

**Relationships between musical and linguistic skills in
early development: the role of informal musical
experience in the home.**

**A thesis submitted in partial fulfilment of the requirements for the
degree of Ph.D in Psychology**

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January 2018

Abstract

Research on the relationship between formal musical training and cognitive abilities has been burgeoning over the last decade, with a specific focus on the relationship between language and music skills. However, a significant gap exists when looking at the start of the developmental path of the relationship between these abilities: whereas something is known about infants and a significant amount has been learned about school-aged children, very little is known about preschool children. Aiming to fill this gap, this research has moved along two interlocking paths: first, studying the early relationship between cognitive processing of both music and language, and second, evaluating a dimension so far unexplored: the influence of informal musical interaction and exposure in the home on musical and linguistic development. Using a correlational design and a set of novel age-appropriate musical abilities tasks, Study 1 examined the relationship between a range of musical skills and linguistic development in 3- and 4-year-old children. The second study investigated the contribution of informal musical experience in the home in the development of these skills. Based on the findings from Study 2, which suggested a significant association between informal musical experience in the home and the development of key language areas, Study 3 sought to develop a validated instrument with good psychometric properties for the assessment of informal musical experience. To this end, two online surveys were conducted, and factor analytical and confirmatory methods were used to explore and consolidate the factor structure of the new instrument (*Music@Home Questionnaire*). Reliability and validity of the new instrument were also investigated. Study 4 focused on a specific aspect of music and language processing namely, the processing of structure, and examined the hypothesis that these skills are related in 4- and 6-year-old children. Study 4 also investigated the impact of home experience with music, as assessed with the newly developed instrument, on language and music structural processing.

The combined findings of the present thesis contribute towards a comprehensive account of the relationship between language and music from a developmental perspective. They also provide researchers with new tools to assess musical abilities in young children and with a novel parent-report instrument for the assessment of a largely unexplored area of environmental experience: i.e. informal musical experience in the home.

Acknowledgements

I first and foremost would like to thank my director of studies, Dr Fabia Franco for her continuous support and guidance. Her rich knowledge and enthusiasm for this line of research fostered my motivation and development as a researcher and her skill, kindness and patience made this Ph.D not only a stimulating, but also a joyful journey. I feel lucky to have had her as a mentor. The contribution of my supervisor Dr Paul de Mornay Davies, has also been instrumental for the development and completion of this work. I sincerely thank him for his encouragement, support and valuable feedback at crucial time points during these years.

I must also thank Prof Lauren Stewart for the fruitful discussions, insightful feedback and active support, all of which have provided an important source of inspiration, Dr Daniel Müllensiefen and Dr Marcus Pearce for their enormous help in technical but also conceptual aspects of this project, and Prof Simone Dalla Bella and Dr Nicolas Faruggia whose help with intricate methods of analysis has been of paramount importance. I feel fortunate to have learned so much from them and I deeply appreciate their time and support. I also extend my thanks to Dr Daniele Shön for being so generous with his time and offering valuable feedback at the early stages of this project.

I am grateful to sound engineer Peter Williams, animator Eleonora Quario and particularly Pedro Kirk for their brilliant contributions in building tasks that proved to be not only flawless from a technical point of view but also stimulating and enjoyable for my young participants. I would also like to thank John Verney and Smaragda Lekkou for their assistance and valuable feedback and Prof Wendy Valerio and her colleagues for granting me access to their data. And, of course, I am deeply thankful to all the schools that offered me access to their classrooms and, most importantly, to young participants and their families whose cooperation made this project possible.

Lastly, I would like to thank my family for their love and encouragement. My parents, Dimitris and Effie for raising me with a love for intellectual stimulation and my aunt and uncle Eleni and Dimitris for their much needed support. I particularly owe a great deal to my partner in life Filippou, and gratefully acknowledge that this work would not have been possible without his loving support and constructive critique. I finally dedicate this thesis to my baby son Alexandros.

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CHAPTER 1: LITERATURE REVIEW

Abstract

Chapter 1 presents a review of relevant literature. The body of literature reviewed is organized around the two interwoven aspects of the research program: musical and linguistic skill development in young children and the relationship between them on the one hand, and the role of musical experience (formal and informal) on the development of these skills on the other hand. Sections 1.1 and 1.2 summarize research related to music cognition and how musical skills develop in young children. Section 1.3 highlights research related to key areas of language development in the pre-school child that have been considered in the present project, namely phonological awareness and language grammar. Section 1.4 outlines theoretical frameworks of the relationship between music and language while section 1.5 summarizes the research investigating links between these two areas by looking at the effects of formal musical experience on language and cognition and the influence of informal musical experience in the home on child development. Sections 1.6 and 1.7 outline the aims and key questions of the present thesis.

1.1. Music as a biologically determined cognitive system

How to define music conceptually has been the object of intense debate in musicology, so much so that Blacking (1976) provided an overarching definition of it in terms of "humanly organized sound" (1976, p. 26). According to Lerdahl and Jackendoff (1983), music is a complex domain involving two main aspects: rhythm and melody. In their turn, the rhythmic and melodic structures of music include separate components (e.g., rhythm involves a grouping and a metrical structure). Analyzing the complex nature of music and musicality is outside the scope of this review, it is however important to note that due to the multidimensional nature of music that greatly complicates tracking music cognition and development as a whole, much of the existing research focuses on distinct aspects of musical aptitude.

From the perspective of cognitive science, music is undoubtedly one of the most fascinating and puzzling attributes of human culture. It appears spontaneously in all known human societies and it is integrated in the vast majority of cultural activities and rituals related to major life events such as weddings, funerals, harvest and religious

ceremonies. Yet, although music generates enjoyment and an array of emotions for those who take part in it, it does not yield directly observable biological benefits when compared to other pleasurable experiences such as eating or sleeping (McDermott & Hauser, 2005). Unravelling the mystery of music and human musicality as well as how and why it evolved in the human brain, has long presented a challenge for musicologists, psychologists and cognitive neuroscientists with views ranging from those that consider music as a mere cultural invention (Blacking, 1990; Schönberg, 1984) to addressing the development of music as a biologically-based cognitive function (e.g., Dissanayake, 2000; Zatorre & Peretz, 2001).

From an evolutionary-biological perspective, several theories have suggested that music might have evolved to support biological functions such as attracting sexual partners or maintaining social cohesion in central group activities such as religion and war (Darwin, 1871; Dissanayake, 2000; Miller, 2000; Hagen & Bryant, 2003). In the discussion revolving around the biological origins and nature of musicality, two main notions have emerged: [a] viewing music as a biologically determined and specialized cognitive function with unique benefits for the human brain (Fitch, 2006; Honing & Ploeger, 2012; McDermott & Hauser, 2005; Patel, 2003; Peretz, 2006; Zatorre & Peretz, 2001) and, [b] addressing music as a mere by-product of other important cognitive functions such as language (Pinker, 1997; 2007). These two opposing views have a direct impact not only on the scientific study of musicality, but also on the assessment of musical abilities, clinical applications and educational policies. Thinking of music as either a cultural invention or as simply a side-effect of other cognitive functions presents a problem: it does not explain why music has been present in every known human society extending back to the Neanderthal civilization (Arensburg et al., 1989) and why to this day people of all cultures still devote a huge amount of time and resources to making and enjoying music (McDermott & Hauser, 2005; Trainor & Hanon, 2013). Furthermore, it considers any endeavour of delving into the study of musical abilities and the musical mind as fruitless, clearly rejecting the educational value of music. In contrast, a view of music as a biologically determined cognitive trait has triggered a series of advances in the study of the musical brain (see Peretz, 2006; Honing & Ploeger, 2012 for reviews) that has made it possible to refine our knowledge about the nature of music. Indeed much of the study of musical abilities appears to have benefited from a biological and/or cognitive approach, as this has provided the grounds for studying the development of separate musical skills using a series of specialized

experimental paradigms. Similarly, the idea that music perception and production share some biologically-based universal characteristics among civilizations (Carterette & Kendall, 1999; Savage, Brown, Sakai, & Currie, 2015; Trehub, 2000), has fed into the exploration of infant musicality since this can provide remarkable insights about the nature of these characteristics. Moreover, considerable research has recently emerged from the finding that some neural circuitry participating in musical processing may overlap with other cognitive functions (this has especially been suggested for language, e.g., Patel, 2003) and that musical training can induce positive changes in other areas of cognition such as auditory perception (e.g., Kraus, Skoe, Parbery-Clark, & Ashley, 2009) or motor control (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995).

Overall, viewing music as a biologically based cognitive system has facilitated the uncovering of the musical abilities of infants, children and adult musicians and non-musicians by providing the theoretical grounds for exploring the nature and development of cognitive skills relating to the perception and production of music. It has also opened the door for the study of this system's capacity to change and adapt, in other words, its neuroplasticity. Driven by this notion, and given that this is instilled in the vast majority of research in musical development as well as in the development of musical aptitude testing, the present research project addresses children's musicality as a complex cognitive system comprising of many different perception and production skills. This perspective as well as a review of research on musical skill acquisition and musical skill measurement in young children has direct implications for this research project as it capitalizes on previous findings to devise age-appropriate musical ability tasks for 3- to 6-year-old children. The following sections summarize research that examines the development of musical skills from infancy to the preschool years.

1.2. Musical skill acquisition and measurement in typical development

From birth, infants appear to exhibit a keen interest in music, leading some researchers to propose that this inclination may be innate (Trehub & Hannon, 2006). Indeed, irrespective of cultural background caregivers instinctively sing to their infants in an expressive manner, while infants show increased responsiveness and engagement to singing compared to speech (Nakata & Trehub, 2004; Shenfield, Trehub, & Nakata, 2003). Furthermore, infants from a very young age appear to be equipped with perceptual musical skills comparable to those of adults (Cirelli, Spinelli, Nozaradan, & Trainor, 2016; Trehub, 2001). In the next three sections the developmental trajectories

of separate musical skills are outlined (rhythm, pitch and singing) as these have been explored in a body of research with young children and infants. To assist the reader, Table 1.1 provides definitions of the basic musical concepts presented in the following sections.

Table 1.1. Glossary of musical terms.

Rhythm → Rhythm is an ordered sequence of musical elements that can be temporally distributed in either a regular or an irregular fashion (Fraisse, 1982). In a melody, rhythm is the pattern of durations marked by sounds (notes) and silences (rests) (McAuley, 2010).
Tempo → In music tempo refers to how fast or slow a musical piece is. It is typically associated with the rate of periodic events (beats) that listeners perceive to occur at regular (equal) temporal intervals. In musical notation tempo is given in terms of beats per minute (bpm) (McAuley, 2010).

Grouping → Grouping refers to how we perceive boundaries between groups and subgroups of elements within a musical sequence (Trehub & Hannon, 2006).

Beat → Perceived beat is a series of approximately periodic and accented (prominent to the listener) time points. Beats are often aligned with onsets of musical notes, but not necessarily (McAuley, 2010).

Meter → Meter is a way to organize sounds into equal or unequal subdivisions over time (Radocy & Boyle, 2003).

Pitch → Pitch is a musical feature that allows the listener to identify how high or low a sound is (Benward, 1985).

Tone → The term tone is used to define pitches with a definite frequency. Tones as well as pitches consist of several **partial tones (or frequencies)**, the lowest of which is called the fundamental **tone or frequency** and the others harmonics or overtones.

Notes → In music, tones are often referred to as notes.

Pitch contour → Contour refers to the shape of a melody and it can be ascending or descending (Dowling & Bartlett, 1981 as cited in Fancourt et al., 2013)

Scale → Scale refers to the collection of discrete pitch categories or subdivisions of the octave. Each musical system uses a specific set of scales. In Western scales, each note of the scale relates to the others in a unique way and different notes of the scale have different degrees of stability and create different degrees of tension. This is referred to as tonal hierarchy (Trainor & Unrau, 2012).

Key → In the Western musical system, 12 major scales can be formed. The initial note of each scale is a subdivision of the octave (this is divided in 12 equal intervals called semitones). Each one of these scales is called a musical key, and Western musical compositions are typically composed in one key at a time (Trainor & Unrau, 2012).

Harmony → Chord accompaniment of melodies or chord sequence.

1.2.1. Rhythm skills from infancy to the preschool years

Rhythmic entrainment and mutual coordination has been argued to facilitate mother-infant bonding (Trainor & Hannon, 2013), foster pro-social behaviour in infants (Cirelli, Einarson, & Trainor, 2014) and preschoolers (Kirschner & Tomasello, 2010) and contribute to social cohesion among large groups (e.g., Fitch, 2006; Merker, 2001). Although young infants are very limited in coordinating their movement to an external rhythm or beat, their perception of rhythmic patterns appears to be sophisticated and comparable to that of adults. For example, young infants appear able to identify groupings in musical sequences based on temporal cues such as final phrase lengthening. Trainor & Adams (2000) tested 8-month-old infants and adults on the detection of silent intervals within series of tonal sequences where tones were identical in frequency and only differed in duration. Both infants and adults were found to be less accurate in detecting gaps after long-duration tones than after short-duration tones, indicating that the increase in duration might mark the group boundaries. Infants also appear able to encode the relative temporal patterns of rhythmic sequences (Trehub & Hannon, 2006) as shown in the ability of 7- to 9-month-old infants to detect changes in rhythmic patterns irrespective of concurrent manipulations in frequency and tempo (Thorpe & Trehub, 1989; see also Demany, McKenzie, & Vurpillot, 1977). Similarly 7-month-old infants are competent at discriminating rhythmic and melodic sequences on the basis of meter variations (Hannon & Johnson, 2005) while infants as young as 2 months of age have been shown to be able to detect changes in tempo (Baruch & Drake, 1997). Notably, Winkler et al. (2009) using electroencephalography and a mismatch negativity paradigm demonstrated that newborn infants were less accurate in detecting the omission of weak versus strong beats in rhythmic patterns, implying that even at such a young stage, infants can perceive beat.

Temporal perception appears to improve with age. Preschool children can detect subtler changes in duration of auditory stimuli compared to infants (Morrongiello & Trehub, 1987). More specifically, 5-year-old children can discriminate between duration changes as short as 15ms whereas infants can only discriminate changes >20ms, suggesting that the discrimination threshold in duration appears to drop with age. Similarly, 12-month-old infants can detect smaller gap durations between pairs of tones (gaps of 8ms) compared to 6-month-old infants who were unable to detect gaps shorter than 12ms (Trehub, Schneider, & Henderson, 1995). Furthermore, 3- and 4- year old children can detect small changes in tempo, an ability that has been shown to improve

with age (Drake, Jones, & Baruch, 2000; Bobin-Bègue & Provasi, 2005). Another ability that develops with age is the perceptual fine-tuning into the rhythmic structure of one's musical culture. Although 6-month-old infants in North America can detect variations in both Western and Balkan music meters equally well (Hannon & Trehub, 2005a; Hannon & Trehub, 2005b) 12-month-old infants, as well as adults, are facilitated by the isochronous meter typical in Western music (Hannon & Trehub, 2005). This perceptual narrowing bias that develops throughout infancy into early childhood has been extensively investigated in the language domain (e.g., Werker & Tees, 2005; Langus et al., 2016) while it has only relatively recently been introduced into the research of musical perception with the majority of studies focusing on the acquisition of pitch structure of one's musical culture. Although only a brief mention of the issue of enculturation to one's musical environment is presented here, more detailed accounts of relevant research will follow in subsequent sections.

