same strength in the main study. These results in spatial-temporal tests were adverse for the intervention and the control groups which indicates that the music programme did have an impact on the participating children.

As in the pilot study, when specific mathematical skills were considered for the groups who during the main study were in Year 1, the results showed large differences between the intervention and control groups. Number recognition to 10 was not correlated with scores in the spatial-temporal or memory tests for either of the groups. For the music group, all other mathematical skills had a strong relationship with the puzzle test, while only number recognition to 20, 3D shapes and practical addition and subtraction were correlated with the picture test and these correlations were of only moderate strength. Results in the memory test were related with counting to 10 and 20, 2D, and 3D shapes. For the control group the picture test was only correlated with number recognition to 20 and counting to 20, while the scores in the puzzle test related to number recognition to 20, counting to 20, 2D, and 3D shapes. These results showed a more complex picture than those from the pilot study.

To achieve more robust results from a larger sample, the scores of the children who throughout the whole project were in Year 1 were combined. When this was done number recognition to 10 again did not reach statistically significant levels for either the intervention or the control group. For the music group, all other mathematical skills were strongly correlated with scores in both spatial-temporal tests and the memory test which suggests that the relationship between spatial-temporal abilities and mathematical skills was strong and became stronger over time as participation in the music programme accelerated the development of children's spatial-temporal skills, especially in these children who participated in the programme for a period of two years. The results for the control group were similar to those in the pilot study with all mathematical skills apart from number recognition to 10 correlated with both the picture and the puzzle tests and only practical addition and subtraction correlated with the memory test.

Table 12.5 sets out which correlations between specific mathematical skills and the scores in spatial-temporal and the memory tests were statistically significant in the pilot study, the main study and the combined groups from both years of the programme for the intervention groups. Cases where such correlations were recorded in all three conditions of measurement are shaded, the stronger the correlations the more intense the colour. 3D shapes and practical addition and subtraction both had a strong relationship with both spatial-temporal reasoning tests. Also, the results relating to 2D shapes were strongly correlated with the puzzle test. The strongest correlation with the scores in the memory test was observed in 3D shapes.

Table 12.5 Statistically significant correlations between specific mathematical and spatial-temporal and memory skills over three conditions of measurement (pilot study, main study and combined Yr1 results) for the music group

	Number recognition up to 10			Number recognition up to 20			Counting to 10			Counting to 20			2D shapes			3D shapes			Addition and subtraction		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Picture Test	✓			✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓
Memory Test				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Puzzle Test				✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

All presented correlations were statistically significant.

I – refers to the **pilot study**, II – the **main study**, III – the **combined results** from all groups.

Table 12.6 presents those correlations between specific mathematical skills and the scores in spatial-temporal and the memory tests which were statistically significant in the pilot study, the main study and the combined groups from both years of the programme for the control groups. As shown, far fewer specific mathematical abilities were correlated with the scores in spatial-temporal reasoning and the memory tests. This is particularly the case for skills such as 2D and 3D shapes, and the most complex practical addition and subtraction.

Table 12.6 Correlations between specific mathematical and spatial-temporal and memory skills over three conditions of measurement (pilot study, main study and combined Yr1 results) for the control group

	Number recognition up to 10			Number recognition up to 20			Counting to 10			Counting to 20			2D shapes			3D shapes			Addition and subtraction		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Picture Test				✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓		✓	✓		✓
Memory Test						✓				✓						✓			✓		✓
Puzzle Test				✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓

All presented correlations were statistically significant.

I – refers to the **pilot study**, II – the **main study**, III – the **combined results** from all groups.

12.5.2 Mathematical skills assessed in Year 2 classes

During the main study, two of the groups were in Year 2 so the specific mathematical skills in which they were assessed were more advanced. These were: counting to 100, counting back from 20, counting objects accurately, using the number line, attributes of shapes, symmetry patterns, and problem solving. For the intervention group, all of these skills were statistically significantly correlated with scores in both the spatial-temporal tests and the memory test. Typically, the strength of correlations with both spatial-temporal tests reflected the same specific mathematical skills. Using number line, problem solving, and counting back from 20 had the strongest relationships whilst counting to 100 the least strong. Also, performance relating to attributes of shapes and symmetry patterns were strongly correlated with the picture and the puzzle tests. The strength of the correlations with the memory test did not follow the same pattern. For the control group the correlations between spatial-temporal and the memory tests were moderate of a very similar strength with the exception of counting back from 20 where the relationship was not statistically significant. Correlations with using the number line, symmetry patterns and problem solving were the strongest, although less strong than for the music groups.

Placing these specific mathematical skills within a cognitive model of learning mathematics as proposed by Spelke (2008), number recognition to 10 and 20 and counting to 10 and to 20 use a combination of systems of object representation and of representing large approximate numbers. In contrast, 2D and 3D shapes and practical addition and subtraction use combinations of both of the number related systems with representation of space, including the mental number line.

Of the skills which were assessed in the older children, counting to 100 uses specifically number related systems. Counting back from 20 however involves operation of the mental number line and as such is related with spatial awareness. Tasks such as using number line, attributes of shapes, and symmetry patterns use systems of spatial representations. Problem solving is a more complex activity which uses multi step operations and as such involves not only number and geometric representations but also uses temporal organization.

Spelke (2008) showed that students who had music training performed better than controls on these mathematical tasks which included spatial reasoning, whether the skills used solely the spatial system or a combination of the spatial system with either object or number representations. Similarly, in this study it was the skills related to geometric awareness which were most strongly correlated with the results in spatial-temporal reasoning and the memory tests and also with most specific musical skills.

12.6 What are the relationships between specific mathematical skills and achievement in music? Which particular musical activities might have the strongest impact?

In both the pilot and the main study there was a strong relationship between children's results in music and their scores in spatial-temporal tests, the memory test, and in mathematics.

Assessments in specific mathematical skills showed that the results in music were correlated with most of the mathematical abilities. Similar to the relationships with spatial-temporal skills, scores in music were correlated most strongly with 3D shapes, practical addition and subtraction and 2D shapes whilst only moderately or not related with number recognition to 10 as presented in table 12.7.

Table 12.7: Pearson's correlations between music and specific mathematical skills for the three conditions of measurement

	Number recognition up to 10	Number recognition up to 20	Counting to 10	Counting to 20	2D shapes	3D shapes	Practical addition and subtraction
Music pilot	*n.s.*	.618**	.381*	.422*	.911**	.908**	.908**
Music main study	*n.s.*	.468**	.538**	. 550**	.517**	.647**	.615**
Music combined	.307*	.547**	.443**	. 473**	.749**	.808**	.797**

** correlation significant at the 0.01 level (2-tailed) * correlation significant at the 0.05 level (2-tailed)
value of p = .0001 in all unmarked cases

12.6.1 Music skills assessed in the first year of learning music

During the first year of the music programme the following skills were assessed: *keeping a beat with the group, keeping a beat individually, singing and clapping the beat, singing and clapping the rhythm, walking to the beat, and repeating one bar of a 4-beat rhythm.* The scores from these were summed to calculate an overall music score. The results from all of these measurements were generally strongly correlated with achievement in mathematics for both intervention groups apart from keeping the beat individually and walking to the beat which were moderately correlated. This was also the case for the children who started the programme at the beginning of the main study.

Analysing the relationships between scores in musical skills and specific mathematical skills was only possible for the groups which had participated in the programme in Year 1 and Year 2 classes as the national assessment in the foundation stage was not broken down into specific mathematical skills. The results from the pilot study showed that there was a relationship between all musical skills and some, rather than all mathematical skills. All of the musical skills were strongly correlated with number recognition to 20, 2D and 3D shapes and practical addition and subtraction. These were also the skills which were strongly correlated with the scores in spatial-temporal reasoning and in part the memory tests. The only cases which did not fit this pattern were the correlations between singing and clapping the rhythm, walking to the beat and counting to 20. Repeating one bar of a 4-beat rhythm was correlated with both counting to 10 and counting to 20.

12.6.2 Music skills assessed in the second year of learning music

The children who learned music for the second year were assessed on: *clapping a strong beat in a 4-count bar, clapping a strong beat in 3-count bar, repeating 2 bars of 4-count rhythm, imitating a rhythm for 4 bars, playing a bar of rhythm from notation, and improvising a bar of a 4-count rhythm*. These scores were summed to calculate an overall music score. Examination of the relationships of scores in these assessments and the same mathematical skills showed that none of the musical skills were correlated with number recognition to 10. The strongest relationships were between the music skills and 3D shapes and practical addition and subtraction. There were less strong relationships with number recognition to 20, 2D shapes, and counting to 10 and 20. This is similar to the relationships between spatial-temporal reasoning and the memory tests and specific mathematical skills. There was one musical skill which was only correlated with 3D shapes and addition and subtraction - improvising a bar of a 4-count rhythm.