Observations of infants and children's musical behaviour have also been fruitful in uncovering the developmental trajectories of musical development. Based on an observation of 500 children, Moog (1976) reported that infants' initial responses to music including overt movement take place between the ages of 4 and 6 months. At this stage movement to music can be characterized as whole body movement (e.g., bouncing up and down) and repetitive, rarely synchronizing with the music. According to Moog (1976), as the child develops her/his movements begin to match the music being heard, usually somewhere between the ages of 18 and 24 months. This observation has been partly corroborated by recent research with infants, using manual coding from video clips and 3-D motion capture (Zentner & Eerola, 2010). These authors demonstrated that infants between the ages of 5 to 24 months did not accurately match their movements to music but [a] rhythmic and musical stimuli elicited significantly more rhythmic movement than speech and [b] infants showed flexibility in adjusting their movements to changing tempo i.e., faster tempi generated faster movement. While younger infants did display less rhythmic movement overall compared to the older age group, nevertheless, no significant differences in the ability to adjust movement to tempo were found between older and younger participants (Zentner & Eerola, 2010).

With regards to synchronizing to an external stimulus, Rainbow (1981) demonstrated that 40–60% of 4-year-old children could maintain a steady beat by clapping or using rhythm sticks. Several studies have since examined preschoolers' synchronization abilities demonstrating that this improves with age and identifying

optimal tempo rates to facilitate young children's performance. Relevant to the optimal tempo rate for synchronization is the notion of preferred tempo¹ that is usually assessed by asking participants to tap freely at the most comfortable tempo i.e., spontaneous motor tempo or SMT. It has been argued that the SMT coincides with an optimal sensitivity zone or referent period where the processing of musical intervals is facilitated (Jones, 1976; Jones & Boltz, 1989) and synchronizing to an external beat becomes more accurate (Eerola, Luck, & Toiviainen, 2006). The SMT and preferred tempo have been shown to slow down with age; 4-year-old children exhibit an SMT of around 300-400ms (150-200bpm), for 5-year-old children SMT is close to 450-500 ms (120-130bpm) (Drake & Botte, 1993) while for adults the SMT is close to 600ms (100bpm) (McAuley et al., 2006). The fact that young children prefer faster tempi (close to 300-400ms) has been corroborated in a number of studies (Drake et al., 2000; Provasi & Bobin-Bègue, 2003; Rainbow, 1981; Vanneste, Pouthas, & Wearden, 2001) while Provasi and Bobin-Bègue (2003) also demonstrated how the ability to adjust tapping to different tempo rates (600 and 800ms) improves between the ages of 2 and 4-years. Similarly, van Noorden, de Bruyn, van Noorden and Leman (2009), showed that 3- and 4-year-old children could only synchronize to a tempo around 500ms (120bpm) while children above the age of 4 can synchronize to a wider range of tempi. It is important to note however, that when the testing condition involves children tapping along to another human adult rather than mere auditory stimuli such as metronome clicks or recorded music, participants as young as 2.5- and 3-years-old demonstrate more flexibility and have been shown to synchronize with an Inter-Stimulus-Interval (ISI) of 600ms (100bpm) (Kirschner & Tomasello, 2009; Woodruff-Carr et al., 2014).

1.2.2. Pitch processing from infancy to the preschool years

As with temporal aspects of music, infants appear to be relatively sophisticated listeners and are equipped to process key aspects of pitch structure early in life (Trainor & Unrau, 2012). From 4 months of age, infants appear to be competent at discriminating between isolated (pure) tones (Berg, 1972) while infants between 5 and 8 months old can make relatively fine discriminations (Olsho et al., 1982) showing a perceptual bias for higher frequencies (i.e., they perform comparably to adults with

¹ From an entrainment perspective, this relates to the intrinsic rate of internal oscillators (McAuley et al., 2006).

frequencies > 4000Hz; Olsho, 1984). Seven-month-old infants can already integrate different harmonics into a complex pitch (Clarkson & Clifton, 1985), an ability that appears to emerge between 3 and 4 months (He & Trainor, 2009). In an elaborate experiment He and Trainor (2009) used event-related potentials (ERPs) to measure electrical brain responses to pairs of complex tones in adults, 7-month, 4-month and 3-month –old infants. All groups except the 3-month-old infants showed differential responses to deviant pairs of tones where the harmonics of the second tone lined up to generate the pitch of a missing fundamental frequency that was lower than the pitch of the first tone (although the second tone increased in frequency compared to the first tone similarly to standard stimuli), indicating that infants < 4 months do not possess the ability to integrate harmonics. Furthermore, between 6 and 8 months of age infants can detect changes in tones integrated within melodies while detection is more accurate when these changes are salient i.e., they extend the pitch range of the standard melody and/or violate the contour of the standard melody (Trehub, Thorpe, & Morrongiolo, 1985; Trehub, Bull, & Thorpe, 1984). Like adults, infants can process melodic structures that have been transposed to another key as similar to the original melodies. For example, infants can detect variations between melodies that only coincide in relative pitch distances but do not have any notes in common (Trainor & Trehub, 1992; Chang & Trehub, 1977).

Awareness of another crucial organizing principle for pitch structure also appears to emerge early in life, that is, sensitivity for the consonance/dissonance continuum (Schellenberg & Trainor, 1996; Trainor, 1997; Trainor & Trehub, 1993). For instance, infants are able to detect a dissonant tone inserted within a highly consonant interval, but are unable to detect a consonant interval when presented among sets of dissonant intervals (Trainor, 1997). Furthermore, infants can easily detect pitch changes embedded in melodies with consonant intervals relative to pitch changes occurring in melodies with dissonant intervals (Trainor & Trehub, 1993). Interestingly, in addition to a perceptual facilitation for consonant intervals, infants also exhibit a preference for consonant tones. For instance, infants as young as 2-months old, prefer to listen to consonant versus dissonant intervals both when these are presented in isolation or within melodic contexts (Trainor, Tsang, & Cheung, 2002).

Although pitch-processing skills have been extensively investigated in infancy, the development of these abilities across the ages of 12 months to 4 years of age is more limited. This might be due to methodological limitations in the study of toddlers whose

increasing motor capacity and verbal development makes the use of implicit measures typically used with pre-verbal infants more challenging (see section 1.2.4 for more information on the measures used with infants and preschoolers). At the same time, toddlers and young pre-schoolers have limited cognitive capacity to perform elaborate tasks mastered by school-aged children. Nevertheless, a few studies have looked at pitch perception in children ≥ 4 years. Difference thresholds for pitch discrimination acquired in studies using fundamental frequencies vary as a function of the specific pitch used as the standard stimulus, and are inconclusive as to whether difference thresholds improve between infancy and preschool years. In fact, findings so far appear to show that pitch discrimination does not show much improvement across the early years of development. More specifically, although the pitch discrimination difference threshold in infants ranges between 6.5 and 57Hz (Olsho, 1984), Thomson et al., (1999) found that thresholds ranged between 25 and 64Hz in five 5-year-old children (in both studies participants were tested with a standard stimulus of 1000Hz). In addition, Jenhsen and Neff (1993) found a mean threshold of approximately 70Hz for 4-year-old children when tested with a standard stimulus of 440Hz (range is not reported).

It is important to note that the above findings regarding 4- and 5-year-old children's pitch discrimination were based on very small samples (e.g., $N = 5$). Clearly, the sample sizes and the difference in methods used between the infant and pre-schooler studies described above do not allow for definite conclusions. Trehub and her colleagues (1980; 1986) have however drawn a clearer picture of auditory development by looking at auditory sensitivity (i.e., intensity and frequency thresholds for detecting sound) using frequency-band² noises as stimuli. In these experiments, the authors showed that both intensity and frequency detection thresholds decreased between 6 months and 5 years of age (age groups tested: 6-, 12-, 18 month-old infants and 3- to 5-year old children), with sensitivity increasing for all frequencies, both high and low (Schneider, Trehub, Morrongiello, & Thorpe, 1986; Trehub, Schneider, & Endman, 1980). Combined with Maxon and Hochberg's (1982) findings showing that pure tone discrimination and auditory sensitivity improves from the ages of 4 to 12 years, the above findings could lead to the assumption that pitch perception is likely to improve across the early years of development as well.

² In a frequency band the highest frequency is twice the lowest frequency. For example, an octave filter with a centre frequency of 1kHz has a lower frequency of 707Hz and an upper frequency of 1.414kHz. Any frequencies below and above these limits are rejected.

Some research has also been conducted on melody and pitch direction perception in preschool children. It appears that, comparable to infants, preschool children are competent in detecting one-semitone changes embedded in melodies (Trehub et al., 1986). Similarly to what the research with infants has shown, pre-school children's detection ability is facilitated by changes that violate the contour of the standard melody. Furthermore, they more readily detect salient changes that alter the standard tone by a greater number of intervals (Morrongiello, Trehub, Thorpe, & Capodilupo, 1985). Contour or pitch direction perception has been argued to be anatomically separable from individual pitch perception in the adult brain (e.g., Stewart, Kriegstein, Warren, & Griffiths, 2006) and several developmental studies have explored these abilities separately (Fancourt, Dick, & Stewart, 2013; Stalinski, Schellenberg, & Trehub, 2008; Trehub et al., 1984; 1985; White, Dale, & Carlsen, 1990). White et al. (1990) found that the majority of 5-year-old pre-school children, (but not 3- or 4- year olds) were competent at making discriminations of pitch based on direction. Similarly, Stalinski et al., (2008) showed that 5-year-old children were already able to detect changes in pitch direction and that this ability improved with age (age range tested: 5 to 11 years).

1.2.2.1. Enculturation to musical pitch structure of one's musical environment

As seen in the previous section the essential perceptual mechanisms for the processing of pitch appear to be in place from infancy, setting the basis for the learning of higher-level pitch structures that form the building blocks of musical composition, such as scales (Trainor & Unrau, 2012). Although every musical system is composed of sets of scales that divide the octave into intervals, specific scales vary across different cultures. In the same way that infants learn the structure of their language through mere exposure to their native linguistic environment, they also appear to acquire implicit knowledge of the scale structure that forms the musical system of their culture.

Although infants as young as 2 months can already discriminate familiar from unfamiliar melodies (Plantinga & Trainor 2009) it takes some time before they become sensitive to the sets of notes that belong in a musical key. For example 8 to 11-month-old infants are similarly able to detect in key and out-of-key changes in melodies, while 4- to 6-year-old children more readily detect changes that violate the key of a sequence (Trainor & Trehub, 1994; Trehub et al., 1986). From a cross-cultural perspective,

Western infants but not adults are able to detect out-of-key notes in non-native Javanese pelog scales, in addition to those in the native Western chromatic scales (Lynch, Eilers, Oller, & Urbano, 1990). Although the developmental trajectory of acquiring sensitivity to native musical scales is largely unknown, when looking at studies examining the ability to detecting out-of-key versus in-key changes in melodies, it appears that 4- and 5-year-old children's pattern of responses is already driven by implicit knowledge of Western melodic structures (Corrigall & Trainor, 2009; Trehub et al. 1986; Trainor & Trehub, 1994). Furthermore, 4- and 5-year-old children appear to be sensitive to key membership when asked to make explicit judgments of preference for familiar melodic sequences that were either in-key or out-of-key (Corrigall & Trainor, 2010). However, 5- but not 4-year-old children exhibit preference to in-key melodies when tested with unfamiliar melodies (Corrigall & Trainor, 2013).

Implicit acquisition of Western harmonic knowledge (knowing which chords/notes are more likely to follow others in a musical piece) has been argued to develop later in life, not achieving adult levels until early adolescence (Costa Giomi, 2003). This is presumably because the intricate harmonic structure, which is fairly unique to Western music (Trainor & Unrau, 2012), requires more elaborate knowledge of the hierarchical arrangements of notes and chords within a musical key. However, when tested with implicit measures such as electroencephalography (EEG) children aged 4 and 5 years showed early event-related potential (ERP) responses to irregular chords³ that exhibited adult-like scalp distributions (Corrigall & Trainor, 2013). In another study, the typical early EEG response to harmonic irregularities in chord sequences was observed in children as young as 2 years old, although this was not followed by a later negativity (N5) typically present in adults and older children (Jentschke, Friederici, & Koelsch, 2014). Since this later negativity is thought to reflect processes of harmonic integration, the authors concluded that these are still under maturation in toddlers. Another type of implicit task that has been used to elicit implicit harmonic knowledge in young children is the harmonic priming paradigm (Schellenberg et al., 2005). In this task, children are presented with chord progressions that end with

³ Violations of irregular chords usually elicit two brain responses in adults: the early right anterior negativity (ERAN) and a later negativity, the N5. The ERAN in adults is maximal around 150–200ms after stimulus onset, and has a frontal scalp distribution with right-hemispheric weighting. In children, ERAN latencies are usually longer (Jentschke et al., 2008). The early ERP response in the Corrigall and Trainor study (2013) had a positive instead of negative polarity.

either expected (in harmony) or unexpected (out of harmony) chords. Half of the endings are rendered with a different instrument than the preceding context, while children are required to identify the correct timbre, typically by pressing a key so that response times are measured. Expected chords are assumed to prime children's responses i.e., children respond faster to expected versus unexpected chords. Using this method, children as young as 4.5 years old have been shown to possess implicit knowledge of harmonic structure when tested with chord progressions (Marin, 2009).

Interestingly, adults and 7-year-old children have also shown evidence of implicit harmonic knowledge when asked to rate how well individual tones completed melodies that lacked a chord accompaniment (Schellenberg et al., 2002). Indeed, harmonic structure can be implied in isolated melodies setting up expectations in listeners for an underlying chord progression (Trainor & Unrau, 2012). The formation of expectations has been argued to reflect the enculturation of individuals to their musical environment (Bigand & Poulin-Charronnat, 2006; Tillmann, 2005) and a number of models have been proposed to account for this process (see Omigie, Pearce, Williamson, & Stewart, 2013 for a review). There is so far no evidence that preschool children have already formed melodic expectations when tested with a paradigm that required them to make explicit evaluative judgments about the continuation of melodies (Corrigall & Trainor, 2013). More specifically in their study Corrigall and Trainor (2013) found that 5-year-old children exhibited a preference for in-key versus out-of-key melodies, but showed no preference for in-harmony versus out-of-harmony melodies (i.e., out-of-harmony melodies ended with a tone that was in-key but less expected according to the rules of Western harmony). Furthermore, Trainor and Trehub (1994) demonstrated that 5-year-olds were unable to detect a note that violated the implied harmony of the melody, while 7-year-old children exhibited adult-like performance. One could therefore conclude that children under the age of 6 do not possess adequate ability to make predictions about isolated melodies that imply a chord/harmonic progression. However, an important caveat in studies with young children so far is that they have not used implicit testing for this type of ability. This caveat, along with the suggestion that forming melodic expectations may reflect the process of implicit acquisition of musical structure in children (Bigand & Poulin-Charronnat, 2006; Tillmann, 2005) informed one of the main aims of this study, namely, to investigate whether this type of knowledge is present in 4- to 6- year-old children when tested with a novel implicit task, more specifically a melodic priming

paradigm (see chapter 5 for more details on the aims of this study and the specific task used).

1.2.3. Singing development

Singing is a complex activity involving the integration of several abilities such as accurate perception of melody (Apfelstadt, 1984), representing and maintaining tonal information in working memory (Koelsch et al., 2009), vocal-motor coordination and control (Hutchins, Larrouy-Maestri, & Peretz, 2014; Welch, 1985) and successful monitoring of vocal production (Welch, 1985; 2005), all of which are necessary to match sung production with an external model. Singing has also been linked to synchronization abilities in non-musicians suggesting that sensorimotor translation mechanisms similar to the ones operating in speech production might underlie the production of sung words (Dalla Bella, Berkowska, & Sowiński, 2015). Singing is considered to be a natural developmental behaviour while the outcome of the development of singing competencies can be positively or negatively influenced by experiences and events during childhood (Welch, 2006).

According to Moog's (1976) observations, soon after infants begin to move to music vocal responses also begin to emerge. Vocal responses were termed by Moog as "musical babbling" and they differ from speech babbling in that more exaggerated pitch patterns are produced (see also Tafuri & Villa, 2002). Notably, research has shown that musical elements of infant vocalizations during the first year of life such as melodic and temporal patterns (D'Odorico & Franco, 1991; D'Odorico, Franco, & Vidotto, 1985), and manner of phonation (Franco, 1984) are produced in specific communicative contexts (see also Papaeliou & Trevarthen, 2006). Between the ages of 1 and 2 years Moog (1976) observed that children start to imitate songs, first by reproducing solely the words, then the rhythmic structure and then the pitch, while a regular meter is already noticeable in 2-year-old children's singing (Gembris, 2006). A small proportion of children in Moog's sample (16%) however, began to imitate rhythm and pitch in songs between the ages of 1 and 2 while they started integrating words between 2 and 3 years of age. By the age of 2.5, 22% of children imitated solely words and rhythm. However, 80% of 3-year-old children imitated words, rhythm, and pitch, with 50% of 3-year-olds being able to imitate entire songs. Based on these observations, Moog concluded that while precursors of rhythmic movement and singing are in place before

the age of 2 years, the ability to integrate words, rhythm, and pitch in singing begins to emerge at around 2.5 years. At 4 years of age, most children appear to be able to match the rhythm to the words of a song but can only approximate the pitch (Moog, 1976). In addition, children of this age seem unable to maintain a steady beat while singing a song on their own, suggesting that they have difficulty being accurate in producing words and maintaining steady rhythm and pitch at the same time (Sloboda, 1985).

According to Vihman (1996) the earliest vocal behaviour that includes singing characteristics such as pitch and rhythmic variations, is infant crying. Indeed, pitch patterns and temporal characteristics with specific communicative intent have been identified in both cry and non-cry infant vocalizations of 4- to 10-month-old infants (D’Odorico et al., 1985; Franco, 1984; 1997) while infants as young as 3 months appear to imitate and repeat prosodic contours purposefully (Gratier & Devouche, 2011). Graham Welch (2006), a pioneer in the research of singing development states that by the age of 2 to 4 months infant vocalizations expand to include quasi-melodic features while infants start to develop vocal control between 4 and 7 months. Vocal activity in the first year appears to be linked to the prosodic features of one’s native language (Meltzoff, 2002). Spontaneous infant song, a typical vocal behaviour emerging between the ages of 1 and 2 years may include repetitions of one melodic phrase with identifiable rhythmic and melodic characteristics. By the age of 3 years, one phrase singing becomes uncommon and three or more different phrases can often be identified (Dowling, 1999). These can be improvised or imitations of parts of songs brought together to form, as Moog (1976) termed it, “pot-pourri songs”. From 4 to 5 years, children can match pitch more consistently, although not necessarily displaying tonal stability (Miyamoto, 2007). By the age of five, children’s singing might also become more sophisticated in terms of expressing emotion (Welch, 2006).

Two longitudinal studies on children’s singing development conducted in the US (Rutkowski, 1997) and the UK (Welch, 1998) over periods of 15 and 3 years respectively (starting from preschool years), provided insights for the development of models featuring different phases of early vocal development in children. These models are specifically designed to describe children’s development of skills when performing taught songs (Rutkowski, 1997; Welch, 1998; 2006), an ability distinct from children’s natural habit of inventing songs (Davies, 1992). Taken together, these models suggest that children’s performance progresses from singing that is centred on the words of the song (chant-like singing) to singing within a limited pitch range that might follow the

contour of the target melody. Finally, most children will eventually sing within an extended pitch range (B \flat 4 and above) without performing significant melodic or pitch errors. Dowling (1982) has also witnessed the pattern of young children imitating the general contour of the melody before being able to accurately reproduce melodic intervals.

Overall, although the path of singing development is not necessarily linear for any particular child (Welch, 2006), singing competency appears to develop from infant vocalizations following melodic patterns to near accurate imitations of melodic phrases or entire songs by the age of three. Some children can, by the age of 3 and 4, to some extent, combine words, pitch and rhythm, although not necessarily successfully integrating all three features at the same time. Two existing longitudinal studies with young children (Rutkowski, 1997, Welch, 1998) have been extremely valuable in identifying discrete steps in vocal and singing development and forming a model that can be used in the assessment of musical abilities in young children. This is particularly relevant to this research project, as Study 1 made use of these research-based validated scales to assess singing development in a sample of 3- and 4-year-old children. It is important to note, however that the work described above, as well as most studies of singing development come from a music education, rather than from an experimental perspective.

1.2.4. Musical skill measurement in preschool children

1.2.4.1. Measurement of musical perception

The measurement of musical perception abilities in young preschoolers has long suffered from methodological limitations related to the cognitive characteristics of this age group, such as limited attention and memory span or restricted understanding of intricate verbal instructions (e.g., Bobin-Bègue & Provasi, 2005) and relational concepts (e.g., higher/lower; White et al., 1990). Due to such methodological limitations the musical abilities of preschool children had for years remained understudied, or studies showed limited evidence of musical competences in this age group (White et al., 1990). To take one example coming from the study of pitch change detection and pitch direction discrimination in children, adaptive procedures successfully used with 6-year-old children have appeared to be of limited use with children as young as 5 (Fancourt et al., 2013). In this study, the authors used an odd-one-out paradigm using frequency

glides as stimuli, where participants were required to verbally indicate whether the “first” or the “last” interval was different than the one heard in the middle. To calculate thresholds for each of the above abilities, 18 levels of difficulty were incorporated in each task and participants would move to the next level only if they gave correct responses to all trials in a given level. The task was terminated following 10 “reversals” to previous levels. Notably, although 6-year-old children successfully performed the task, 8 out of 13 5-year-old children were found to exhibit fluctuating attention or failure to understand the task. Likewise, a study using a similar adaptive procedure to examine pitch discrimination in children did not report reliable results with the 5-year-old age group because only 5 out of 16 of these children managed to complete the task (Thomson et al., 1999).

The use of implicit tasks such as the head-turn procedure, which has been successfully used in revealing remarkable auditory capabilities in infants, can be challenging with preschoolers as their advanced motor and verbal development makes it harder for them to remain seated and avoid verbal interaction for long periods of time. The *conditioned head-turn procedure* consists of continuous presentation of musical stimuli. Occasionally, a deviant stimulus is presented and if participants turn their heads more than 45° towards the deviant sound they are rewarded with dancing toys. No other head turns are rewarded, and discrimination is determined by comparing the proportion of head turns when there is a deviant stimulus to when there is not. This procedure has been piloted with preschoolers, revealing that their spontaneous tendency to commence conversations from time to time masked the auditory stimuli and hindered data collection (Trainor & Trehub 1994). The use of neural measures has been more successful with young preschoolers as this can also be carried out inattentively while the child is performing another task (Corrigall & Trainor, 2013; Moreno et al., 2011; Putkinen, Tervaniemi, & Huotilainen, 2013). For example, Putkinen et al. (2013) simultaneously measured a number of ERP responses in 3- and 4-year-old children that have been argued to reflect change detection in the pitch and temporal structure of sounds [mismatch negativity (MMN), P3a, late discriminative negativity (LDN), and reorienting negativity (RON)]. Standard and deviant sounds were presented through loudspeakers in a sound attenuated booth while children were concentrating on a book or muted DVD for the duration of the experiment (50 minutes).

Despite the constraints in testing preschool children behaviorally, few paradigms have appeared to be successful in assessing musical abilities in this age group. Anvari et

al. (2002) used a number of same-different tasks with 4- and 5-year-old children's melody, rhythm and chord discrimination abilities. These tasks were presented to children as games where they interacted with a dog puppet. They also received a book in which they were allowed to add a self-selected sticker each time they completed a task. Children in these tasks would listen to a pair of musical stimuli (10 trials) and were required to say whether these were the same or different. Two additional tasks assessed rhythm production and chord analysis; in the rhythm production task children were required to vocally reproduce rhythmic patterns and in the chord analysis task, children determined whether a sound was composed of a single note or two notes played simultaneously. In a similar fashion, Trainor & Trehub (1994) used a same-different procedure to assess change detection in melodies in 4- and 5-year-old children. In their task, children listened to a standard melody 3 times and were then presented with a 4th melody. They were required to determine verbally or by pressing one of two buttons (there were illustrations of two identical cats next to the *same* button and illustrations of a dog and a cat next to the *different* button), indicating whether the target melody was the same or different to the standard one.

The behavioural assessment of 3-year-old children can be even more challenging, given that these children have usually just been initiated in the "structured" environment of a nursery and are less accustomed to standard procedures. However, a small number of studies that have used computerized tasks that included visual features have been successful in the assessment of this age group (Bobin-Bègue & Provasi, 2005; White et al., 1990). White et al. (1990) tested pitch direction discrimination in 3- and 4-year-old children with a computerized odd-one-out task. In this task the child heard three 3-note melodies, two of which were identical and one that was different. The melodies were presented to the child via a computer screen where three identical colourful shapes appeared simultaneously with each stimulus (i.e., each auditory stimulus was linked to a shape on the screen) while variations of these shapes would appear in each different trial. The child was required to indicate which shape-melody pair was different than the other two by touching the corresponding shape on the computer screen. Importantly, children could re-listen to the melodies before giving an answer if they needed to do so. This provision was essential, given that holding all three combinations of auditory-visual information in memory may impose a significant cognitive load. A familiarization phase and three training trials were included before the task and feedback was provided after each trial to help maintain the children's interest.

Bobin-Bègue and Provasi (2005) also used a computerized task with visual reinforcement to assess tempo perception in the same age group. In their task, children in each trial were presented with a sequence of 10 tones in a fixed Inter-Stimulus-Interval (ISI) that was either fast or slow (the fast and slow ISI were either side of a 600ms ISI, i.e., 120bpm). Children were required to determine whether each ISI sounded slow or fast, by pressing a button with either a picture of a rabbit (corresponding to fast) or a tortoise (corresponding to slow). Five testing sessions (20 trials each) with increasing level of difficulty were administered on different days. A training session where the child performed the task with the help of the experimenter was included before the test sessions and visual feedback was provided on a computer screen after each trial to maintain attention and increase motivation. Three-year-old children's performance was above chance in all testing sessions except the last, demonstrating that they were able to successfully perform the task.

Overall, although the behavioural testing of children as young as 3 years old presents challenges, it appears that specific test formats that minimize distraction can be successfully used to assess music perception in this age group. Apparently the use of visuals during the task and especially the use of visual reinforcement in feedback can provide a pleasant framework that can help to maintain young children's attention for longer periods of time. Furthermore, self-paced procedures (i.e., trials initiated either by the child or the experimenter) ascertaining that the child is attentive before each trial seem to be essential in reducing cognitive load for young preschoolers.

1.2.4.2. Measurement of musical production

Assessing music production, which has been very informative in evaluating musical abilities in studies with older children (e.g., Flaunacco et al., 2014) presents different challenges with young preschoolers. For example, it was observed during the present project that often the emotional state of 3- and 4-year-old children can greatly affect their performance on any given day (e.g., the child can be very shy or moody, refusing to sing or singing in a very low, near-whisper volume). Therefore, the evaluation of singing in very young children has largely benefitted from observational methods of spontaneous singing behaviors including invented songs (Davies, 1992; Dowling, 1984; Moog, 1976) since formally structured singing assessments can often have negative effects on the child's demonstrated proficiency (Welch, 1994). This

might depend on whether the experimenter has adequately evaluated the sample characteristics, such as age and experience and has chosen an appropriate location and context for the assessment (Welch, 1994). It appears that for children as young as 3 and 4, developing a rapport with the experimenter and creating a welcoming environment where the child can be comfortable is crucial to the success of the assessment. In two studies that have successfully used structured singing assessments (Flowers & Dunne-Sousa, 1990; Verney, 2013), building a rapport between the experimenter and the child was achieved through a number of familiarization sessions with small groups of children from the final sample, where the experimenter acted as a music instructor. These structured singing assessments required participants to sing a self-selected song, imitate pitch patterns, sing a taught song (Flowers & Dunne-Sousa, 1990; Verney, 2013) or sing along to a recording of a familiar song with or without the voice of the experimenter accompanying the child (Verney, 2013). In both studies a very small proportion of children refused to perform the task (4 out of 93 and 2 out of 100 children) and the authors acquired rich data, indicating that the context provided was suitable for this age group.

Another type of music production evaluation that has been used with young preschoolers is synchronization tasks (Kirschner & Tomasello, 2009; Woodruff-Carr et al., 2014, Van Noorden et al., 2009). Critically, Kirschner and Tomasello (2009) explored young children's (age range 2.5 to 4.5 years) ability to synchronize their tapping to an external beat in three contexts: drumming along with a drumming machine with an attached lever (audio-visual condition), drumming along with a human partner (social condition) and drumming along to a drum sound coming from a speaker (acoustic condition). Results showed that children of all age groups (2.5, 3.5 and 4.5 years) performed considerably better in the social condition than in the audio-visual and acoustic conditions. Notably in the social condition, even participants as young as 2.5 years were able to adjust their tapping to an ISI of 600ms (100bpm). This finding is in contrast to previous studies showing that children of this age can only synchronize with a tempo of 500ms (120bpm) or faster (Provasi & Bobin-Bègue, 2003; Van Noorden et al., 2009). Other researchers who have replicated Kirschner and Tomasello's social condition to test synchronization ability in 3- and 4-year-old children, corroborated the finding that this type of social context can facilitate children's adjustment of tempo; they found that more than half of the young participants in their sample could

synchronize with both rates of 100 and 120 bpm (Woodruff-Carr et al., 2014).

Overall, production tasks can be a rich source of information regarding young children's musical abilities. Although music production testing with children as young as 3- and 4-years-old can present some challenges linked to cognitive and emotional characteristics of this age group, previous research provides considerable insights regarding testing contexts and procedures that are appropriate for young participants.