The oldest group taking part in the project was assessed on more advanced musical and mathematical skills. The strongest relationships were recorded between all musical skills and using number line and problem solving and the least strong with counting to 100. Most of the results were also strong or moderate with attributes of shapes, symmetry patterns and counting back from 20. These findings reflect those found in relation to spatial-temporal tests. The musical skill least related with mathematical skills was improvising a bar of a 4-count rhythm.

Overall, these results suggest that all of the musical skills included in the assessment were mostly strongly correlated with scores in spatial-temporal and some mathematical tests with the possible exception of improvising a bar of a 4-count rhythm. The differences between the strengths of relationships for different musical skills were minimal. This suggests that all of these rhythmic related musical skills had similar impact on the development of spatial-temporal reasoning and some mathematical skills.

12.7 What are the long-term relationships and is the impact sustainable?

The academic literature is ambiguous about the long-lasting effects of musical intervention programmes and about the length of time required to reach a sustainable impact.

Suggestions about the required length of participation in music to acquire sustainable impact on mathematics have been proposed by Rauscher. However, findings from two of her studies are contradictory. The earlier study (Rauscher, 2000) observed that children who received music instruction maintained improvement in spatial-temporal tests throughout the 4 years of the intervention and that these results decreased once the programme was finished. In another study (Rauscher and LeMieux, 2003) children continued to score higher in mathematical tests compared with controls two years after the instruction ended.

To explore these issues further, children's assessments were collected one year after the programme was ended. Unfortunately, it was only possible to gather the scores from the teachers' assessments. Collection of data relating to spatial-temporal reasoning and memory tests was not possible.

Immediately following the end of the intervention, scores in mathematics were compared between music and control groups. Throughout this year, the progression of the children from the control groups was slightly greater than of their peers. However, the differences between these changes of scores were not statistically significant. Also, only levels in reading, writing, and mathematics could be collected as the school was preparing for the removal of National Curriculum levelling (Sept 2014) and these changes in assessment procedures were being implemented throughout the school.

In this study, it was the children from control groups whose progression in mathematics was greater in the year after the music activities were withdrawn. It is possible that the gains achieved specifically in spatial-temporal skills were sustainable, however such data collection was not possible. To investigate these issues in greater detail, the analysis of the relationships between the final scores in the spatial-temporal reasoning and the memory tests and the achievement in mathematics at the end of the year after the programme was withdrawn was undertaken. These analyses showed that these scores were still strongly correlated for the intervention group. For the control group, they were strongly correlated with the memory test but there was only a moderate or no relationship with the results in the spatial-temporal tests.

Further analysis of the relationships between achievement in mathematics and in spatial-temporal reasoning and the memory tests at the end of first and second year of the programme and at the end of the year after the programme had ended revealed some differences between the intervention and the control groups. For the music groups, the relationship between the results of the mathematics and memory tests was strong throughout the whole project. The correlations between the results of the mathematics and spatial temporal tests started as either moderate or statistically non-significant and became stronger as the programme progressed, including the year when the intervention had stopped. For the control group, the relationship between the results of the mathematics and memory tests was very similar to that for the intervention group. When spatial-temporal skills were considered, the correlation with the picture test was strong during the first year and became less strong in the next two years. The correlation with the puzzle test was the strongest at the end of the first year and then it became statistically non-significant. All these findings support the suggestion from the previous research in this area that two years of participation in rhythmic instruction has a sustainable impact on spatial-temporal skills. The development of spatial-temporal skills achieved by the music group continued to have a strong relationship with the performance in mathematics even a year after the intervention had ended.

12.8 What is the impact of the programme on different groups of children (SEND, FSM, EAL, gender differences)?

12.8.1 Children with Special Educational Needs and Disabilities

The findings of the current study constitute the first consideration of the possible impact of a music programme on children with learning difficulties. Such relationships have not been reported previously. The results suggested that participation in the music programme had a more pronounced impact on the development of spatial-temporal and memory skills in children with special educational needs as compared to children without learning difficulties. Pupils with SEND progressed statistically significantly more than their peers in both, the picture and the puzzle test, and in the memory test group (respectively $p = .001$, partial eta squared = .113; $p = .000$, partial eta squared = .263; $p = .000$, partial eta squared = .198). However, once the academic areas of assessment were considered there was not such an impact. It is possible that because of children's additional needs longer participation in music is required to achieve enhanced development in academic areas of assessment. Further research is required to examine this issue in more depth.

12.8.2 Children eligible for free school meals

The findings of the current study suggested that the impact of participation in the music programme was not different for the FSM children as compared to children who were not eligible for Free School Meals. Progression of both groups was similar in most areas of assessment with the exception of reading and writing in which the non-FSM group had greater change of scores (respectively $p = .037$, partial eta squared = .049; $p = .032$, partial eta squared = .051). Once the progression of the FSM music group was compared with the FSM control group, children who took part in the intervention performed better than their peers in the picture test ($p = .019$, partial eta squared = .127). This difference was statistically significant.

12.8.3 Children for whom English in an additional language

The findings from the current study constitute the first insight into how music programmes might impact on children for whom English is an additional language. This area has not been researched or reported on before. Considering the progression of children for whom English in an Additional Language as compared to the control EAL group, children who participated in the music lessons achieved a greater change of scores. However, the only statistically significant difference was observed for the puzzle test ($p = .046$, partial eta squared = .098). Within the intervention group, the non EAL pupils achieved greater mean difference in most areas of measurement apart from the puzzle test. Differences in reading, writing, mathematics, and the memory test were statistically significant (respectively $p = .036$, partial eta squared = .049; $p = .041$, partial eta squared = .046; $p = .012$, partial eta squared = .069; $p = .026$, partial eta squared = .055).

These findings suggest that participation in the music programme did not have a different impact on the EAL children as compared with the EAL control group or with the non EAL music group. These results are not surprising as children from the EAL group have to acquire language skills in order to be able to access academic work.

12.8.4 Gender differences

The current study provided an early insight into any possible gender differences in the impact that a music intervention might have on children's learning. Both girls and boys from the music groups achieved higher scores than their peers in one or both spatial-temporal tests. These differences were statistically significant ($p = .009$, partial eta squared = .918 for girls in the picture test; $p = .037$, partial eta squared = .954 for boys in the picture test and $p = .015$, partial eta squared = .588 for boys in the puzzle test). The results of the analyses suggested that the impact of the music programme on boys and girls was similar. There was only one statistically significant difference in progression between girls and boys from the music group. This was the memory test in which the boys outperformed the girls ($p = .047$, partial eta squared = .044).

12.9 Contribution to knowledge

Previous investigations have provided compelling evidence that actively making music develops a variety of abilities in participants, especially in young children. There is a sizeable body of literature about the link between music and reading, but the relationship between music and mathematics has been researched much less. One of the cognitive abilities developed through music established in earlier studies is spatial-temporal reasoning. Its close connection with mathematical skills is often referred to. No study however has examined whether this improvement in spatial-temporal skills actually impacts on the learning of mathematics. The aim of the current research project and its distinctive contribution to knowledge was to examine whether the connections between active participation in music and the development of spatial-temporal abilities influenced academic achievement in mathematics. The findings demonstrated that in two out of the three periods of measurement there were statistically significant differences between progression in mathematics over time in younger children. The music groups outperformed their peers from the control groups. These results paralleled statistically significantly greater progression in one or both spatial – temporal tests. Although the older groups also recorded statistically significant differences in outcomes in one or both spatial – temporal tests, these scores were not related to a statistically significant difference in achievement in mathematics.

Having established the relationships between musical activity, spatial reasoning and mathematics, the investigation moved towards considering specific mathematical skills rather than overall attainment. The current study was the first to have explored specific mathematical and specific musical skills and the relationships between them. The findings showed that not all mathematical skills were impacted on by the participation in music. The mathematical abilities which were correlated with the musical skills assessed in the study were also strongly related to scores on spatial-temporal tests. This shows that the development of spatial-temporal skills through music facilitated the enhancement of the mathematical abilities.

Within the range of mathematical skills required by the English National Curriculum at the early primary stage, some were not affected by the music training, some were moderately related to musical training and some were impacted on very strongly. The most basic mathematical skills like number recognition to 10, counting to 10 and to 20 were not impacted on by participation in music lessons. This seemed to be because these skills are based on memorising sequences of elements, in this case numbers, not on the mathematical skills related to spatial abilities like number sense or strategy choice. Skills related to geometry which were: 2D and 3D shapes, attributes of shapes, and symmetry patterns, were unsurprisingly closely related with the music programme. This was a result of the impact of the music instruction on spatial-temporal abilities. One unexpected finding was the strong relationship between musical training and arithmetic skills like addition and subtraction, using number line, and problem solving. The theoretical framework underpinning this study points to the importance of the development of mental number line as a predictor of achievement in mathematics. The close relationship between this construct and spatial skills developed through participation in the music programme explains why these most complex mathematical abilities were strongly correlated with music instruction. Because of the form of assessment in mathematics and music which was available for the current research the relationships reported here are correlational. These findings are new and provide the basis for further research exploring the relationship between the learning of music and the learning of mathematics. They may also be useful in pedagogical practice which at the moment does not always acknowledge the importance of spatial skills in acquiring mathematical proficiency and the use of music instruction in moderating this process.

The literature points to rhythmic instruction as having the most pronounced effect on the development of spatial-temporal skills. The music lessons used in this intervention were based on such activities and the study examined the relationships between specific skills in all three areas of interest in more detail than before. A variety of rhythmic abilities corresponded with spatial-temporal skills and most specific mathematical competencies confirming the importance of rhythm in this relationship. The only skill which was consistently unrelated with mathematics was rhythmic improvisation suggesting different cognitive processes are implicated in improvisation. The range of rhythmic skills included in the programme contained clapping beats and rhythms with a group and individually, walking to a beat, playing beats and rhythms on percussion instruments and a variety of fine and gross movement with music. The strong relationship between all of these abilities and spatial-temporal reasoning has implications for classroom practice. Even if teachers have limited time, resources or experience to lead the music programme developed for this research, the use of any of the elements of the rhythmic instruction will have a positive influence on pupils' spatial-temporal reasoning and through this on some mathematical skills.

The positive outcomes of the music intervention were stronger in the younger children confirming the findings of previous studies. The longitudinal character of the study made it possible to evaluate the sustainability of the impact. Very few studies have addressed this matter before. The findings suggest that once children have participated in a music programme, they develop many skills on a higher level than peers who have not participated. However, the effects were not sustained after the intervention ended with the results of the music group similar to those achieved by the control groups.

The literature provides mixed evidence about the impact of music training on visual memory (Costa-Giomi, 1999, Hetland, 2000a, Ho et al., 2003, Hallam, 2015). The findings are also mixed in the current study, although, they follow a consistent pattern with none of the younger music groups achieving scores statistically different from their peers from the control groups, while in most of the older groups statistically significant differences were observed. Interestingly, the memory test was the only measurement on which there was a statistically significant difference between genders with boys achieving greater scores.

The current study was the first to consider possible differences in the way that a music programme might affect children with learning difficulties and children for whom English is an additional language. In both cases, academic attainment was not dissimilar from the control groups but once spatial-temporal skills were examined, children who took part in the music intervention achieved higher scores than their peers. Within the group of all children who took part in the music programme, pupils with learning difficulties progressed statistically significantly more than their peers in the picture and the puzzle test and in the memory test. Neither of these groups of children have been considered in similar studies before and these findings make a distinctive positive contribution to knowledge and open new possibilities for teaching children with these specific needs. The findings also suggested that children from disadvantaged backgrounds might benefit more significantly from the music programme as their achievement in spatial-temporal tests was greater than those in the control group. No previous research has been undertaken into whether music instruction impacts differently on boys and girls. The current study established that the only statistically significant gender difference was in the memory test.

The findings of the current study contribute not only to theoretical but also to pedagogical knowledge, especially within early years and early primary settings. At the moment music teaching in primary schools is of variable quality with many teachers lacking the confidence or the appropriate skills to promote pupils' musical development (Rogers et al., 2008, Hallam et al, 2009, OFSTED, 2009, Henley, 2011). The current research was based on a programme prepared with these issues in mind. It is easily accessible even for teachers who are not confident in delivering music lessons in their classrooms. All activities were explicitly suited for Foundation Stage (FS) and KS1 pupils and were arranged to promote a range of competencies. The programme also informs teachers knowledge in two particularly challenging areas of teaching music, progression and assessment. It does not involve any additional budgetary requirements in terms of resources or staffing.

The project was undertaken in a typical, state primary school which was representative of schools in the UK. The music programme could be implemented in any school. In this particular case, the music programme was delivered by the researcher, but the intervention was carefully planned to make it possible for generalist teachers to follow it with little additional preparation. Each learning unit was created as an independent part which could be used separately. The way the learning units were put together supported the development of musical skills in pupils and illustrated for teachers how to support their progress. Even if teachers only used some elements of the programme, for example, the form of assessment, the programme provided teachers with deeper understanding of what constitutes progression in music and also enhanced pupils' musical abilities. The benefits that the music programme brings to the development of spatial-temporal skills and the learning of mathematics, and the ease of its implementation by generalist teachers could contribute to more children experiencing a rigorous music education in early years and early primary education.

12.10 Limitations of the study

12.10.1 The sample

For a quantitative study, the research had a relatively small sample which on occasion limited the statistical analysis which could be undertaken, although the sample size was appropriate for comparisons to be made between intervention and control groups.

The assessment in reading, writing and mathematics in the Foundation Stage classes was less formal than in the Year 1 classes which meant that these groups had to be considered separately from those of the older children.

The size of the sample was limited by the fact that the programme lasted for three years. This period of time enabled more thorough examination of the potential effects of the intervention. This benefit outweighed the limitations of sample size.

To include analysis of a larger sample some results were combined from two different years of the intervention. This was appropriate as the children were taught the same material and assessed in the same way. However, the lessons were delivered by different teachers in slightly different environments. This may have impacted on the delivery of the programme. Positively, this reduced the role of the researcher which may have contributed to the results being more objective and generalizable.

12.10.2 The music programme

The music programme was limited to using predominantly rhythmic instruction. A conscious decision was made regarding this as the previous research had suggested that rhythm was most effective in developing spatial-temporal abilities in children. This decision narrowed the perspective of the study but enabled more detailed investigation of the specific musical skills acquired. This meant that the programme did not entirely comply with the requirements of the English National Curriculum for music and adjustments would be required if it was to be used more widely within school settings.

The intervention was intentionally simplified in terms of the musical skills required from the teacher, for example no piano accompaniment was used. The reason for this was to create a programme which could be used in the future by any primary teacher whether they were a music specialist or not. This might have had some effect on the extent of the impact but being able to implement the activities as part of wider pedagogical practice was considered to be of a high priority.

This study set out not only to explore the relationships between learning music and learning mathematics but also to look for ways in which the findings could be implemented in teaching in schools. For this reason, using testing driven by the National Curriculum was an important element of the project. The impact of the music programme presented through links with the results of teacher led assessment was felt to have the potential to enhance the validity of the research in the eyes of teachers and facilitate the replication of the study in other educational settings.

Collection of only quantitative data from the participating pupils limited the findings. Having tried in the pilot study to collect children's qualitative responses about their attitudes towards the programme and their impressions about the potential effect that the lessons might have had on their learning from the older group of children showed that the children were unable to articulate meaningful responses. The process was soon recognized as being limited and not always reliable so no further attempts were made to collect such data. In addition, the data from teachers was very limited as only a few teachers took part in the music lessons. Only one teacher observed the programme on several occasions, liked it and was keen to use it in the future. The initial idea of investigating the links between changes in behaviour and attitude to learning and the participation in the programme from the teachers' perspective was also abandoned since the comments made did not provide sufficiently robust data.

12.11 What are the educational implications of this study?

At the moment, many primary teachers do not feel comfortable in teaching music. The requirements of the UK National Curriculum for music are very broad and open to interpretation which makes it difficult for non-specialists to access them, let alone confidently teach pupils. Especially in the early-years music is often reduced to singing in class or in school assemblies and productions and occasional playing of percussion instruments. Teachers are not prepared to plan for progression or to assess progression in music and much teaching lacks this vital element. The popularity of programmes like Sing Up and Voices Foundation which support educators in teaching music shows that there is much need for development.