1.2.4.3. Published musical ability assessments for children

In their systematic review of musical aptitude tests for adults and school-aged children published in the course of the 20th century, Boyle and Radocy (1987) explain that many of these tests were specifically developed to fit specific goals in music education. Musical ability tests suitable for school-aged children devised since the Seashore Test of Musical Talent (Seashore, 1938) offer normative data for children between the ages of 9 and 17 (Gordon, 1971; Mursell, 1937; Shuter, 1968). More recently musical abilities assessments for younger children have been developed for both educational and research purposes. The Montreal Battery for Evaluation of Musical Abilities (MBEMA; Peretz et al., 2013) is a test developed to assess congenital amusia in younger children since the adult version of the same test is suitable only for children above the age of 10. The MBEMA was validated in a sample of 6- to 8-year-old children and exhibits excellent psychometric properties. It includes five tests of musical perception (20 trials for each test), namely *contour*, *interval*, *scale*, *rhythm*, and *memory for melodies*. All tasks except for the *memory for melodies* task feature a same-different format requiring children to judge in each trial whether the standard and comparison melodies are the same or different. In the *memory for melodies* task, children are presented with 10 melodies that have been used as stimuli in the previous perception tasks, and 10 foil melodies, and are asked to judge whether they have previously heard each melody. The Primary Measures of Musical Audiation (PMMA: Gordon, 1986) includes tasks of perceptual musical ability and normative data for slightly younger children i.e., 5- to 8-year-olds. The PMMA refers to "audiation" rather than aptitude or ability as this is considered to be a separate concept. Audiation is related to musical creativity and refers to hearing music through recall, without the sound being necessarily physically present. According to Gordon (1979), in order to conceive and appreciate music in a meaningful manner, one needs to *audiate* music heard on previous

occasions. In that sense, administration of the PMMA does not require short or long-term memory for melodies, as the participant reacts intuitively to what is aurally perceived. The PMMA includes two tape-recorded subtests, the *Tonal* and the *Rhythm* test. In both subtests the participant listens to pairs of melodies and is required to indicate on a piece of paper whether the stimuli in each pair are the same or different (“same” and “different” is denoted with pictures of two identical or of two different faces). Gordon (1989) also developed Audie’s test, an assessment that, to our knowledge, is the only published musical test for children as young as 3- and 4-years-old. The Audie’s test includes two subtests for melody and rhythm discrimination and similarly to the PMMA it is based on the concept of *audiation*. In these tasks children listen twice to a 3-note melody at the beginning of the task. They subsequently hear ten 3-note melodies and they are required to hold the original melody in memory while saying whether each new stimulus is the same or different as the original one. Although Gordon (1989) did not provide norms for this age group, the test exhibited good reliability and it has been widely used in the assessment of young preschoolers ever since (e.g., Woodruff-Carr et al., 2014).

To summarize, although a number of musical abilities assessments for children have been published during the course of the 20th century, the only test suitable for young preschoolers is the *Audie’s test* (Gordon, 1989; 3- and 4-year-old children) while the PMMA is suitable for children as young as 5-years-old. Both the PMMA and *Audie’s test* rely on the concept of musical *audiation* and include two subtests, *Melody* and *Rhythm Perception*. Aspects of music perception such as pitch and tempo, and most importantly music production tasks, which could provide a rich source of information for children’s musical abilities, have so far not been included in young preschool children’s formal musical assessments.

1.3. Development of key language areas in the preschool years

In their path towards becoming proficient speakers of their native language, children must acquire knowledge of the basic phonology of words and phrases and master the articulatory movements needed to generate these words and phrases (Stoel-Gammon & Sosa, 2007). Acquisition of the sound system of one’s native language interacts with vocabulary learning as increasing phonetic repertoires allow for an increase in word production and, in turn, the expansion of vocabulary boosts

phonological development to allow children to maintain sound distinctions among the words they have acquired (Hoff & Shatz, 2007). Children must also develop the ability to understand and generate morphologically correct words and syntactically correct sentences, a major landmark in their path to language proficiency (Saxton, 2010).

The following sections summarize the research literature on the nature and development of both these key areas of language development namely, grammar (syntax and morphology) and phonology. Together these areas have been linked to the successful acquisition of literacy skills and academic attainment (Cunningham & Carroll, 2015; Deacon & Kirby, 2004; Melby-Lervag, Lyster, & Hulme, 2012) and have been considered prerequisites for the development of more fine-grained aspects of language production and understanding, such as pragmatics (Hoff & Shatz, 2007). Due to their central role in school readiness and later academic success, they were both considered in the present research (Studies 1 and 4) with the aim of identifying possible links between these key skills and musical developmental during the early preschool years. For the reader's convenience, Table 1.2 provides definitions of basic linguistic concepts mentioned in the following sections.

Table 1.2. Glossary of linguistic terms.

Language grammar

Grammar → In linguistics, **grammar** is the set of structural rules governing the composition of clauses, phrases, and words in any given natural language. The term refers also to the study of such rules, and this field includes morphology, syntax, and according to some accounts, phonology, often complemented by phonetics, semantics, and pragmatics.

Morpheme → The smallest unit of meaning in a language e.g., the word “flowering” includes two morphemes, the basis “flower-“ and the inflection “-ing” (Saxton, 2010).

Morphology → The branch of grammar devoted to the study of the grammatical structure or forms of words. It is traditionally distinguished from syntax (Brown, 1973).

Syntax → The set of principles or rules, which dictates how words can be combined to form sentences. All words in a language belong to different syntactic categories such as verb, noun, adjective, and preposition (Saxton, 2010).

Phonological awareness

Phonology → Phonology is a branch of linguistics concerned with the systematic organization of sounds in languages. It has traditionally focused largely on study of the systems of phonemes in particular languages, but it may also cover any linguistic analysis at a level beneath the word (including syllable, onset and rhyme).

Phoneme → The smallest phonetic unit in a language that is capable of conveying a distinction in meaning, as the *m* of *mat* and the *b* of *bat* in English. The difference in meaning between the English words *kill* and *kiss* is a result of the exchange of the phoneme /l/ for the phoneme /s/.

Onset – rhyme → A monosyllabic word can be divided into two parts: the onset, which consists of the initial consonant or consonant blend, and the rhyme which consists of the vowel and any final consonants. So in the word “strap”, “str” is the onset and “ap” is the rhyme.

1.3.1. Phonological awareness and its development in the preschool child

Phonological awareness refers to a set of skills necessary to recognize and manipulate the sounds that make up words in a given language, such as syllables, rhymes and phonemes (Anthony & Francis, 2005; Cunningham & Carroll, 2015). Phonological awareness is critical in learning to read, as children who develop the ability to identify and manipulate individual sounds of words are better able to couple the sounds of phonemes with their respective written symbols (Bradley & Bryant, 1983; Goswami, 1990). It appears that children who can identify similarities and differences among sounds at the beginning, middle and end of words are more likely to notice how these sounds relate to their orthographic representations. For example, a child who understands that “pat” and “pen” begin with the same sound or that “mat” and “hat” share the same ending should have less difficulty understanding that these words share the same spelling patterns (Goswami, 1990). Indeed, a number of studies have demonstrated that phonological awareness can be a strong predictor of reading skills (Bradley & Bryant, 1983; Cunningham & Carroll, 2015; Wagner & Torgesen, 1987) and poor readers typically exhibit difficulties in the perception of rhyme and alliteration (Bradley & Bryant, 1978).

Gombert (1992) reports two types of phonological awareness, *implicit* or *epilinguistic* and *explicit* or *metalinguistic* awareness. The former refers to a general sensitivity to similarities and differences between speech sounds and develops during the preschool years before reading acquisition, whereas the latter refers to consciously perceiving and manipulating phonemes within words, and develops during the early school years when the child learns to read. Both these skills can be encompassed within the term *phonological sensitivity*, which refers to the ability of both perceiving and manipulating sound units (Anthony et al., 2003). In a longitudinal study with 288 children followed from kindergarten to second grade of elementary school, *phonological sensitivity* exhibited the strongest link to literacy acquisition (Wagner, Torgesen, & Rashotte, 1994). According to other researchers, phonological awareness might also involve other sets of skills such as *phonological naming*, or *phonological short-term memory* (Whitehurst, & Lonigan, 2001). *Phonological naming* refers to the ability to access phonological information from long-term memory (e.g., quickly retrieving the names of objects) (Wagner et al., 1993; Whitehurst, & Lonigan, 2001) while *phonological short-term memory* is linked to the recall of sequences of words or speech sounds (Wagner et al., 1993; Baddeley, 1992). Consistent with the idea that

phonological awareness consists of a number of phonological skills, studies using large samples and advanced statistical methods such as confirmatory factor analysis and/or structural equation modelling, have repeatedly demonstrated that phonological awareness is a construct that can be expressed behaviourally in a number of skills (Anthony et al., 2002; Anthony & Lonigan, 2004; Schatschneider et al., 1999; as reviewed in Antony & Francis, 2005) and that may follow different developmental rates (Wagner et al., 1994). Furthermore, phonological awareness manifests striking stability overtime and across its different component abilities (Anthony & Lonigan, 2004; Wagner et al., 1994).

According to the prevailing account regarding the development of phonological sensitivity, children become more sensitive to increasingly smaller sounds units within a word (Anthony et al., 2003; Anthony & Francis, 2005; Goswami & Bryant, 1990; Ziegler & Goswami, 2005). Therefore, children gradually become competent at perceiving and/or manipulating syllables, then onsets and rhymes and finally individual phonemes. In a grand scale study, Anthony et al. (2003) investigated the developmental trajectory of phonological awareness skill acquisition in a sample of 947 participants between the ages of 2 and 6 years. They examined phonological perception and manipulation (i.e., the ability of children to detect blending and omission as well as to blend and omit sound units) at four levels of complexity, namely word, syllable, onset/rhyme and phoneme. Results revealed stable patterns in the order of acquisition of these skills after task complexity had been controlled for: children gradually progressed from mastering word-level skills, to mastering phoneme-level skills. Furthermore, rather than pointing to a rigid progression of developmental stages, children appeared to refine phonological awareness skills in parallel to acquiring new ones (Anthony et al., 2003). These findings were corroborated by another study by Ziegler and Goswami (2005), who extended the progression from large sound units to smaller ones, and in languages other than English (e.g., Turkish, Italian, Greek, French and English).

Carroll, Snowling and Stevenson (2003) tested an alternative trajectory of phonological acquisition broadly based on Gombert's (1992) theory of *epilinguistic* (global awareness of similarities in speech sounds) and *metalinguistic* (manipulation of speech sounds) phonological awareness. According to their account, children's understanding of phonological information might progress from a global sensitivity to large units within a word (i.e., syllables and rhymes) to awareness and explicit manipulation of smaller sound units (i.e., phonemes). Carroll et al. (2003) tested this

hypothesis by administering a series of phonological tasks to a sample of 3-year-old children at three time points. Their sample was considerably smaller ($N = 67$) than the Anthony et al. (2003) study, however the fact that they used a longitudinal design constituted an advantage. Their results were in line with their hypothesis, in that performance between syllable and rhyme awareness did not differ at any point of the assessment, whereas phoneme awareness appeared to emerge at the last stage. Their findings came into contrast with other researchers' conclusions (Anthony et al. 2003; Treiman, & Zukowski, 1991; Ziegler & Goswami, 2005) about a progression from syllable awareness, to onset/rhyme and finally to phoneme awareness, although Anthony et al., (2003) did concede that there may be overlap in the stages of phonological awareness acquisition.

Irrespective of the the precise developmental progression of phonological understanding, a considerable body of research agrees that phonological sensitivity in the preschool years emerges as one of the strongest predictors of learning to read and that overall, young children appear to pay attention to larger sound units such as syllables and rhymes earlier than phonemes. Furthermore, a finding with important implications for the present research is that 3- and 4-year-old children already show awareness of differences and similarities between the sounds of words at the syllable- and onset/rhyme level (Antony et al., 2003; Bradley & Bryant, 1978). Drawing from this body of research, the design of this research project (Study 1) focused on the assessment of phonological sensitivity skills that have previously been tested in 3- and 4-year-old children (e.g., Anthony et al., 2003; Bradley & Bryant, 1978; Carroll et al., 2003), namely, word and syllable blending and segmentation (detection and manipulation at the word and syllable level) and rhyme and alliteration detection (awareness of the onset/rhyme level).

1.3.2. Language grammar and its development in the preschool child

Although in linguistics the term *grammar* may often be used to encompass linguistic aspects such as phonology or phonetics, in language development research, *grammar* traditionally refers to the sets of rules that govern the morphology of words as well as the syntactic relationships between them (Brooks & Kempe, 2012; Chomsky, 1986; Saxton, 2010). Therefore, throughout this research project the term *language grammar* will be used to denote morphology and syntax. Two main accounts have been

proposed to explain the remarkable process of how children acquire grammar without explicit instruction; both are briefly outlined below.

The nativist approach The nativist approach is based on arguments first put forward by Noam Chomsky (1965). Chomsky reasoned that the knowledge that children attain about grammar is exceptionally rich compared to the poor linguistic input that they receive from their environment (*poverty of the stimulus* argument; see also Pinker, 1994). Therefore, children must be equipped with an innate language learning mechanism that poses constraints on their presumably infinite hypotheses about the grammatical structures of their language (Chomsky, 1965; 1986). This assumption led Chomsky to propose his theory of *Universal Grammar* (UG) according to which, all human languages share the same underlying syntactic principles differing only in a specific set of peripheral properties or parameters. The UG mechanism can be described as an innate highly specialized potential for learning language without relying on environmental influences (Saxton, 2010). The variation between languages represented by the differing parameters⁴ must be learned by the child via the action of *trigger* from the environment (Scholz & Pullum, 2006). In other words, children need to be exposed to relevant phrases in their environment that will trigger the setting of a parameter (Brooks & Kempe, 2012; Saxton, 2010). The problem with this assertion (that has not so far been resolved by the nativist approach) is that, for parameters to be triggered, the child must have already acquired a great deal of knowledge about the language (Saxton, 2010). Another central feature of the nativist approach that has not been well supported by empirical data is the idea that the child's environment is impoverished. Most of the main theories within the nativist tradition, including UG, derive from this assumption; however recent research has shown that the environmental input that children are actually exposed to might be far richer than was previously supposed (e.g., Reali & Christiansen, 2005; Tomasello, 2000).

The usage-based approach. Consistent with the above findings, the usage-based approach has been largely based on research refuting nativist arguments (Tomasello, 2000). Many of the researchers who have challenged Chomsky's ideas⁵, highlight that, contrary to the *poverty of the stimulus* hypothesis, children are exposed to rich and

⁴ For example, one of these parameters refers to whether a dependent element (e.g., a verb) appears before or after its "*head*" (e.g., a direct object). In *head-initial* languages such as English, the verb comes before direct objects (e.g., *Eat your vegetables*) whereas in *head-final* languages such as Japanese, the verb follows the direct object (Brooks & Kempe, 2012)

⁵ For a review see Brooks & Kempe (2012).

complex linguistic environments and may be capable of extracting statistical regularities from this input in order to acquire grammar (Saffran, Newport, & Aslin, 1996; Saffran, 1999). General learning mechanisms act in combination with children's strong inclination to imitate others and participate in social situations. Usage-based approaches have also contradicted the view that language learning comes about without feedback from caregivers (Saxton, 2000; Saxton, Houston-Price, & Dawson, 2005). For example, Saxton et al. (2005) demonstrated that caregivers tend to use clarification questions to correct their children's utterances and that children respond to these questions by recasting their phrases (Saxton et al., 2005). Consistent with the usage-based approach, Goldberg (1995; 2006) has proposed that morphological and syntactic knowledge emerge from exposure to the co-occurrences of words or phrase *constructions* (e.g., noun-verb-noun). The constructions within which words occur are stored alongside the words in the child's vocabulary and children can gradually build their knowledge of grammar by using the same constructions to generate new sentences. Children's representations of language grammar may therefore develop from memorized word sequences to specific item-based constructions and finally generalize to abstract grammatical rules (Tomasello, 2003). Indeed, observational studies have provided some evidence that grammatical knowledge is based on item-based utterances (Lieven, Pine, & Baldwin, 1997; Tomasello, 1992). For example, through observing his 2-year-old daughter Tomasello (1992) found that she only used specific verbs in more complex utterances (e.g., *Draw on something*) while other verbs were used exclusively in their simplest form. The use of the past tense was also wholly uneven and did not generalize across verbs, i.e., the past tense was used for some verbs but not for others). Similarly, Lieven et al. (1997) observed (through recordings and maternal diaries) that 2- and 3-year-old children used all verbs in their lexicon in very specific contexts, i.e., each verb was used in only one sentence frame. As the majority of these children grew older, all multi-word expressions that they gradually started using derived from their previous lexically-based simpler patterns, suggesting that their syntactic knowledge was built around specific items and expressions. Consistent with this conclusion, evidence from an experimental study where the researchers taught novel verbs to 2- and 3-year-old children, demonstrated that they could use these verbs in their transitive forms (e.g., *He is tamming the car*) only if they had previously heard them being used in this way (Tomasello & Brooks, 1998). However, the majority of children by the age of 3.5 to 5.5 years can already use novel verbs in a transitive form even if they have only been

presented to them in intransitive forms (Maratsos, Gudeman, Gerard-Ngo, & DeHart, 1987; Pinker, Lebeaux, & Frost, 1987).

When studying the development of grammar in young children, Brooks and Kempe (2012) agree that morphology and syntax should not be considered separately given that the same general learning mechanisms may play a role in the acquisition of both these categories. After reviewing a rich body of literature, they conclude that the majority of typical children follow a similar progression of stages. According to this progression, children early in their lives start producing single-word utterances that they use, for example, to greet family members, make, accept or refuse requests, ask questions or express interest. By the age of two years most children have moved on to generating longer utterances, marking their passage to grammar knowledge. Their utterances become increasingly longer and more complex overtime, and by the age of 5 years children are already proficient users of language, combining and modifying words in ways that abide to the conventions and rules of their linguistic environment (Brooks & Kempe, 2012). In his classic book "*A first language: The early stages*" Brown (1973) also proposed a progression of developmental stages considering both areas together (see Table 1.3). This detailed account of progression from simple structures and word forms to more complex ones is still widely acknowledged to be true by the majority of speech pathology practitioners (Bowen, 2011).

However, a considerable body of research in psychology has examined morphology and syntax separately especially with respect to their impact on general literacy acquisition and skills (e.g., Carlisle, 1995; Storch & Whitehurst, 2002). Looking at morphology, a rich body of literature has demonstrated that early morphological awareness can have positive effects on other literacy skills such as vocabulary, spelling and reading comprehension skills (Carlisle, 1995; Cunningham & Carroll, 2015; Lyytinen & Lyytinen, 2002; McBride-Chang et al., 2008; Nagy, Carlisle, & Goodwin, 2014; Pacton & Deacon, 2008; Siegel, 2008; Storch & Whitehurst, 2002). To take one example, Cunningham and Carroll (2015) investigated the contribution of both phonological and morphological awareness in word reading accuracy and reading comprehension during the early school years (7-9 years old, $N = 164$). Results showed that morphological awareness had a direct effect on reading comprehension over and above phonological awareness. This is in line with another longitudinal study assessing phonological and morphological awareness in 85 children at two time points, first and second grade of elementary school (Carlisle, 1995). Findings revealed that phonological

awareness in 1st grade was the strongest predictor of phonetic analysis ability in 2nd grade, whereas morphological awareness was the strongest predictor of reading comprehension. This specific relationship between morphological awareness and reading comprehension may arise because knowledge of individual morphemes and the ways they are combined may provide a means to comprehend and learn all the derived and/or morphologically complex words used in school children's readings (Carlisle, 1995). Other studies have provided evidence of a relationship between morphological awareness and reading accuracy over and above phonological awareness (e.g., Berninger, Abbott, Nagy, & Carlisle, 2010; Nagy, Berninger, & Abbott, 2006). Evidence for a strong influence of morphological development on vocabulary has been reported in a grand scale longitudinal study with three groups of pre-schoolers coming from three different language backgrounds (Cantonese, Korean and Mandarin; McBride-Chang et al. 2008). Results revealed that morphological awareness at Time 1 predicted unique variance in vocabulary at Time 2 even after phonological awareness, reasoning ability and vocabulary knowledge at Time 1 had been controlled for.

Syntactic awareness has also been shown to be associated with literacy skills such as reading comprehension (Demont, & Gombert, 1996; Nation & Snowling, 2000; Scarborough, 1990; Tong et al., 2014) and general reading skill (Bentin, Deutsch, & Liberman, 1990; Tunmer, Nesdale, & Wright, 1987). To take one example of a well-cited longitudinal study with typical children, Scarborough, (1990) found that those who exhibited poor syntactic knowledge at 2.5 years (as assessed via their speech production) were subsequently characterized as deficient readers, while production of syntactically complex utterances at this early stage uniquely predicted reading performance at 5.5 years of age. Other research has indicated that school-aged children who score poorly on reading measures such as reading comprehension, word recognition, pseudo-word naming and reading fluency also show poor performance on tests of syntactic awareness (Nation & Snowling, 2000; Tunmer et al., 1987). Another group shown to exhibit difficulties with comprehension of syntactically complex sentences is preschool children with delayed onset of speech production (D'Odorico, Assanelli, Franco, & Jacob, 2007). Notably, syntactic skills have been shown to modulate reading deficits in children and adolescents with developmental dyslexia in different linguistic contexts (Casalis, Leuwer & Hilton, 2013 in French; Friedmann, Tzailer-Gross, & Gvion, 2011 in Hebrew; Chung et al., 2013 in Chinese).

To summarize, two main accounts have been proposed for the developmental

acquisition of language grammar: the *nativist* and the *usage-based* approach. Although the debate between supporters of each side is still ongoing, experimental evidence appears to lend most support to the *usage-based* account, which suggests that children gradually build their grammar knowledge around specific word patterns aided by rich linguistic input and feedback from their environment. With respect to the development of grammar acquisition, this appears to progress from simple two-word utterances and word forms at the age of two to multi-word grammatically complex expressions by the age of five. A great deal of evidence suggests that grammatical knowledge at early stages has direct effects on later literacy achievement. Given the importance of language grammar for vocabulary and readings skills and later academic attainment, this research project (Studies 1 and 3) has focused on the assessment of both morphology and syntax using age-appropriate standardized measures, in order to uncover possible associations between specific musical abilities and these two key language areas.

Table 1.3. Brown's stages of morphological and syntactic development

Brown's Stage	Age in Months	Morphological Structure/Operations of reference	Examples
Stage I	12-26		
		Nomination	That car
		Recurrence	More juice
		Negation-denial	No wee wee
		Negation-rejection	No more
		Negation-non-existence	Birdie go
		Action + Agent	Daddy kiss
		Action + Object	Push track
		Action + Locative	In bath
		Entity + Locative	Dolly bed
		Possession	Kim car
		Entity +Attributive	Water hot
		Demonstrative + Entity	This train
Stage II	27-30	Present progressive (-ing)	it going
		in	in box
		on	on box
		s-plurals (regular plurals)	my cars
Stage III	31-34	Irregular past tense	me fell down
		's possessive	man's book
		Uncontractible copula (the full form of the verb to be when it is the only verb in a sentence)	Is it Alison? Yes, it is . Was it Alison? Yes, it was .
Stage IV	35-40	Articles	A ball on the book.
		Regular past tense	She jumped .
		Third person regular, present tense	The puppy chews it. Jason likes you.
Stage V	41-46+	Third person irregular	She does . He has .
		Uncontractible auxiliary (the full form of the verb 'to be' when it is an auxiliary verb in a sentence)	Are they swimming? Were you hungry? I'm not laughing; she is . She was laughing; not me.
		Contractible copula (the shortened form of the verb 'to be' when it is the only verb in a sentence)	She's ready. They're here. Daddy's got tomatoes. My dog's lost his collar.
		Contractible auxiliary (the shortened form of the verb 'to be' when it is an auxiliary verb in a sentence)	They're coming. He's going. I'm opening it up. We're hiding. It's freezing.

1.4. Shared features between music and language

In recent years, scientific research has turned its attention towards the empirical study of the relationship between music and cognition, and findings about the cognitive and linguistic benefits that musical engagement can have in typical and atypical populations are rapidly accumulating. Considerable focus has been directed towards the relationship between music and language, and a number of studies have suggested overlap in neural substrates and behavioural resources between these two cognitive domains (see Patel, 2014 for a review).

Music, like language, is a highly complex system. Like language where smaller units such as phonemes and morphemes are combined together to form higher-order structures such as words and sentences, music is highly structured and consists of separate units (itches) that are combined together to form higher-order sequences such as musical phrases and compositions. Musical and linguistic phrases both contain melodic and rhythmic patterns (melody and rhythm in music and prosody in language) and evidence indicates that the prosody of one's native language can be reflected in the meter and pitch variability of one's musical compositions (Patel, Iversen, & Rosenberg, 2006). From a developmental perspective, the remarkable sensitivity that infants exhibit to melodic features such as contour and pitch changes (e.g., Trehub et al., 1985) may arise from the early auditory, in utero experience of maternal speech (Kisilevsky et al., 2004; Mampe, Friederici, Christophe, & Wermke, 2009). The distinctive way adults speak when addressing infants, also known as *Infant Directed (ID)* speech or "*motherese*" (Fernald, 1985; Fernald, & Kuhl, 1987), is characterized by higher pitch and exaggerated rhythmic and melodic patterns (Fernald, 1985, Trehub, Trainor & Unyk, 1993). These patterns presumably convey communicative meaning (Fernald, 1989) and evoke differential emotional responses in infants (e.g., bell-shaped pitch contours in motherese usually capture infant's attention; Fernald, 1985). This richly intonated type of speech that efficiently conveys the prosodic features of one's native language may shape infant vocal production in the first year of life. Indeed it has been argued that not only are infants' early vocal "musical" behaviors directly linked to the prosodic characteristics of their native language (Ruzza, Rocca, Boero, & Lenti, 2003; Welch, 2006) but also newborn cry vocalizations imitate their surrounding native speech prosody (Mampe et al., 2009). Such observations appear to substantiate Brown's (2001) hypothesis that a type of communication termed musi-language may have been the evolutionary precursor of both music and language. According to Brown, these

domains later specialized in different directions while sharing basic features and organizational principles.

1.4.1. Processing structure in language and music: The *shared syntactic integration resource hypothesis* (SSIRH)

Behavioural evidence appears to indicate that musical and linguistic structural processing may rely on shared cognitive resources (Patel, 1998; 2003; Slevc & Reitman, 2013; Slevc, Rosenberg, & Patel, 2009) and an overlap in brain areas that process structure (or “syntax”) in both domains has also been identified both in adults (Patel et al., 1998; Sammler et al., 2013) and in preschool and school-aged children (Jentschke & Koelsch, 2009 with 10- and 11-year-old children; Jentschke et al., 2008 with 4- and 5-year-old children). To take one example, Slevc et al. (2009) simultaneously presented participants with sentences and chord progressions while manipulating structural processing demands in both sets of stimuli. Linguistic structure was manipulated by introducing a word that would create syntactic ambiguity within the sentence (an unexpected word) while musical structure was manipulated by introducing an unexpected out-of-key chord. Unexpected elements in both types of stimuli were presented simultaneously. Other types of sentences that either manipulated semantic expectancy (i.e., a semantically unexpected word was introduced in parallel with the unexpected chord) or did not involve any type of manipulation (filler sentences) were included as controls. Results showed that participants’ reading times were slowed for both syntactic and semantic ambiguities, however, only the effect related to syntactic ambiguity interacted with harmonic expectancy i.e., reading times for the syntactically unexpected word were considerably slower when participants were simultaneously presented with the unexpected chord. These results support the notion that the effects of harmonic expectancy on language processing may be specific to syntax, in other words, that syntactic but not semantic integration in language and music rely on shared cognitive resources (SSIRH hypothesis; Patel 1998; 2003). To further support this idea, Patel and his colleagues (2008) examined a group of individuals with Broca’s aphasia showing specific deficits in grammatical comprehension. Participants were tested on their sensitivity to harmonic relations in chord sequences with both an explicit and an implicit measure. Results showed that these aphasic individuals were impaired in both measures of music structural processing compared to unimpaired controls.

The SSIRH hypothesis put forward by Patel (1998) argues that the psychological experience of syntactic processing in music and language share many similarities such as the experience of structural ambiguity and resolution during the unfolding of a sequence (Sloboda, 1985) or the fact that in both domains, the structural integration of new elements largely relies on working memory. Based on electrophysiological data suggesting that structural integration in language and music elicit event-related brain potentials (ERPs) with similar latencies, amplitudes and scalp distributions (Patel et al., 1998) Patel suggested that aspects of linguistic and musical syntactic processing rely on shared neural resources. To accommodate evidence suggesting dissociations between music and language syntactic processing, such as the fact that brain damage can impair the processing of harmonic relations while linguistic syntactic processing remains intact (Peretz et al., 1994), Patel (2003) argued that linguistic and musical long-term knowledge systems may indeed be independent. However, the online process of integrating new items in unfolding structures (sentences in language; chord progressions in music) may rely on cognitive and neural resources that are common to both domains (Patel, 1998; 2003). The SSIRH hypothesis has since been supported by a body of behavioural and neuroscientific research (Fedorenko et al., 2009; Kunert et al., 2015; Sammler et al., 2013; Slevc & Reitman, 2013) while additional evidence comes from the developmental literature (Jentschke & Koelsch, 2009; Jentschke et al., 2008). To take one example of a well-cited study Jentschke et al. (2008) examined whether 4- and 5-year-old children with specific language impairment (SLI) typically exhibiting difficulties in the processing of linguistic structure, would also demonstrate impairments in music structure processing. Using electrophysiological testing they showed that compared to typical controls, children with SLI did not elicit the ERP components typically associated with unexpected chords (ERAN and N5; see section 1.2.2.1 for a description of these ERP components). These results strengthen the proposition of an interrelation between language and music structural processing and suggest that this connection might be evident from a young age.

1.4.2. Rhythm in speech and music: The Temporal Sampling Framework

Both music and language are organized in a temporal manner, i.e., they are both thought of as having underlying rhythmical patterns. Even though rhythmical organization is not as evident in language as in music, general agreement exists among linguists that language is rhythmically organized, linguistic rhythm being interpreted as

a combination of different linguistic features such as the arrangement of the durations of different syllables or the patterns of stressed versus unstressed syllables (Arvaniti, 2012; Cummins, 2015; Kohler, 2009; Patel, 2003). Similar to the observation that the pitch variability of one's language is reflected in one's musical pieces, Patel and Daniele (2003) used a measure of rhythmic variability to compare patriotic music from England and France, two linguistic environments that are rhythmically distinct (predominantly trochaic and iambic respectively⁶). They found that the musical compositions varied in a similar direction and fashion as do the English and French languages, suggesting that the brain might not use distinct operations to process rhythm in one or the other modality.

A specific mechanism that proposes direct links between temporal perception in language and in music has been proposed by Goswami (2011; *Temporal Sampling Framework*) to explain specific phonological deficits in developmental dyslexia. According to the Temporal Sampling Framework, speech perception relies on the encoding of temporal modulations across different frequencies relevant for speech while poor speech segmentation skills in dyslexic children arise from a specific difficulty in tracking the sound "rise time" (the time taken for the sound to reach its peak amplitude). Rise times in natural speech reflect modulations in sound intensity, duration and fundamental frequency. For example the syllable "da" has a fast rise time incorporating a sharp change in intensity, while the syllable "wa" has a slower rise time accompanied by a gentler change in intensity (Verney, 2013). Rise times are critical for segmenting the speech signal into syllables, as they reflect the patterns of amplitude modulation marking the passage from one sound to another. According to Goswami (2011), oscillations of networks of neurons might entrain to an input rhythm marked by syllable rise times in speech, which form patterns of strong and weak beats. A similar mechanism could come into play when attending to musical rhythm where metrical structure also relates to strong and weak beat patterns; accurate perception of rise time may therefore be critical for extracting periodicity (Huss et al., 2011). Indeed, a recent experiment examined accurate perception of musical meter, perception of syllable rise times, phonological awareness and reading performance in children with and without developmental dyslexia (Huss et al, 2011). Results demonstrated that not only was

⁶ Trochaic = long syllable or stressed syllable, followed by a short or unstressed one. Iambic = short or unstressed syllable followed by a long or stressed one.

performance in metrical perception of music significantly associated with perception of rise times, but it also accounted for 40% of the variance in phonological awareness and reading performance. In another study, children with developmental dyslexia showed poor performance in musical beat and syllable rise time perception tasks when compared to younger children matched in their reading abilities, suggesting that their linguistic deficits might be rooted in poor temporal perception for both language and music (Goswami et al., 2013, see also Overy et al., 2003). Since metrical structure is more overt in music than in language thus facilitating the segmentation of syllables and words from the speech stream, rhythmic-based musical interventions could potentially improve reading skills in children with developmental language disorders (Goswami 2011, Overy, 2000; 2003).