The music programme used in the current study was created with this in mind. Delivering it does not require highly complex musical skills, it is progression led with clearly specified ways of assessing children. It uses resources widely available in most primary school and early-years settings, for instance, untuned percussion instruments. Investigation would be required to establish whether such a programme delivered by teachers who were not music specialists would still be beneficial for the learning of mathematics. However, the enhancement of children's musical abilities and knowledge achieved by participation in such a programme would be beneficial of itself.

If school teaching staff were to deliver the programme themselves across a broader age spectrum from 3 to 7 years old, such practice would facilitate the collection of a larger data set and enable assessment of the impact on children but also the teachers themselves. Possible change in teachers' confidence in delivering music, better understanding of musical concepts and experience of using a variety of musical activities could open the potential for a cross-curricular approach with music and all its benefits accessible to all students.

In the school where the current project took place, one teacher regularly observed the music lessons, took notes and having been provided with the programme by the researcher, continues to use it in the classroom. Other teachers visited the lessons occasionally and claimed that it gave them a clearer understanding of progression in music which hopefully led to the improvement of their practice.

Evidence from the neuroscientific and psychological studies (Colwell, 2006, Hallam 2015, Hetland 2000a, Hutchinson et al., 2003, Peretz and Zatorre, 2009, Schlaug, 2001) suggests that music training needs to be sustained to achieve a long-term impact on brain and cognitive abilities. The findings from the current study from the year after the programme ended support this as there were no statistically significant differences between the intervention and the control groups in any academic areas at this time. This points to the necessity of continuation of music programmes if the positive impact they have on a variety of skills is to be sustained.

12.12 Ideas for further research

The findings of the current study confirmed many of the previous findings about the relationship between the learning of music and the learning of mathematics and revealed new relationships and phenomena which indicate potential directions for further research in this area.

As the sample in the current study was limited to children from one primary school, to obtain more data and enable more detailed and robust analysis it would be beneficial to carry out further study based on similar methodology with a larger number of pupils in schools from different areas of the UK.

The results of the current research suggested that the most pronounced effects were observed in the youngest children. However, the youngest children included in the study were from the oldest Foundation Stage classes. If the impact is related to the age of the participants, the creation of a simplified version of the music programme, delivering it to the youngest children in FS2 and FS3 and examining the outcomes for these pupils would provide further insight into the relationships between music and mathematics.

One unexpected finding of the current study was the strong relationship between musical training and arithmetic skills and problem solving. This new insight provides a basis for the better understanding of the relationship between the learning of music and the learning of mathematics. Because of the form of assessment of mathematical and musical skills which did not allow for the analyses of changes of scores the results from the study are correlational and future research is necessary to study these relationships further.

The sustainability of the impact of the programme was another area of interest in the current study, however timing limitations and constrained access to data collection beyond that readily available through the data schools were required to collect for national data sets after the intervention ended limited the scope for this. Development of the programme for the whole of the Foundation Stage and KS1 alongside relevant outcome data would provide a much broader perspective, especially if it was possible to prepare and train teaching staff to deliver such a programme. An evaluation of such teacher training and the impact of this on their pedagogical practise would be another interesting avenue for further research. Its findings could contribute to the improvement of the quality of music education and enable its delivery in a greater number of primary schools.

To consider the possibility that participation in a music programme might be especially beneficial for children from low-income families, children with learning difficulties and children for whom English in not the first language, data related to this matter was collected during the current study. The analyses of it were based on a small sample but provided some indications of such relationships. There were some statistical differences for the SEND, FSM and EAL groups and these interactions should be examined further.

12.13 Conclusion

The findings of the current study confirmed the strong impact of participation in music on spatial-temporal abilities as proposed by many authors in the academic literature (Costa-Giomi, 1999; Graziano et al., 1999; Hallam 2000; Hetland 2000a; Rauscher and Zupan, 2000; Rauscher 2002; Hannon and Trainor 2007; Spelke, 2008; Neville et al., 2008; Rauscher and Hinton 2011; Hallam 2015).

The current research expanded understanding of the relationships between music instruction and the learning of mathematics, and of the moderating role of spatial skills in this process. Although the enhancement of attainment in general mathematics was not always consistent, the investigation into specific mathematical skills and their correlations with musical abilities revealed new, previously unexplored associations, upon which this relationship is established. The findings offered insight into which explicit areas of mathematics are strongly correlated with rhythmic instruction. This knowledge could inform pedagogical practice and lead to better achievement in mathematics.

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APPENDICES

Appendix 1 Music Programme

Term 1

'Humpty Dumpty'

1. Singing welcome (on 3rd minor),
2. Singing 'Humpty Dumpty', reminder of the lyrics,
3. Singing the song and rocking the body with the beat,
4. Singing the song and clapping the beat, repeat,
5. Singing the song and clapping the rhythm, repeat,
6. Clapping the beat without singing, counting to 4,
7. Clapping the strong 1 (beginning of each line),
8. Marching the beat with singing,
9. Marching with just the teacher singing, add the clap on 1,
10. Music like chocolate comes in chunks, those chunks are called bars, how long are bars in this song? How many steps are we making between the claps?
11. In two groups: one claps the beat, the other one claps the rhythm, repeat,
12. Change the groups and follow the same exercise,
13. Teacher introduces slower beat, pupils try to adjust the speed of the song,
14. Why do we need to start with the beat?
15. Recap on terms: beat, rhythm, bar.

'Humpty Dumpty'

1. Singing welcome (on a 3rd minor),
2. Singing names,
3. Reminder of words: rhythm, beat, bar
4. Warming up the mimic muscles with singing the vowels,
5. Singing 'Humpty Dumpty' – all together, nice sound, mid volume,
6. Clapping rhythm – follow teacher's beat. Why do we start with the beat?
7. Clapping beat – comparison with the heartbeat, feel your heart, how does it beat?
8. Half a group claps the rhythm, half a beat – change groups,
9. Instruments – 3 groups: tambourines, drums, scrapers,
10. In groups, one group at the time: try your instrument, how can you play it, play loudly and softly,
11. Play the rhythm of the song, make sure it sounds together, like it was one person playing it, stop playing when the song is finished,
12. Play softly but carefully follow the rhythm,
13. Pass your instrument to the person on your left, repeat instructions 10, 11, 12,
14. Pass your instrument once again, repeat instructions 10, 11, 12,
15. Playing softly join in with the singing – you've just managed to make an orchestra!

‘Humpty Dumpty’

1. Singing welcome,
2. Marching to the beat clapped by the teacher,
3. Sitting in a circle, singing a song – remember about nice volume and sounding together,
4. Singing and clapping the rhythm,
5. Singing and clapping the beat,
6. Instruments – what instruments did we use before, introduction of shakers,
7. Play your instruments loudly or quietly following what teacher shows you to do,
8. We are going to make an orchestra, different groups of instruments will have something different to play,
9. Tambourines – play the beat, practise it twice with singing,
10. Scrapers – play only on ONE, practise it twice with singing,
11. Drums – play the rhythm, practise it twice with singing,
12. Let’s play it together – try to remember your role, make sure the playing isn’t too loud,
13. Practise it a few times, each time correcting the mistakes, groups might need to be reminded what are they supposed to play,
14. What is an orchestra, what instruments can we see in orchestras?
15. Teacher pretends to play different instruments, pupils guess what are they,
16. Play the accompaniment again, make it sound soft and then loud,
17. Singing, march to the beat of the song.

'Humpty Dumpty'

1. Singing welcome,
2. Children click fingers as the teacher does (medium speed beat),
3. Add counting to 4,
4. On 1 click with a big wave,
5. The same with clapping, on 1 clap above your head,
6. Stand up, walk the beat, keep clapping and counting,
7. Do you remember when we said that music is similar to chocolate because it comes in bars? We've just marked those bars, each clap started a bar and each bar was counted to 4,
8. The teacher plays the beat on an instrument, children try to walk to the beat,
9. Teacher changes the speed (twice faster, twice slower) and children adapt their walk,
10. Sitting in a circle – teacher gives out three groups of instruments,
11. Try out your instruments, give me a loud sound and then play as the teacher shows you – changing from loud to quiet with the hand gestures. What was I just doing? – showing how loud should the music be, when to start, when to finish. Those are some of the things a conductor does when he stands in front of the orchestra and waves his arms,
12. Let's try clapping 1 and singing the song again, count how many times did we clap, how many bars were there? So our Humpty Dumpty is made out of 4 bars that count to 4,
13. The same with the instruments – children play on 1,
14. Repeat until all children play the right thing,
15. Pass your instrument to the person on your left, everybody plays the rhythm this time,
16. Pass your instruments again, everybody plays the beat,
17. Stand up, lest go to the woods and see the butterflies (teacher play the tambourine - fast) and the bears (teacher plays the drum - slow).

‘Humpty Dumpty’

1. Singing welcome,
2. Teacher claps steady beat, pupils join in, keep going until all pupils follow the beat,
3. Add counting to 4 and an accent at 1, clap 1 to the side, to the other side, up and down, making sure that pupils are still with the beat,
4. Is it easy to count to 4 with music? Would it be easy to have to count to 12? That’s why music comes in chunks a bit like chocolate bars, and each chunk of music is called a bar. How long were our bars, how many did we count to? How many bars are there in our song – teacher sings it, counting “one and two and three and four” instead of lyrics. So our song has 4 bars which count to 4.
5. Let’s keep counting to 4 but clap only at 1 and 3, is our clapping faster or slower?
6. Do the same but clap only at 1, how did the clapping changed?
7. Let’s try to fit two claps in each number.
8. Sit down in a circle, teacher gives out the instruments (drums, tambourines and scrapers),
9. Let’s try out those instruments, pupils play louder and quieter following the teacher’s gestures,
10. Join in with my beat, teacher play the beat and counts to 4, pupils join in, repeat until all pupils play with the beat,
11. Let’s play this beat and sing our song,
12. Change the instruments – pass yours to the person on your left,
13. Let’s try to play the slower beat with only 1 and 3, keep singing, after that change the instruments,
14. Let’s play only at 1,
15. Let’s try to play it with a conductor, I’ll be a conductor and you need to keep looking at me and follow my beat, look out for changes in volume (loud or quiet),
16. What do you think the conductor does? – starts, finishes, shows the beat, changes the volume.
17. Shall we finish our lesson with a marching band – stand up, we’ll sing the song and play and march the beat, teacher might suggest to do it faster or slower.

Term 2

‘Twinkle, Twinkle’

1. Singing welcome,
2. Let’s pretend we are in the forest – when you hear the tambourine imagine you are a butterfly, when you hear the cymbal – pretend you are a scary bear. Try to match your steps with the beat,
3. Today we are going to sing ‘Twinkle, Twinkle Little Star’ – do you remember the words? Singing the song together,
4. Let’s try to match the song to my slow beat,
5. Let’s try to sing it rather quickly but all together (try to not to speed up),
6. Listen carefully to the song and try to tell me how many parts can you hear, are they similar or different? (three parts, the 1st and the 3rd are the same),
7. In two groups with singing, one group claps the rhythm for the first and the third part, the second group clap the second one, repeat,
8. Change the groups and repeat the activity,
9. The same, but the second part will be played twice faster, you need to watch the teacher,
10. Similarly, adding a faster end (on “how I wonder what you are”),
11. Change the groups and repeat the activity, teacher takes over the changes in tempo and children have to watch the conducting,
12. In this song there are two kinds of notes: shorter ones and longer ones.
    - Which ones can you hear at the beginning? (short ones)
    - How many short ones? (6)
    - And then how many long ones? (1)
13. Let’s try to sing this tune counting to four (one and two and three and four). Each time we count to four we are measuring a piece of music called a bar. So the bar in this song is four beats long and has 6 shorter notes and 1 longer one. If we wanted to write it down it would look like this. . . . . . _| this line is there to finish the bar,
14. March the beat, clap the rhythm and sing ‘Twinkle, Twinkle’.

‘Twinkle, Twinkle’

13. Singing welcome,
14. Trip to the woods – when you hear a tambourine pretend you’re a butterfly, a drum – a bear and stand still when there is no rhythm,
15. Singing ‘Twinkle, Twinkle’ with a fast beat,
16. Singing the tune counting to four, clap at 1 and stomp your foot,
17. In two groups, one group claps at 1, the other group claps the 2, 3, 4, repeat to ensure that all the children clap their parts correctly,
18. Change the roles,
19. Give out three groups of instruments: drums, shakers, tambourines, children try out their instruments following teacher’s gestures showing the volume,
20. Children imitate the beat conducted by the teacher,
21. Drums play the 1, shakers and tambourines play the 2, 3, 4,
22. Pass your instrument to the left, repeat exercise 7, 8, 9,
23. Once again pass the instruments and repeat 7, 8, 9,
24. Stand up, march the beat, sing and play the rhythm.

‘Twinkle, Twinkle’

1. Singing welcome,
2. Singing ‘Twinkle, Twinkle’ with a fast beat,
3. In a circle, singing the tune with counting to 4 (one and two and three and four) and walking into the centre in a bar (1-4) and out of the centre in a bar (1-4),
4. In a circle, singing the same, jump at 1,
5. In a circle, singing the same, clap at 1,
6. In a circle, three groups of instruments are given (tambourines, drums and shakers), children try out their instruments following teacher’s gestures showing the volume (quiet, loud),
7. Teacher conducts a beat and the children follow it on their instruments,
8. All children sing and play the rhythm of ‘Twinkle, Twinkle’.
9. Tambourines play the first part (“Twinkle, Twinkle, little star how I wonder what you are”), shakers – the second part (“up above and not so high, like a diamond in the sky”) and the drums play the third part.
10. Pass the instruments to the right and repeat exercises 6, 7, 8, 9,
11. Once again pass the instruments and repeat 6, 7, 8, 9,
12. Sing the song, play the rhythm and walk the beat around the classroom.

‘Twinkle, Twinkle’

1. Singing welcome,
2. Singing ‘Twinkle, Twinkle’ counting to four. Do you remember when we were talking about bars in music – like chocolate music comes in chunks. In our tune each bar counts to 4. Let’s sing the sing and put our hands up in the first bar and keep the hands down in the second bar – repeat that pattern for the rest of the song,
3. Keeping the same pattern, sing all odd bars and keep silent through even bars (sing when your hands are up, keep silent when they are down), repeat few times,
4. Give out tambourines, drums and shakers,
5. Tambourines play the rhythm, drums play the beat (1,2,3,4) and shakers play on 1, repeat until all children follow their part.
6. Teacher explains that the group have just become an orchestra, what is an orchestra, have you ever seen an orchestra? What did it look like? Was there somebody directing from the front? What’s the name for such person? What does the conductor do?
7. Repeat the above arrangement for instruments.

‘Twinkle, Twinkle’

1. Singing welcome,
2. In a circle, children sing ‘Twinkle, Twinkle’ counting to 4, first 4 they step into the circle, next four – out. We’ve just divided this song into chunks, each of them was 4 beats long. Do you remember what are those chunks called?
3. The same exercise, children sing going into the circle and keep silent whilst stepping out.
4. Sitting in the circle, children sing and clap the rhythm of the odd bars and keep silent in the even bars,
5. Children divided into two groups, one group sings and claps odd bars and the other group – even bars,
6. The same exercise with children singing the lyrics rather than counting to four,
7. Two groups of instruments (tambourines and shakers), the above exercise with the instruments.
8. Add some drums, children who have a drum keep the beat, other repeat the above exercise,
9. Change the groups twice so all children can try each of the instruments.
10. Trip to the woods – tambourine – butterflies, drum – bear, shaker – snake, break in music – stay still.

‘Twinkle, Twinkle’

1. Singing welcome,
2. Singing odd bars in ‘Twinkle, Twinkle’, keep silent in even bars,
3. Singing odd bars and clapping the rhythm in even bars (without singing),
4. Four groups of instruments (each group sits together) – two of them play and sing one bar, the other two play and sing following bar,
5. Each group sits separately in front of the teacher, each group will play only one bar and the teacher will conduct which group is playing next. Children need to follow the song internally and carefully watch the teachers,
6. Repeat few times to make sure the same beat is kept throughout the song,
7. One group plays the beat, each of the other groups play and sing one part
    a. Twinkle, Twinkle...
    b. Up above.....
    c. Twinkle.....
8. Change three times so each group can try each part.
9. Trip to the woods – tambourine – butterflies, drum – bears, shaker – snake, try to follow the rhythm.