1.4.3. Learning in language and music: Extracting statistical regularities?

From a learning perspective, the acquisition of the structures of both language and music in infancy and early childhood appears to take place implicitly without any conscious effort. For example, several studies have shown that the acquisition of the sounds of one's native language takes place in the first year of life by passive exposure to a specific linguistic environment (Kuhl, Williams, Lacerda, Stevens & Lindbloom, 1992; Mugitani et al., 2009, Werker & Tees, 1984; Werker & Tees, 2005). Among a set of early influential experiments, Kuhl et al. (1992) showed that by 6 months of age, American and Swedish infants have become accustomed to the vowels of their native language. Similarly, Werker and colleagues (1984; 1988) showed that 6-month-old but not 10- and 12-month-old infants and adults can discriminate between both native and non-native consonants (Werker & Lalonde, 1988; Werker & Tees, 1984). Since these earlier demonstrations of a shift from "universal" to native phonetic perception within the first year of life, several experimental studies have replicated the findings using both behavioural and brain measures (e.g., Cheour et al., 1998; Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005).

A similar pattern of implicit learning through passive exposure has also been shown to occur for musical sounds. As described in section 1.2.2.1 young infants do not seem to be enculturated into the tonal structure of Western music; for example, Western infants but not adults are able to detect out-of-key notes in non-native Javanese pelog scales, in addition to those in the native Western chromatic scale (Lynch et al., 1990).

However, children aged 4 and 5 already have knowledge of Western harmonic functions when tested with implicit measures such as electroencephalography (EEG; Corigall & Trainor, 2013) or harmonic priming tasks (Schellenberg et al., 2005). The developmental trajectory for acquisition of one's native music structure has been relatively understudied compared to language, but available evidence suggests that Western children as young as 2 years old already possess implicit knowledge of Western harmonic rules when tested with EEG (Jentschke, Friederici, & Koelsch, 2014). Taken together, these findings suggest that both music and language may employ similar cognitive processes for learning (e.g., a process of perceptual narrowing; Lewkowicz, 2014) and may develop in parallel although not necessarily at the same rate.

One influential auditory learning theory supported by several contemporary researchers argues that infants and young children might use statistical distribution of sounds for acquiring structure in both speech and music (e.g., Saffran et al., 1996; Saffran, 1999; François & Schön, 2014). Statistical learning refers to extracting patterns from the auditory environment and implicitly acquiring knowledge of their statistical properties without direct feedback (Patel, 2005). In an elegant experiment Saffran, Newport and Aslin (1996) showed that 8-month-old infants could extract information related to the transitional probabilities of syllables from a continuous speech stream of non-words from an artificial language, after only two minutes of exposure. Transitional probabilities track the contingency between events in speech, representing the likelihood of a syllable following another; in natural languages transitional probabilities are higher for syllables following one another within words than between words (Saffran, 2003). To demonstrate that speech segmentation can utilize transitional probabilities in a natural language, Pelucchi, Hay, and Saffran (2009) used Italian as the familiarization stimulus instead of an artificial language. Although Italian was a novel and complex language for the English learning 8-month-old infants in the study, the results showed that they could distinguish familiar from novel words after familiarization with Italian speech. These researchers further showed that infants were capable of discriminating words presented during familiarization from novel words, the syllables of which were presented within the familiarization corpus with equal frequency. This suggested that learning of syllable sequences rather than individual syllables had occurred (Pelucchi et al., 2009). Interestingly, infants appear to be sensitive to other types of statistical information as well. Maye, Werker and Gerken

(2002) familiarized two groups of infants with streams of consonants ([da] – [ta]) presented in either unimodal or bimodal distributions. Results showed that infants were sensitive to this information and that different statistical distributions affected their speech perception and learning. Taken together, the findings of these studies provide robust evidence to support infants' sensitivity to statistical cues in language stimuli and the importance of statistical learning in language acquisition.

An account by which a similar mechanism might underly the learning of musical information is not unlikely, given that data on the statistical distribution of notes and chords in Western music has shown that some musical elements occur more frequently than others (Krumhansl, 1990). Indeed, studies have indicated that adults are sensitive to pitch distributions and statistical learning can occur for tonal patterns incorporated within novel musical sequences (Krumhansl, 2000; Oram, Cuddy, & Oram, 1995). Furthermore, Saffran, Johnson, Aslin and Newport (1999) showed that adults and 8-month-old infants were able to use statistical information from a continuous stream of tones to extract sequences in a process similar to that employed with linguistic information (see also Jonaitis, & Saffran, 2009; Thiessen, Hill, & Saffran, 2005). Reviewing a body of literature providing evidence of shared neural resources that underlie statistical sensitivity in music and speech, François and Schön (2014) suggest that statistical learning is a domain-general ability underlying both modalities. Given the potentially shared learning mechanism between music and language, the authors support the view that musical experience could boost an advantage in speech processing (François & Schön, 2014; Patel, 2011; 2013). The next section will review studies that have addressed the links between musical and linguistic skills, as well as research looking at transfer effects between the two domains.

1.5. Evidence of connections between musical and linguistic abilities

Accounts of a shared learning mechanism between these two modalities predict that musical and linguistic skills are linked and that enrichment of experience in one domain could boost development in the other. Indeed, a number of correlational studies with children have reported associations between musical temporal processing and linguistic aptitudes such as phonological awareness and reading ability across development (Flaugnacco et al., 2014; Gordon et al., 2014; Goswami et al., 2013; Woodruff Carr et al., 2014), leading some researchers to suggest that the neural

encoding of rhythm and beat modulations could underlie both musical and linguistic abilities (e.g., Temporal Sampling Framework; Goswami, 2011).

Musical pitch perception also appears to be relevant to the processing of language, given that pitch and melody are important elements of language prosody, the element of speech that conveys a wide range of information including speakers' intention of emotion, as well as information about phonological and grammatical content and word boundaries (Speer & Ito, 2009; Brooks & Kempe, 2012; Xie, 2012). Indeed, pitch and melody discrimination abilities have been linked to phonological awareness and early reading ability in 4- and 5-year-old children (Anvari et al., 2002). Importantly, in this study music perception abilities (rhythm and pitch perception in 4-year-old and pitch perception in 5-year-old children) explained unique variance in reading ability even when the effect of phonological awareness had been accounted for (Anvari et al., 2002). Similarly, Lamb and Gregory (1993) found that discrimination of pitch, but not timbre, contributed to both phonological awareness and reading ability in a sample of 4.5- and 5-year-old children. Furthermore Forgeard et al., (2008) showed that pitch discrimination strongly predicted phonological awareness performance in 6-year-old children, while the contribution of pitch discrimination to phonological awareness was also present for 10-year-old dyslexic children.

Based on the fact that a chronological, step-by-step order of skill acquisition has been proposed for both music (e.g., Dowling, 1982; Trehub et al., 1986) and language (e.g., Bloom, 1998) a recent correlational study with 5- to 7-year-old children classified interrelationships between distinct musical and linguistic skills across 5 hierarchically organized levels, with skills within each level reflecting similar cognitive processes (Cohrdes et al., 2016). Specifically, musical and linguistic tasks were organized according to the size of elements relevant to processing. Thus phoneme and word discrimination corresponded to the discrimination of timbre and short melodic phrases (Level 1), perception and production of words and syllables (phonological awareness), as well as prosody corresponded to melody and rhythm repetition (Level 2), processing of syntactic information corresponded to processing of harmonic sequences (Level 3). Level 4 is relevant to the recognition of emotion in both linguistic and musical phrases and Level 5 pertains to the processing of high-level elements such as stories and songs. Indeed, these researchers found that musical and linguistic tasks within each level showed stronger associations relative to relationships between different levels, suggesting that interrelations between distinct musical and linguistic competencies can

be systematically categorized according to the degree of cognitive processing that they require.

Analogies between musical and linguistic skills at the perceptual level have also been reported in studies looking at atypical groups such as children with Autistic Spectrum Disorders (ASD) (Heaton, Davies, & Happé, 2008; Järvinen-Pasley & Heaton, 2007; Järvinen-Pasley et al., 2008), a group of neurodevelopmental disorders primarily marked by social communication and interaction deficits with or without concurrent language impairment (American Psychiatric Association, 2013, p. 53). For instance, children with ASD show enhancements relative to controls for both speech and musical pitch, but only when speech is processed at the perceptual and not the semantic level (Järvinen-Pasley & Heaton, 2007; Järvinen-Pasley et al., 2008). Similarly, an adult with high-functioning ASD and absolute pitch exhibited advantages in processing perceptual components of speech compared to typical controls who also possessed absolute pitch (Heaton et al., 2008). These results suggest that a specific link between perceptual aspects of music and speech exists in individuals with ASD that, contrary to patterns of music-language associations that occur in typical individuals, may not extend to more general linguistic abilities. Indeed, in typical individuals the development of pitch discrimination from childhood to the adult years has been associated with receptive vocabulary skills, unlike high-functioning individuals with ASD whose musical ability shows no correlation with vocabulary (Mayer, Hannent, & Heaton, 2014).

The findings from correlational and cross-sectional studies that have investigated direct links between specific auditory perceptual abilities in typical as well as atypical development therefore appear to support accounts of shared processing and learning mechanisms between music and language. Another promising and fruitful method for exploring the association between these two domains involves examining musical experience and exploring how this can affect language and cognition in adults and children. A considerable number of cross-sectional and longitudinal studies have been conducted, specifically investigating formal musical experience and how this can affect how the brain processes the sounds of language.

1.5.1. Formal musical experience and language

Considering that both music and language heavily depend on auditory learning and that experience-dependent plasticity in auditory networks has been shown to occur

in adults (Song, Skoe, Wong, & Kraus, 2008), it appears plausible that changes in neural processing in one domain could induce changes in the other, a process referred to as *cross-domain* plasticity (Patel, 2013). In his highly influential OPERA⁷ hypothesis, Patel (2010; 2013) proposes that transfer effects from one domain to the other occur when five conditions are met: [1] neuroanatomical overlap between areas responsible for music and speech, [2] higher precision in auditory processing demanded by music practice relative to speech on these shared neural networks, [3] musical engagement involves positive emotion, [4] music practice involves frequent repetition and finally, [5] musical engagement is strongly associated to focused attention.

Indeed auditory perception enhancements linked to years of musical experience appear to boost a musician's advantage in both linguistic and musical processing (see Kraus & Chandrasekaran, 2010 for a review) and several studies have reported musician gains in the subcortical encoding of musical and speech sounds (Kraus et al., 2009; Krishnan, & Gandour, 2009; Lee, Skoe, Kraus, & Ashley, 2009; Musacchia, Sams, Skoe, & Kraus, 2007; Parbery-Clark, Strait & Kraus, 2011; Strait et al., 2009; Wong, Skoe, Russo, Dees, & Kraus, 2007). To take one example, Musacchia et al. (2007) used EEG to measure brainstem activity in response to music and speech stimuli. They found that musicians were more sensitive to sound onset in both types of stimuli as reflected by earlier latencies and larger amplitudes of the onset response. Furthermore, musicians exhibited enhanced encoding of speech (syllable 'da') and music stimuli (G₂ tone played with cello) sharing the same fundamental frequency (F₀ = 100 Hz). To take another example, Parbery-Clark et al. (2011) recorded brainstem responses to the same speech syllable in a predictable and in a variable condition (in the latter, the syllable /da/ was randomly presented among seven other syllables). They found that musicians' subcortical enhancement in the predictable compared to the variable condition was superior to that of non-musicians. Interestingly, in both of the above studies subcortical enhancements were linearly associated with years of musical practice. These findings suggest an enhanced neural sensitivity to speech-relevant regularities (i.e., musicians more readily detect regularities in speech sounds), an ability that strongly relates to speech-in-noise perception (Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011).

Further substantiating a link between auditory processing in music and language,

⁷ Initials correspond to Overlap, Precision, Emotion, Repetition and Attention.

language experience also appears to influence musical processing. In recent studies, experienced speakers of tonal languages have exhibited enhancements in behavioural measures of pitch and melody processing as well as on a neural measure (ERP mismatch negativity) of pitch discrimination compared to non-musician controls (Bidelman, Hutka, & Moreno, 2013; Hutka, Bidelman, & Moreno, 2015). Furthermore, highly proficient bilingual speakers (simultaneous interpreters) have shown a differential pattern of brain activation compared to controls that suggests the use of top-down control in a pure tone discrimination task (Elmer, Meyer, Marrama, & Jäncke, 2011). Interestingly, the effect of tonal vs non-tonal language experience is evident from infancy. For instance, Chinese infants discriminate tones equally well at 6 and 9 months for both speech and non-speech suggesting that phonetic representations for tone based on linguistic experience are already established (Mattock & Burnham, 2006). Conversely, English and French infants who are exposed to lexical tones in their linguistic environment, successfully discriminate between the same stimuli at 6 but not at 9 months of age (Mattock & Burnham, 2006; Mattock, Molnar, Polka, & Burnham, 2008).

A number of cross-sectional studies have also reported linguistic and cognitive advantages for musician vs non-musician children, despite the fact that the years of musical training are not comparable to professional musician level. For example musically trained 6- to 15-year-old children exhibited enhanced performance in measures of verbal but not visual working memory (Ho, Cheung, & Chan, 2003). Musician 10- and 11-year-old children also appear to be more sensitive to violations of language and music structure than children without musical training (Jentschke & Koeschl, 2009; Jentschke, Koeschl, & Friederici, 2005) while musically trained 3- to 6-year-old children also demonstrate an advantage in detecting in key and harmony violations (Corrigall & Trainor, 2009). In addition, musician 8-year-old children can detect pitch changes in both music and language more readily than non-musician children, as demonstrated using both behavioural and electrophysiological measures (Magne, Schön, & Besson, 2006). Finally, 10-year-old musicians outperformed non-musicians in behavioural and neural measures of speech-in-noise perception (Strait, Parbery-Clark, Hittner, & Kraus, 2012). Overall, it appears that through formal musical practice individuals develop a heightened sensitivity for acoustic features such as frequency and duration of sounds that are critical for music but also for speech perception (e.g., Besson, Chobert, & Marie, 2011).