Term 3

Let's Create

1. Singing welcome,
2. Game "Walk in the Woods" – When children hear a drum they pretend to be bears, tambourine – butterflies, rainmaker (shaker) – snake, stand still when there is no music,
3. Whilst talking about different kinds of weather, children use their voices and bodies to make sounds which represent weather,
4. *Do you think we could play those different sounds on percussion instruments?* Teacher lays various instruments in the middle of the circle (shakers, scrapers, whistles, drums, cymbals, tambourines etc.) and asks different children to play a sound for: rain, wind, storm, thunder, sunshine making sure that all children have their go,
5. Let's imagine a story with those different sounds. As you listen to the story think of which sounds could we play on our instruments or make by using our voices. *We went out for a walk and the rain started falling, first very gently, then it got stronger. The wind became stronger and stronger and as the storm approached there were some thunders. After a while it all stopped and the sun came out. We kept walking and came upon a stream. Away on the hill there was a playground, we run to it. We swung on squeaky seesaw, dashed down the slide and then we had a race. We had such a good time.*
6. What sounds can we play, show us your ideas – children explain what are they trying to illustrate and show the others how are they going to play it,
7. All children choose an instrument, the teacher says the story and the children play or use voices at appropriate moments remembering that different instruments come at different time and that we are trying to sound as closely to the real sound as we can,
8. Teacher explains what went well in the composition and what could be improved. Repeat the exercise couple of times, children might change instruments.

Let's Create

1. Singing welcome,
2. Let me tell you a story of St. George, as you listen to the story think when could we illustrate the story with instruments.
   St. George was a brave knight and once he'd heard about a beautiful town in Arabia he decided to go there. He set out on his horse and travelled for many days. One day the rain started and quickly it turned into a storm with a strong wind and thunders. St. George stopped for the night. Another time his horse became so tired that it could hardly walk. At last he reached the valley and could see the most beautiful town. He got through a heavy gate and thought that people who live there must be very happy to live in such wonderful place. But all he could hear was people crying. He didn't understand it so asked an old man why those people are so unhappy. He told him about the scary dragon which moved in the nearby cave and wants the people to send him some children or he will destroy the town. Many knights tried to fight him but they didn't succeed and the people have no choice but to do as the dragon tells them. St. George felt that he must do something. He went to see this dragon, and as he got to the cave he could hear the scary rumbling coming from inside. Then the dragon got out and roared. St. George was scared but he promised to fight so he got his spear out. But the dragon's scales were very hard and when St. George attacked on his horse, his spear broke and fell into pieces. St. George fell off the horse and couldn't move. Luckily, he fell under a magic orange tree which soothed his wounds and gave him an idea. The only way to kill the dragon was to cut under his wings. St. George moved swiftly and hit the dragon with a mighty blow. The dragon roared and fell down. The people celebrated his victory with music and dance.
   Teacher writes a list of pupils' suggestions on the board: horse, rain, wind, thunder, stream, horse getting tired, squeaky gate to the town, crowd despairing crowd, dragon, fight, broken spear, magic orange tree, fight, killing the dragon, celebrations.
3. Teacher divides children into groups, each group chooses the instruments and prepares their sounds (following the list made earlier on),
4. Teacher says the story and the children accompany it with sounds they created,
5. Children and teacher discuss how to improve the composition and play it again.

Let's Create

1. Singing welcome,
2. Creating a singing dialogue – teacher sings a simple question for individual children (what's your favourite breakfast, what's your favourite colour, what do you like for pudding etc.) and children try to sing their reply starting the sentence with I LIKE ....
3. Once all the children had a turn, they play Pass the Question – one child names a friend they want to ask and sings a question, their friend answers and asks the next person.
4. Teacher introduces a poem by Spike Milligan "Ning, Nang, Nong" – children listen to the rhythm of the poem,
5. Children learn first 6 lines of the poem, keeping the rhythm,
6. Once the children are familiar with it, add clapping with the rhythm,
7. Teaches gives out three kinds of instruments –drums, shakers and tambourines, pupils recite the poem and play the rhythm on the instruments, making sure that they play gently so the poem can be heard,
8. Pass the instruments to the left, repeat the exercise,
9. Pass the instruments again, repeat the exercise,
10. Children try to copy rhythms played by the teacher.

Appendix 2 Descriptive statistics, homogeneity of variance, and homogeneity of intercorrelations for the repeated measures analyses

Table 1: Descriptive statistics for the repeated measures analysis for the older groups (music 1 and control 1) in the pilot study

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	Intervention	3.00	.802	29
	Control	3.03	.850	30
Reading July	Intervention	4.52	1.353	29
	Control	4.70	1.264	30
Writing Sept	Intervention	3.00	.802	29
	Control	2.90	.759	30
Writing July	Intervention	4.45	1.325	29
	Control	4.37	1.245	30
Mathematics Sept	Intervention	3.03	.626	29
	Control	3.33	.479	30
Mathematics July	Intervention	4.83	1.037	29
	Control	5.10	.885	30
Picture test Sept	Intervention	32.66	10.255	29
	Control	31.07	11.522	30
Picture test July	Intervention	28.48	9.291	29
	Control	28.60	11.527	30
Memory test Sept	Intervention	7.55	2.746	29
	Control	8.00	1.912	30
Memory test July	Intervention	8.55	2.733	29
	Control	9.20	2.041	30
Puzzle test Sept	Intervention	2.592	.850	29
	Control	2.696	.962	30
Puzzle test July	Intervention	2.253	.754	29
	Control	2.478	.923	30

Table 2: Homogeneity of variance and homogeneity of inter-correlations for the older groups (music 1 and control 1) in the pilot study

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.514	.730
	Box's test of equality of covariance matrices	.257		
Writing	Levene's test of equality of error variances		.867	.726
	Box's test of equality of covariance matrices	.916		
Mathematics	Levene's test of equality of error variances		.626	.370
	Box's test of equality of covariance matrices	.394		
Picture test	Levene's test of equality of error variances		.653	.228
	Box's test of equality of covariance matrices	.006		
Memory test	Levene's test of equality of error variances		.078	.098
	Box's test of equality of covariance matrices	.112		
Puzzle test	Levene's test of equality of error variances		.324	.081
	Box's test of equality of covariance matrices	.524		

Table 3: Descriptive statistics for the repeated measures analysis for the younger groups (music 2 and control 2) in the pilot study

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	Intervention	.90	.301	31
	Control	1.17	.379	30
Reading July	Intervention	2.48	.570	31
	Control	2.17	.592	30
Writing Sept	Intervention	.90	.301	31
	Control	1.03	.183	30
Writing July	Intervention	1.97	.706	31
	Control	2.00	.743	30
Mathematics Sept	Intervention	1.10	.539	31
	Control	1.07	.254	30
Mathematics July	Intervention	2.55	.506	31
	Control	2.43	.568	30
Picture test Sept	Intervention	36.68	15.598	31
	Control	39.07	13.726	30
Picture test July	Intervention	31.03	13.428	31
	Control	33.49	13.108	30
Memory test Sept	Intervention	6.42	2.248	31
	Control	6.00	1.819	30
Memory test July	Intervention	6.61	1.726	31
	Control	6.67	1.647	30
Puzzle test Sept	Intervention	2.5	.788	31
	Control	2.948	1.077	30
Puzzle test July	Intervention	2.174	.678	31
	Control	2.767	1.012	30

Table 4: Homogeneity of variance and homogeneity of inter-correlations for the younger groups (music 2 and control 2) in the pilot study

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.110	.249
	Box's test of equality of covariance matrices	.674		
Writing	Levene's test of equality of error variances		.065	.792
	Box's test of equality of covariance matrices	.071		
Mathematics	Levene's test of equality of error variances		.099	.329
	Box's test of equality of covariance matrices	.031		
Picture test	Levene's test of equality of error variances		.711	.896
	Box's test of equality of covariance matrices	.307		
Memory test	Levene's test of equality of error variances		.069	.544
	Box's test of equality of covariance matrices	.432		
Puzzle test	Levene's test of equality of error variances		.093	.085
	Box's test of equality of covariance matrices	.154		

Table 5: Descriptive statistics for the repeated measures analysis for the oldest groups (music 1 and control 1) in the main study