Informative as they may be however, correlational and cross-sectional studies such as the ones reported above do not demonstrate causality (Schellenberg, 2004) as there is a high possibility that demographic factors, cognitive ability and personality are pre-existing factors that contribute to whether or not a child takes music lessons (see Corrigan, Schellenberg, & Misura, 2013). To overcome this important limitation, a number of studies have employed longitudinal pre-test- training –post-test designs to investigate the effects of musical training on linguistic and cognitive development. To strictly control for pre-existing traits that could account for differences in cognitive abilities of musician children such as general IQ (Schellenberg, 2004), researchers have used randomized controlled trials designs (RCT). In these studies, children are randomly assigned to musical training, no training or other types of control training, with the groups matched on several cognitive and demographic measures (e.g., Barac et al., 2011; François et al., 2013). In one such study, Slater et al., (2014) followed a group of 6- to 9-year-old children from disadvantaged backgrounds who were offered free music classes as part of a community based project (Harmony Project; <https://www.harmony-project.org>) aimed at promoting low-income children’s healthy growth through the study of music. Children were pseudo-randomly assigned to music training and control groups and were matched on a number of variables including age, gender, IQ, maternal education and reading ability. Reading ability and general IQ were assessed at the start of music instruction and one year later, with results showing that the children who were receiving music lessons maintained an age-appropriate level of reading ability, while the performance of the control group weakened. In other words, musical training worked as a protective factor for children whose underprivileged background could potentially lead to lower levels of language proficiency (e.g., Fernald, Marchman, & Weisleder, 2013). Likewise, Kraus et al., (2014) demonstrated that after 2 years of community music lessons, participating children showed improvements in their brainstem response to speech stimuli relative to controls. In another well-designed RCT study, François et al. (2013) pseudo-randomly assigned 37 8-year-old children to either music or painting classes, controlling for socio-economic factors and differences in neuropsychological profiles. The two groups of children followed a two-year training program and were tested on behavioral and neural (ERP) measures of speech segmentation (i.e., ability to extract pseudo-words from a continuous stream of nonsense syllables) before, during and after training. Results showed that the music group outperformed their control group counterparts on both electrophysiological and

behavioral measures of speech segmentation. Other RCT studies have shown that children receiving music classes of different type and duration show enhanced performance in phonological awareness skills (Degé & Schwarzer, 2011, 20-week conventional music training with 5- and 6- year-olds), vocabulary (Barac et al., 2009, 20-day group computerized training with 4- and 6-year-olds), and both reading measures and pitch discrimination abilities in speech (Moreno et al., 2009, 24-week conventional music training with 8-year-olds). Therefore, robust evidence appears to point to positive effects of formal music classes on linguistic abilities that are closely related to auditory enhancements, such as speech segmentation or pitch discrimination/prosodic abilities, a process referred to as *near transfer*. However, whether music classes can induce changes in more general domains seemingly unrelated to music instruction such as general IQ or spatial abilities (*far transfer*), is still a question of debate as evidence from existing RCT studies is inconclusive (see systematic review from Mehr, Schachner, Katz, & Spelke, 2013).

Taken together the results from cross-sectional and longitudinal studies appear to indicate that specific associations between musical and linguistic abilities do exist and that positive near-transfer from music to language is a well-documented possibility. If musical experience induces transfer effects to neighbouring cognitive domains, what about its effect on musical processing and development?

1.5.2. Experience-induced musical aptitude

One would expect musical processing to be susceptible to experience-induced malleability as has been shown with other cognitive domains (e.g., Callan et al., 2003; Maguire et al., 2000). It should not therefore come as a surprise that long-term musical training induces enhancements in musical aptitude and the processing of musical stimuli. Much of the compelling evidence about how musical training can affect human hearing and musical sound processing comes from the auditory neuroscience laboratory led by Nina Kraus at Northwestern University, U.S.A. In their extensive research programme, these researchers have shown that adult musicians demonstrate heightened sensitivity in discriminating deviations in pitch and discontinuities in sounds (Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011; Strait, Kraus, Parbery-Clark, & Ashley, 2010), show stronger and more accurate auditory brainstem responses to pitch, timbre, timing (Kraus et al., 2009; Musacchia et al., 2007) and musical intervals (Lee et al., 2009) and more robust detection of changes in pitch contour (Chandrasekaran, Krishnan, & Gandour,

2009). One limitation of these studies is the extensive employment of the brainstem response to demonstrate auditory gains. Although this is a sensitive, well-established measure, the use of convergent methods (combining neural with behavioral measures) in this line of research is arguably more useful.

As mentioned briefly in the previous section, musical processing appears to be affected by non-musical experience such as language. Using mismatch negativity responses (MMN), an ERP component thought to reflect the early detection of auditory change or deviation in a sound stream (this is based on sensory memory; Naatanen, Paavilainen, Rinne, & Alho, 2007), Hutka et al. (2015) investigated pitch processing in non-musician tone language speakers (Cantonese) and both musician and non-musician English speakers. They found that both English musician and Cantonese speakers showed superior detection of subtle pitch changes than non-musicians as reflected in their ERPs, suggesting that language experience also influences the way the brain processes this essential component of music, namely pitch. Other studies with tone language speakers have corroborated these findings in typical populations (Bidelman et al., 2013; Fujioka et al., 2004; Wong et al., 2012) as well as a population with congenital amusia (i.e., a disorder in processing variations in pitch, commonly known as tone-deafness; Wong et al., 2012). Outside the study of tonal languages, research has been scarce. One example of such research comes from Bhatara, Yeung and Nazzi (2015) who examined whether foreign language experience could predict variability in rhythmic ability in native speakers of French. Results showed that participants who were experienced in a foreign language showed enhanced rhythmic ability, suggesting that exposure to languages that were rhythmically distinct from French may have improved these participants' rhythm perception (participants mainly had second language experience with stress-timed languages such as English and German whereas French is a syllable-timed language).

Given these findings, one would anticipate that the development of music-related aptitudes is in part dependent upon relevant experience (Howe, Davidson, & Sloboda, 1998). Indeed, when tested with magnetoencephalography (MEG), 4- to 6-year-old children who had participated in music lessons for one year were found to have larger auditory-evoked cortical responses to violin tones compared to untrained children (Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006). However, the above study recruited a small number of participants (4 for the experimental and 6 for the control group) limiting the generalizability of its findings. Hyde et al. (2009) used a slightly bigger

sample (31 6-year-old children; 15 in the experimental and 16 in the control group) with the control group matched to the experimental group for age and gender. After 15 months of musical training, the experimental group manifested a greater increase in the size of the right auditory brain area that was associated with greater enhancements in both a melody and a rhythm discrimination task. Taken together the above findings indicate that at least some aspects of musical development can be shaped by relevant experience affecting affecting the organization of music networks organization.

1.5.3. Informal musical experience: The story so far

The overwhelming majority of studies that has revealed beneficial effects of musical experience on early cognitive and linguistic development (e.g., Barac, Moreno, Chau, Cepeda & Bialystok, 2011; Degé & Schwarzer, 2011; François et al., 2013), has focused on conventional musical training given in classrooms or, for infants, on structured musical activities given in groups such as parent-infant music classes (Gerry, Unrau, & Trainor, 2012). For most children under the age of 5 however, musical experience consists of everyday informal musical interaction in the form of singing songs with their parents, dancing, being exposed to recorded music and playing musical games (for a review see Flohr, 2005). This type of shared experience can potentially support learning in the home environment, by providing a pleasant framework in which parents engage in learning activities with their children. Indeed, studies looking at the quality of the early home learning environment have recognized the supportive role of joint musical activities in young children's learning, and measures of shared learning activities have often included items related to music making (e.g., Williams, Barrett, Welch, Abad, & Broughton, 2015).

With respect to the effects that the home environment can have on children's healthy development, ample evidence indicates that the amount and quality of language input in the early years is crucial for language acquisition (Hoff, 2003; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Pan, Rowe, Singer, & Snow, 2005; Rowe & Goldin-Meadow, 2009; Weisleder, & Fernald, 2013). A considerable body of literature has also demonstrated that the quality of the home learning environment (conceptualized as everyday interactions and shared activities between children and their caregivers) can have beneficial effects on the development of language and cognition. Enriched home learning environments provide more learning opportunities

for children via increased frequency of learning activities, such as book reading and availability of learning materials. Positive developmental outcomes of enriched home learning environments include improved language and literacy skills (Sénéchal, Pagan, Lever, & Ouellette 2011), early numeracy skills (Anders et al., 2012; Kleemans, Marieke Peeters, Segersa, & Verhoeven, 2012), higher reading scores (Baker, Cameron, Rimm-Kaufman, & Grissmer, 2012; Chazan-Cohen et al., 2009) and optimal social-emotional abilities (Chazan-Cohen et al., 2009; Hartas, 2011). The frequency of musical interactions is usually embedded within measures of the home learning environment but very little research has focused on the home musical environment separately, although a growing number of findings have recently highlighted associations between music and language development (e.g., Woodruff-Carr et al., 2014), and have reported benefits of early music lessons on auditory and language-related skills (e.g., François et al., 2013). But why would this type of experience be beneficial for early linguistic and cognitive development?

One excellent example of informal musical experience introduced early in life is infant-directed (ID- henceforth) singing. ID-singing, similarly to ID-speech (Fernald et al., 1987; 1989), can be distinguished from other types of singing mainly due to characteristics such as higher pitch, slower tempo (Trehub et al., 1997, mostly referring to lullabies), more expressive rendering of lyrics and higher emotional engagement (Trehub, Unyk, & Trainor, 1993; Trehub, Hill, & Kamenetsky, 1997). The use of singing in early mother-infant interactions appears to be ubiquitous (Trehub et al., 1993), is specifically related to phonetic features of each language (Falk, 2007, 2011a, 2011b) and is more effective than speech alone in delaying distress in 7- to 10-month-old infants (Corbeil, Trehub, & Perentz, 2015). In addition, studies have shown that maternal singing can regulate the levels of arousal in 6-month-old infants (Shenfield, Trehub, & Nakata, 2003) and infants show increased responsiveness (visual feedback) to videos of mothers singing versus speaking at 6 months, presumably because mothers' singing performances are rated as more emotional when compared to speech (Trehub, Plantinga, & Russo, 2015). Moreover, analyses of infant and mother vocalizations have revealed that infants and mothers often co-regulate their vocal productions at the tonal level (Van Puyvelde et al., 2010) and that such incidents of tonal synchrony are associated with mother-infant physiological co-regulation as measured by heart rate variability (Van Puyvelde et al., 2014). It has therefore been hypothesized that maternal singing can function as an emotional coordinator between infants and mothers (Nakata

& Trehub, 2004) and that these early vocal interactions may play a crucial role in later social development (Van Puyvelde & Franco, 2015). Studies have also indicated that singing facilitates speech segmentation in both infants (Lebedeva & Kuhl, 2010; Thiessen & Saffran, 2009) and adults (Schön et al, 2008) highlighting its potentially beneficial role in language development. To take one example, Thiessen and Saffran (2009) familiarized infants to a series of digits that were either spoken or sung. Results showed that infants in the sung condition more readily learned the series of digits than infants in the spoken condition, suggesting that singing may serve as “scaffolding” for learning the sounds of language. Indeed, singing may support language learning through the presence of pitch variations that can aid in the discrimination of syllables (Schön et al, 2008). Another possibility is that infants benefit from the combined input, since a second source of information (music) provides additional cues to help them identify structure in the first source (words and syllables) (Thiessen & Saffran, 2009). Moreover, the emotional properties of ID singing may lead to increased interest and attention (Schön et al, 2008; Thiessen & Saffran, 2009).

Parental singing may hold a central position in early musical interactions where infants’ activities are limited, but the repertoire of musical activities becomes enriched, as the child grows older. Indeed, it has been shown that maternal singing is the principal form of musical engagement in infancy (Ilari, 2005; Shoemark & Arnup, 2014), while musical activities expand in the later years (De Vries, 2009; Mehr, 2014; Youm, 2013; Young, 2008). An elegant qualitative analysis of 18 young children’s recordings, parental diaries and interviews with caregivers, provided rich information about parent-child musical activities (Barrett, 2011), which appear to include joint and supported singing (e.g., children’s songs, counting songs, and nursery rhymes), improvising songs to accompany everyday routines, dancing, playing musical (including toy) instruments, and listening to recorded music (Barrett, 2009; 2011). Critically, the majority of studies that have explored the type and frequency of home musical interactions in the early years report that most parents of children under 6 years interact musically with their children in the home environment in various ways (Ilari, 2005; Mehr, 2014; Shoemark & Arnup, 2014; Young, 2008), while musically trained parents are more likely to sing and play music to their infants (Custodero, & Johnson-Green, 2003). Given the predominance and richness of musical activities within family environments and the spontaneous enthusiasm that the majority of young children show for musical play, it is

surprising how little we know about the effects that this dimension of parent-child interactions can have on development.

Only two studies so far have directly addressed the effect of such informal musical experience that is not limited to maternal singing: Putkinen et al.,(2013) and Williams et al., (2015). Putkinen and colleagues asked parents to report how frequently their 2- and 3-year-old children engaged in activities such as singing and dancing as well as how often they interacted musically with their children (e.g., how often they sang to their children). Higher scores in these reports were significantly associated with more refined ERP responses associated with change detection in the duration and temporal structure of sounds [mismatch negativity (MMN), P3a, late discriminative negativity (LDN), and reorienting negativity (RON)]. These results suggested that children whose environment was more musically enriched had developed more mature auditory processing at the neural level. Williams and colleagues (2015) used a longitudinal design to assess the effect of enriched musical activities in the home as measured by parent self-reports when their children were 2 and 3 years old, on cognitive, emotional and social markers of development two years later. Moderate associations were found between the amount of shared musical activities at 2 and 3 years and the children's vocabulary, arithmetic abilities, attentional and emotional regulation, and prosocial skills two years later. More interestingly these small effects were maintained even when the authors controlled for the effect of shared book reading, an activity found to be strongly associated with later academic achievements (Farrant & Zubrick, 2013; Sénéchal et al., 2011). This study is limited by the use of a single item to assess the frequency of musical interaction (*"in the past week, on how many days have you, or an adult in your family, played music, sung songs, danced, or done other musical activities with the child"*) and a 4-point response scale ranging from 1 = *"not in the past week"* to 4 = *"6-7 days"*. Moreover, only one measure of language development was used (vocabulary), which does not allow for further exploration of the associations between home musical interaction and linguistic development.

Another longitudinal study that looked at the frequency of singing songs/rhymes and playing music at home in a sample of 15,600 3- to 5-year-old children (assessed through parental interviews) failed to report linguistic or social-emotional enhancements associated with shared musical activities (Hartas, 2011). However, in this study there

was no direct measurement of children's socio-emotional and language and literacy development but rather results were based on teachers' ratings.

While interest in the effects of informal musical experience on linguistic and cognitive development has recently increased, the effect of parent-child musical interactions on children's musical abilities has been relatively neglected. Although, some studies have looked at the associations between parental attitudes towards music and children's musical attainment and motivation in music classes (Brand, 1986; Driscoll et al., 2015; Sichivitsa, 2007), only one study has directly addressed the question of whether the amount and quality of informal musical experience can influence the development of musical abilities in children as assessed by direct measurement (Brand, 1986). In this study, a parental report for the home musical environment developed for 7-year-old children (Home Musical Environment Scale or HOMES; Brand 1985) was used to examine the relationship between parent and child musical involvement (note that this did not include parent-child musical interactions) and the children's musical profiles. Results indicated a strong relationship between the HOMES scores and children's musical skills as assessed by musical discrimination tasks and teacher ratings, while the strongest predictor of musical achievement was parental attitudes towards music and parent-child musical involvement (Brand, 1986). With regards to whether informal musical experience could affect musical attributes at an earlier age, the Putkinen et al. (2013) findings regarding enhanced auditory discrimination in 3-year-old children with higher levels of musical engagement in the home provide some insight, as it is possible that enhancements in the neural processing of sound would extend to musical as well as linguistic skills. Furthermore, evidence with respect to the effect of formal musical training on young children's (4- to 6-years old) musical abilities has unsurprisingly shown that musician children exhibit advantages in the processing of musical sound (Fujioka et al., 2006; Hyde et al., 2009). Taken together, these findings raise the possibility that an enriched musical environment in the early years, informal as it may be, could positively influence the development of at least some aspects of musical ability in children.