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	Intervention	4.52	1.353	29
	Control	4.70	1.264	30
Reading July	Intervention	8.55	2.148	29
	Control	8.13	1.456	30
Writing Sept	Intervention	4.45	1.325	29
	Control	4.37	1.245	30
Writing July	Intervention	8.07	2.187	29
	Control	7.53	1.613	30
Mathematics Sept	Intervention	4.83	1.037	29
	Control	5.10	.885	30
Mathematics July	Intervention	8.28	1.888	29
	Control	8.30	1.208	30
Picture test Sept	Intervention	28.48	9.291	29
	Control	28.60	11.527	30
Picture test July	Intervention	26.72	9.153	29
	Control	27.80	8.911	30
Memory test Sept	Intervention	8.55	2.733	29
	Control	9.20	2.041	30
Memory test July	Intervention	9.38	2.077	29
	Control	9.80	1.769	30
Puzzle test Sept	Intervention	2.253	.754	29
	Control	2.478	.923	30
Puzzle test July	Intervention	2.036	.726	29
	Control	2.326	.830	30

Table 6: Homogeneity of variance and homogeneity of inter-correlations for the oldest groups (music 1 and control 1) in the main study

Measurement	**Test**	**Value of Sig.**	**Value of Sig. pre-test**	**Value of Sig. post-test**
Reading	Levene's test of equality of error variances		.730	.088
	Box's test of equality of covariance matrices	.027		
Writing	Levene's test of equality of error variances		.913	.075
	Box's test of equality of covariance matrices	.173		
Mathematics	Levene's test of equality of error variances		.370	.178
	Box's test of equality of covariance matrices	.042		
Picture test	Levene's test of equality of error variances		.228	.934
	Box's test of equality of covariance matrices	.227		
Memory test	Levene's test of equality of error variances		.088	.122
	Box's test of equality of covariance matrices	.037		
Puzzle test	Levene's test of equality of error variances		.081	.370
	Box's test of equality of covariance matrices	.308		

Table 7: Descriptive statistics for the repeated measures analysis for the middle groups (music 2 and control 2) in the main study

Measurement	**Group**	**Mean**	**Standard Deviation**	**N**
Reading Sept	Intervention	2.48	.570	31
	Control	2.17	.592	30
Reading July	Intervention	5.81	1.108	31
	Control	5.60	1.221	30
Writing Sept	Intervention	1.97	.706	31
	Control	2.00	.743	30
Writing July	Intervention	5.42	1.025	31
	Control	5.20	1.270	30
Mathematics Sept	Intervention	2.55	.506	31
	Control	2.43	.568	30
Mathematics July	Intervention	6.16	.934	31
	Control	5.83	.834	30
Picture test Sept	Intervention	31.03	13.428	31
	Control	36.03	13.108	30
Picture test July	Intervention	27.94	11.150	31
	Control	32.77	11.110	30
Memory test Sept	Intervention	6.61	1.726	31
	Control	6.67	1.647	30
Memory test July	Intervention	8.42	1.803	31
	Control	7.13	1.383	30
Puzzle test Sept	Intervention	2.174	.678	31
	Control	2.767	1.012	30
Puzzle test July	Intervention	2.035	.637	31
	Control	2.553	.980	30

Table 8: Homogeneity of variance and homogeneity of inter-correlations for the middle groups (music 2 and control 2) in the main study

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.249	.539
	Box's test of equality of covariance matrices	.919		
Writing	Levene's test of equality of error variances		.792	.266
	Box's test of equality of covariance matrices	.463		
Mathematics	Levene's test of equality of error variances		.329	.854
	Box's test of equality of covariance matrices	.520		
Picture test	Levene's test of equality of error variances		.896	.999
	Box's test of equality of covariance matrices	.630		
Memory test	Levene's test of equality of error variances		.544	.052
	Box's test of equality of covariance matrices	.207		
Puzzle test	Levene's test of equality of error variances		.065	.129
	Box's test of equality of covariance matrices	.125		

Table 9: Descriptive statistics for the repeated measures analysis for the youngest groups (music 3 and control 3) in the main study

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	Intervention	1.03	.669	30
	Control	.82	.670	28
Reading July	Intervention	3.23	1.006	30
	Control	2.89	.737	28
Writing Sept	Intervention	.87	.629	30
	Control	.64	.621	28
Writing July	Intervention	3.10	.885	30
	Control	2.75	.701	28
Mathematics Sept	Intervention	1.07	.640	30
	Control	.79	.418	28
Mathematics July	Intervention	3.43	.858	30
	Control	3.04	.508	28
Picture test Sept	Intervention	35.07	8.626	30
	Control	33.57	9.574	28
Picture test July	Intervention	29.60	7.828	30
	Control	30.39	8.107	28
Memory test Sept	Intervention	5.83	1.262	30
	Control	5.57	.920	28
Memory test July	Intervention	6.53	1.106	30
	Control	6.21	1.031	28
Puzzle test Sept	Intervention	2.380	.739	30
	Control	2.334	.653	28
Puzzle test July	Intervention	2.165	.720	30
	Control	2.152	.631	28

Table 10: Homogeneity of variance and homogeneity of inter-correlations for the youngest groups (music 3 and control 3) in the main study

Measurement	**Test**	**Value of Sig.**	**Value of Sig. pre-test**	**Value of Sig. post-test**
Reading	Levene's test of equality of error variances		.515	.161
	Box's test of equality of covariance matrices	.003		
Writing	Levene's test of equality of error variances		.343	.503
	Box's test of equality of covariance matrices	.269		
Mathematics	Levene's test of equality of error variances		.315	.073
	Box's test of equality of covariance matrices	.046		
Picture test	Levene's test of equality of error variances		.496	.620
	Box's test of equality of covariance matrices	.058		
Memory test	Levene's test of equality of error variances		.308	.309
	Box's test of equality of covariance matrices	.354		
Puzzle test	Levene's test of equality of error variances		.609	.428
	Box's test of equality of covariance matrices	.918		

Table 11: Descriptive statistics for the repeated measures analysis for the combined older groups (Yr1 Music and Yr1 Control)

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	Intervention	2.73	.733	60
	Control	2.60	.848	60
Reading July	Intervention	5.18	1.384	60
	Control	5.15	1.313	60
Writing Sept	Intervention	2.47	.911	60
	Control	2.45	.872	60
Writing July	Intervention	4.95	1.268	60
	Control	4.78	1.316	60
Mathematics Sept	Intervention	2.78	.613	60
	Control	2.88	.691	60
Mathematics July	Intervention	5.52	1.186	60
	Control	5.47	.929	60
Picture test Sept	Intervention	31.82	11.927	60
	Control	33.55	12.486	60
Picture test July	Intervention	28.20	10.211	60
	Control	30.68	11.419	60
Memory test Sept	Intervention	7.07	2.306	60
	Control	7.33	1.893	60
Memory test July	Intervention	8.48	2.281	60
	Control	8.17	2.018	60
Puzzle test Sept	Intervention	2.376	.788	60
	Control	2.731	.980	60
Puzzle test July	Intervention	2.140	.699	60
	Control	2.515	.944	60

Table 12: Homogeneity of variance and homogeneity of inter-correlations for the combined older groups (Yr1 Music and Yr1 Control)

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.155	.956
	Box's test of equality of covariance matrices	.620		
Writing	Levene's test of equality of error variances		.685	.457
	Box's test of equality of covariance matrices	.738		
Mathematics	Levene's test of equality of error variances		.913	.060
	Box's test of equality of covariance matrices	.119		
Picture test	Levene's test of equality of error variances		.577	.255
	Box's test of equality of covariance matrices	.096		
Memory test	Levene's test of equality of error variances		.154	.231
	Box's test of equality of covariance matrices	.119		
Puzzle test	Levene's test of equality of error variances		.118	.107
	Box's test of equality of covariance matrices	.069		

Table 13: Descriptive statistics for the repeated measures analysis for the combined younger groups (FS Music and FS Control)

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	Intervention	.97	.515	61
	Control	1.00	.562	58
Reading July	Intervention	2.85	.891	61
	Control	2.52	.755	58
Writing Sept	Intervention	.89	.486	61
	Control	.84	.489	58
Writing July	Intervention	2.52	.976	61
	Control	2.36	.810	58
Mathematics Sept	Intervention	1.08	.586	61
	Control	.93	.368	58
Mathematics July	Intervention	2.98	.826	61
	Control	2.72	.615	58
Picture test Sept	Intervention	35.89	12.581	61
	Control	36.41	12.122	58
Picture test July	Intervention	30.33	10.968	61
	Control	33.31	11.253	58
Memory test Sept	Intervention	6.13	1.839	61
	Control	5.79	1.460	58
Memory test July	Intervention	6.57	1.443	61
	Control	6.45	1.391	58
Puzzle test Sept	Intervention	2.441	.760	61
	Control	2.651	.942	58
Puzzle test July	Intervention	2.169	.693	61
	Control	2.470	.898	58

Table 14: Homogeneity of variance and homogeneity of inter-correlations for the combined younger groups (FS Music and FS Control)

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.762	.925
	Box's test of equality of covariance matrices	.041		
Writing	Levene's test of equality of error variances		.639	.158
	Box's test of equality of covariance matrices	.269		
Mathematics	Levene's test of equality of error variances		.055	.418
	Box's test of equality of covariance matrices	.011		
Picture test	Levene's test of equality of error variances		.887	.630
	Box's test of equality of covariance matrices	.184		
Memory test	Levene's test of equality of error variances		.065	.511
	Box's test of equality of covariance matrices	.208		
Puzzle test	Levene's test of equality of error variances		.076	.130
	Box's test of equality of covariance matrices	.212		

Table 15: Descriptive statistics for the repeated measures analysis for the music SEND and music non-SEND groups

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	SEND	1.23	1.02	22
	Non-SEND	1.75	1.15	68
Reading July	SEND	4.32	2.07	22
	non-SEND	6.32	2.60	68
Writing Sept	SEND	1.23	1.02	22
	Non-SEND	1.68	1.19	68
Writing July	SEND	4.09	1.90	22
	non-SEND	5.96	2.50	68
Mathematics Sept	SEND	1.41	1.05	22
	Non-SEND	1.81	1.09	68
Mathematics July	SEND	4.68	2.23	22
	non-SEND	6.34	2.27	68
Picture test Sept	SEND	41.0	11.43	22
	Non-SEND	32.8	11.45	68
Picture test July	SEND	34.2	9.58	22
	non-SEND	26.1	8.60	68
Memory test Sept	SEND	4.82	1.33	22
	Non-SEND	7.16	2.20	68
Memory test July	SEND	6.68	1.32	22
	non-SEND	8.56	2.05	68
Puzzle test Sept	SEND	3.19	.985	22
	Non-SEND	2.26	.552	68
Puzzle test July	SEND	2.66	.813	22
	non-SEND	1.88	.789	68

Table 16: Homogeneity of variance and homogeneity of inter-correlations for the music SEND and music non-SEND groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.208	.252
	Box's test of equality of covariance matrices	.546		
Writing	Levene's test of equality of error variances		.156	.071
	Box's test of equality of covariance matrices	.492		
Mathematics	Levene's test of equality of error variances		.740	.800
	Box's test of equality of covariance matrices	.995		
Picture test	Levene's test of equality of error variances		.947	.365
	Box's test of equality of covariance matrices	.379		
Memory test	Levene's test of equality of error variances		.019	.010
	Box's test of equality of covariance matrices	.069		
Puzzle test	Levene's test of equality of error variances		.060	.021
	Box's test of equality of covariance matrices	.054		

Table 17: Descriptive statistics for the repeated measures analysis for the EAL music and the EAL control groups

Measurement	Group	Mean	Standard Deviation	N
Puzzle test Sept	Intervention	2.51	.732	21
	Control	2.91	1.25	20
Puzzle test July	Intervention	2.62	.666	21
	Control	2.17	1.06	20

Table 18: Homogeneity of variance and homogeneity of inter-correlations for the EAL music and the EAL control groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Puzzle test	Levene's test of equality of error variances		.425	.224
	Box's test of equality of covariance matrices	.438		

Table 19: Descriptive statistics for the repeated measures analysis for the EAL music and the non-EAL music groups

Measurement	Group	Mean	Standard Deviation	N
Reading Sept		1.33	.856	21
		1.67	1.21	69
Reading July		4.97	1.88	21
		6.19	2.72	69
Writing Sept		1.39	.845	21
		1.49	1.23	69
Writing July		4.72	1.96	21
		5.80	2.57	69
Mathematics Sept		1.43	.978	21
		1.80	1.11	69
Mathematics July		5.04	2.08	21
		6.27	2.40	69
Memory test Sept		5.77	1.46	21
		6.81	2.25	69
Memory test July		7.19	1.33	21
		8.43	2.07	69

Table 20: Homogeneity of variance and homogeneity of inter-correlations for the EAL music and the non-EAL music groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.034	.047
	Box's test of equality of covariance matrices	.245		
Writing	Levene's test of equality of error variances		.046	.067
	Box's test of equality of covariance matrices	.235		
Mathematics	Levene's test of equality of error variances		.328	.453
	Box's test of equality of covariance matrices	.293		
Memory test	Levene's test of equality of error variances		.036	.043
	Box's test of equality of covariance matrices	.078		

Table 21: Descriptive statistics for the repeated measures analysis for the FSM music and the FSM control groups

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	FSM music	1.36	1.00	22
	FSM control	1.76	.995	21
Reading July	FSM music	4.86	1.91	22
	FSM control	6.14	1.87	21
Writing Sept	FSM music	1.27	.985	22
	FSM control	1.62	1.02	21
Writing July	FSM music	4.55	1.92	22
	FSM control	5.71	1.93	21
Picture test Sept	FSM music	35.68	10.79	22
	FSM control	33.95	10.62	21
Picture test July	FSM music	29.00	7.89	22
	FSM control	30.67	8.72	21

Table 22: Homogeneity of variance and homogeneity of inter-correlations for the FSM music and the FSM control groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.873	.765
	Box's test of equality of covariance matrices	.400		
Writing	Levene's test of equality of error variances		.480	.888
	Box's test of equality of covariance matrices	.799		
Picture test	Levene's test of equality of error variances		.998	.746
	Box's test of equality of covariance matrices	.687		

Table 23: Descriptive statistics for the repeated measures analysis for the FSM music and the non-FSM music groups

Measurement	Group	Mean	Standard Deviation	N
Reading Sept	FSM music	1.36	1.00	22
	Non-FSM music	1.71	1.17	68
Reading July	FSM music	4.86	1.91	22
	Non-FSM music	6.15	2.75	68
Writing Sept	FSM music	1.27	.985	22
	Non-FSM music	1.66	1.20	68
Writing July	FSM music	4.55	1.92	22
	Non-FSM music	5.81	2.58	68

Table 24: Homogeneity of variance and homogeneity of inter-correlations for the FSM music and the non-FSM music groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Reading	Levene's test of equality of error variances		.167	.037
	Box's test of equality of covariance matrices	.267		
Writing	Levene's test of equality of error variances		.064	.051
	Box's test of equality of covariance matrices	.463		

Table 25: Descriptive statistics for the repeated measures analysis for the girls' music and the girls' control groups

Measurement	Group	Mean	Standard Deviation	N
Picture test Sept	Girls' music	33.78	11.54	41
	Girls' control	31.98	11.62	42
Picture test July	Girls' music	27.05	8.07	41
	Girls' control	28.31	8.35	42

Table 26: Homogeneity of variance and homogeneity of inter-correlations for the girls' music and the girls' control groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Picture test	Levene's test of equality of error variances		.892	.987
	Box's test of equality of covariance matrices	.734		

Table 27: Descriptive statistics for the repeated measures analysis for the boys' music and the boys' control groups

Measurement	Group	Mean	Standard Deviation	N
Picture test Sept	Boys' music	35.73	12.26	49
	Boys' control	36.98	12.20	46
Picture test July	Boys' music	28.98	10.49	49
	Boys' control	32.15	10.37	46
Puzzle test Sept	Boys' music	2.57	.845	49
	Boys' control	2.95	.972	46
Puzzle test July	Boys' music	2.13	.745	49
	Boys' control	2.60	.867	46

Table 28: Homogeneity of variance and homogeneity of inter-correlations for the boys' music and the boys' control groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Picture test	Levene's test of equality of error variances		.538	.964
	Box's test of equality of covariance matrices	.477		
Puzzle test	Levene's test of equality of error variances		.194	.281
	Box's test of equality of covariance matrices	.543		

Table 29: Descriptive statistics for the repeated measures analysis for the girls' music and boys' music groups

Measurement	Group	Mean	Standard Deviation	N
Memory test Sept	Girls	6.83	2.22	41
	Boys	6.39	2.29	49
Memory test July	Girls	8.02	1.96	41
	Boys	8.16	2.15	49

Table 30: Homogeneity of variance and homogeneity of inter-correlations for the girls' music and boys' music groups

Measurement	Test	Value of Sig.	Value of Sig. pre-test	Value of Sig. post-test
Memory test	Levene's test of equality of error variances		.605	.123
	Box's test of equality of covariance matrices	.886		