In summary, inconclusive findings and limitations in previous research regarding informal musical experience in the home underscore the need for a more detailed examination of this factor and its potential effects on development. Therefore, one of the aims of this research project is to address this gap by exploring informal

musical interaction between parents and children within the family and examining whether this can affect language and musical development.

1.6. Aims of the thesis

As demonstrated above, the relationship between language and music is a burgeoning area of research that has recently provided us with rich behavioural and neuroscientific evidence supporting the links between these two domains and the transfer effects from formal musical training to language processing. Questions remain however regarding the early developmental trajectory of the relationship between these two domains. Specifically, the scarcity of research studies with children under the age of 6 years has prevented us from answering questions such as: [i] Are linguistic and musical skills linked in preschoolers, similar to that observed in older children? [ii] Might there be associations between specific linguistic and musical skills that are stronger than others? [iii] Can differences in melodic and rhythmic skills differentially predict areas of language development? [iv] Can young children process musical structure in an adult-like manner? [v] Is the implicit processing of music structure related to the development of language in young children? Another area of inquiry that warrants specific investigation is whether or not informal musical experience in the home during the early years can shape linguistic development in a manner similar to that reported for formal musical experience.

The main aim of the present thesis is to address these questions. Investigating the relationship between early musical and linguistic abilities could greatly contribute to the creation of a more complete picture of the developmental pathways of the music-language relationship. Exploring the effect of informal musical experience in the family would also enrich our knowledge about environmental influences on child development, generating impact for early childhood educators, practitioners, caregivers and policy makers.

Part of the reason why young children have so far been underrepresented in music cognition research is related to problems with the assessment of this age group. Considerations regarding the testing of young children include their difficulty in maintaining attention, the fact that they are not yet familiarized with structured testing environments and in some cases, their frequent emotional fluctuations or displays of shyness. Given the gap in available musical assessments for this age group, another

major focus of this study was to develop musical measures that would be suitable for children under the age of six.

1.7. Key questions and structure of the thesis

Two main strands of inquiry were followed. The first examined the relationship between the early development of language and music competencies in 3- to 6-year-old children, an age group that has been relatively neglected in the literature. Second, driven by a rich literature reporting the beneficial effects of formal musical experience on language and cognition, the potentially enriching effects of informal musical interaction of the kind experienced in the home environment were explored with regard to linguistic and musical development in early childhood.

To these ends, this research project was divided into four studies. **Studies 1 and 2** posed initial broad inquiries regarding the music-language link in the early years that eventually led to more specific issues addressed in Studies 3 and 4. More specifically, **Study 1** examined links between a broad range of musical skills and the development of fundamental language abilities in 3- and 4-year-old children. **Study 2** investigated the effect of informal musical experience in the home on linguistic and musical development in this age group. Motivated by the findings of Study 2 regarding informal musical experience, **Study 3** set out to develop and validate a systematic questionnaire to measure this type of environmental experience from infancy to the preschool years. It is envisaged that this instrument will be appropriate for use in experimental research addressing the effects of informal musical input on developmental outcomes. Finally, **Study 4** sought to explore a specific link between music and language previously researched only in adults and older children, namely whether there is a link between the processing of language and music structure in children under the age of six. A further aim was to examine whether home experience with music, as assessed by the questionnaire developed in Study 3, is associated with the development of these skills.

This thesis is organized in six chapters. **Chapter 1** presents a review of the relevant literature, organized around the two interwoven aspects of the research program: musical and linguistic skill development in young children and the relationship between them on the one hand, and on the other hand, the role of musical experience (formal and informal) on the development of these skills.

Chapters 2, 3, 4 and 5 present the four empirical studies of this research project. Chapters begin with the rationale that led to each research question, and the aims of each separate study are also outlined. Methods are subsequently described and the results pertaining to each research question are presented. Finally, a summary and discussion of the findings of each study is provided.

The final chapter, **Chapter 6**, provides an overall summary of the research studies and their findings and discusses the implications for, and translatability of the present studies to research, educational and policy contexts. An outline of the limitations of the present program is also provided to inform the directions for future research.

CHAPTER 2: LINKS BETWEEN THE EARLY DEVELOPMENT OF MUSICAL AND LINGUISTIC ABILITIES (STUDY 1)

Abstract

Study 1 employed correlational methods to examine the relationship between a range of musical skills and the development of key language areas in 3- and 4-year-old children. An original set of age appropriate perception and production musical tasks covering a range of musical skills was specifically developed and piloted for this experiment, as no thorough assessment of musical abilities for this age group was available; this new tool is suitable for future large-scale validation, which was not within the scope of the current research. Standardized assessments of language grammar, phonological awareness, verbal memory and non-verbal cognitive ability were administered. Findings pointed to a particularly strong link between both rhythm perception and production abilities and phonological awareness skills, extending previous findings to a younger age group. Results also revealed a specific link between melody perception and the development of language grammar, suggesting that at this young age, specific auditory skills might work to underpin different areas of language development. Possible mechanisms underlying these differential associations are also discussed.

2.1. Background, rationale and aims of Study 1

As discussed in the previous chapter, a number of shared features between music and language suggest that the developmental paths of linguistic and musical skills may rely on common learning mechanisms (François & Schön, 2014; McMullen & Saffran, 2004). Reinforcing this view, research with school-aged children has revealed links between formal musical experience and linguistic aptitudes such as verbal memory (Ho et al., 2003), speech segmentation (François et al., 2013) and reading measures (Moreno et al., 2009).

Research in children younger than 5 years has been scarcer. Two RCT studies involving 4- to 6-year-old children comparing the effects of musical training to other types of training reported enhancements in phonological awareness skills (Degé & Schwarzer, 2011, with 5- and 6- year-olds), and vocabulary (Barac et al., 2009, with 4- and 6-year-olds) suggesting that features of music instruction may strengthen aspects of

linguistic development also in young children. In a correlational study Anvari et al. (2002) showed that both rhythmic and melodic aspects of musical ability were associated with phonological awareness and early reading ability (early identification of letters and reading small phrases) in 4-year-old children. Other researchers have shown that pitch discrimination contributes to phonological awareness in 4.5 to 6-year-old children (Forgeard et al., 2008; Lamb & Gregory, 1993), while a pervasive link between phonological awareness and rhythmic abilities appears to emerge from another two studies with 4- and 5-year-old children (Degé & Schwarzer, 2011; Verney, 2013). Only one study so far has investigated a link between rhythmic abilities and phonological awareness in children younger than 4 years (Woodruff-Carr et al., 2014). In this study, synchronization to an external beat was linked to speech encoding and phonological awareness in 3- and 4-year-old children.

The potential role of pitch and melody perception for children younger than 4.5 years old remains unclear as only one study addressing the music-language link has so far included relevant measures (Anvari et al., 2002). Melody and pitch are however critical elements of speech prosody (Marie et al., 2011) influencing the application of language learning mechanisms such as statistical learning, and conveying crucial information that aid speech segmentation and linguistic pattern extraction (Brooks & Kempe, 2012; Xie, 2012).

Furthermore, aspects of linguistic development other than phonology, such as the development of morphological rules and grammar have been neglected in younger age groups, with only one study in typical children indicating a relationship between rhythm perception skills and language structure and morphology in 6-year-old children (Gordon et al., 2014). It has been argued however that infants and children rely on both rhythmic and melodic prosodic cues to extract grammatical structures. For example, changes in pitch tend to correspond to boundaries between different syntactic clauses and phrases (Brooks & Kempe, 2012) aiding the extraction of grammatical information from continuous speech.

With the aim of tracking the potential effect of musical skills on different aspects of early linguistic development, the present study includes measures of both phonological awareness and language grammar. Although both rhythm and melody are critical elements of language prosody aiding children to extract linguistic information from the speech stream (phonological, morphosyntactic etc.; Snedeker & Yuan, 2008; Speer & Ito, 2009), evidence has pointed to the possibility that separate sets of auditory

skills might work to underpin separate aspects of linguistic skills at different times in development (Gordon et al., 2014). Indeed, the pattern of associations between musical and linguistic skills appears to change as children develop. Although both melodic and rhythmic abilities were associated with the awareness of phonology at 4 years and 5 years of age (Anvari et al., 2002), studies in older children do not appear to corroborate this finding. Two studies have indicated that the link between rhythmic skills and phonological awareness that has been suggested in a number of studies with 4-year-old children does not appear to persist in 6-year-old children (Forgeard et al., 2008; Gordon et al., 2014). Norton et al. (2005) on the contrary, found that phonological awareness was associated with both melody and rhythm perception in 5- to 7-year-old children. Evidence from this study is however inconclusive since one score for both melody and rhythm perception was used in the correlational analysis, rendering unclear the individual contribution of each musical perceptual factor on phonological awareness.

To begin to shed light on the developmental trajectory of the relationship between musical and linguistic skills from a younger age that has been so far understudied, the present study's sample comprised of 3- and 4-year-old children. A reason why younger preschoolers (3-year-olds) have so far been excluded from music perception research, is presumably that the structured environment needed for testing, combined with the auditory nature of the stimuli requires a level of attention which is harder for them to maintain. For this reason a major focus of this study was to develop musical measures that would be suitable for this age group. As discussed in chapter 1, musical testing in young children has for a long time relied on the Primary Measures of Musical Audiation (PMMA: Gordon, 1986), which includes tasks of perceptual musical ability for 5- to 9-year-old children. Another version, *Audie's* test (Gordon, 1989) measures musical perception abilities in 3- and 4-year-old children but only includes two subtests, melody and rhythm discrimination, excluding other aspects of music perception important for musical expression and performance such as tempo (Law & Zentner, 2012) or basic auditory perceptual abilities such as pitch discrimination. Furthermore, it does not include any music production tasks, which can be rich sources of information for a child's musical ability (e.g., how well a child can tap along with a tempo or reproduce a melody). With the aim of shedding light on the contribution of both rhythmic and melodic perceptual and production skills on early linguistic development, this study developed a new comprehensive test including measures of both melody and rhythm perception and production.

Overall, this study aims to make a novel contribution to the existing literature in the relationship between language and music by including the assessment of musical abilities that have previously been neglected in younger pre-schoolers (e.g., singing, tempo perception) and the assessment of language grammar, a linguistic skill not previously examined in studies addressing the link between language and music in younger age groups.

Therefore, Study 1 addresses two research questions: [i] are musical and linguistic skills linked in 3- and 4-year-old children? [ii] Are there specific links between distinct musical and linguistic skills that are stronger than others?

Specific hypotheses with regards to the research questions can be derived from the rationale presented above, and from the existing literature:

A. With regards to the first research question, given the importance of both melodic and rhythmic elements of speech prosody for denoting syllable, word and phrase boundaries and ultimately aiding the acquisition of phonology and grammar in early development, it is expected that both melodic and rhythmic aspects of musical skill will be associated to linguistic skills.

B. The Temporal Sampling Framework (Goswami, 2011) and previous work with 3- to 5-year-old children predicts that a specific link between rhythmic skills (tempo and rhythm perception and synchronization) and phonological awareness will emerge. However, based on research revealing that specific relationships between musical and linguistic skills may change across early development, it is predicted that previously reported language-music associations in children older than 4.5 years might show differential patterns with younger participants (link between rhythm and language grammar in 6-year-old children; Gordon et al., 2014; link between melody discrimination and phonological awareness in 4.5- to 6-year-old children; Forgeard et al., 2008; Lamb & Gregory, 1993)

2.2. Materials and methods

2.2.1. Participants

Participants in this study were 40 pre-school children (21 boys) between the ages of 3 years and 5 months and 4 years and 9 months ($M age = 4$ years, $SD = 4.7$ months). Twenty-eight children were monolingual English speakers and 12 children were bilingual but had English as their first language (as reported by the parents). A language

comprehension test (British Picture Vocabulary Scale; Dunn, Dunn, Whetton, & Burley, 1997⁸) was administered to all participants to ensure that they possessed an adequate level of English comprehension for their age. None of the participants had hearing difficulties or had been diagnosed with developmental delays in the beginning of the study. The sample recruited initially consisted of 42 children. Two children were however excluded from the participant list: one girl scored more than 1 *SD* below the mean in the British Picture Vocabulary Scale (BPVS) and one boy was diagnosed with language difficulties before the testing sessions had been completed. Also, although the overall number of participants was $N = 40$, 7 children completed the majority, but not all the tasks due to either [a] suddenly leaving the nursery for personal reasons ($n = 2$) or [b] being disinclined to perform a certain task e.g., would refuse to repeat sentences in a linguistic task or sing for the singing task ($n = 5$). In cases where the participant would refuse to perform one of the tasks due to lack of inclination on a given day, another effort was made by the experimenter to administer the task on a different day. All of the children experienced comparable musical activities in their nursery as reported by their teachers. Five children also received musical-related training (dancing or singing) outside the home or nursery.

2.2.1.1. Participant recruitment and ethical approval

Participants were recruited from nursery classes in three Children's Centres in the Greater London area. Access to schools was achieved through personal contact. Ethical approval for the study was granted by the Middlesex University Psychology Department's Ethics Committee (application no PG011b). To allow access to children in all London schools and as a prerequisite for ethical approval, an Enhanced Certificate was obtained from the Disclosure and Barring Service dated 22nd of January 2014 (001432403763) (see Appendix A).

Agreement letters were obtained from all participating schools and opt-out consent procedure was used following all necessary regulations. According to this procedure information letters to parents were distributed twice within two weeks and parents were reminded about the launch of the study two days before the start.

⁸ In this task, children are presented with four pictures in each trial while the experimenter reads a word while they are required to point to the picture that illustrates the word. Correct trials are added up to provide an overall raw score.

Information letters to parents clearly outlined the nature of the testing and procedure of the study, and explained the consent procedure (acceptance letters, template, parents information letters, opt-out consent and debriefing forms are provided in Appendix A). The researcher was available at pick-up times to answer any questions the parents may have had.

2.2.2. Musical abilities measures

A battery of age-appropriate musical tasks was designed for this study. All tests of musical ability were presented to the child as “musical games” and included positive feedback after each trial to increase motivation. Two types of musical abilities tasks were included: musical perception and musical production tasks. These were developed based on previous research on the assessment of musical abilities in children (e.g., Gordon, 1986; 1989; Peretz et al., 2013) and adults (e.g., Law & Zentner, 2012) and on a considerable number of studies examining music preferences, perception and production abilities in young children (e.g., Fancourt, Dick, & Stewart, 2013; Jensen & Neff, 1993; Morrongiello & Trehub, 1987; Trehub & Hannon, 2009). Musical perception tasks included the assessment of pitch, melody, rhythm and tempo perception, while musical production tasks included the assessment of singing and tapping along to a beat.

A pilot study was conducted between January and March 2015 in two of the participating nurseries to evaluate feasibility of the musical measures. The following two sections elucidate the construction of the tests and report relevant pilot study observations.

2.2.2.1 Design of music perception tasks.

All music perception tasks (pitch, melody, rhythm and tempo perception) followed the same format. Insights sought in the initial pilot exploration of the task format included feedback on: [a] designing the tasks in a format that would not be cognitively challenging for children of this age group (i.e., the majority of 3- and 4-year-old children would be able to understand and perform the task), [b] making the tasks pleasant and fun for the children in order to motivate them to complete the tasks.

The format that was explored was based on a 2+1 oddity paradigm that has been successfully used with children between the ages of 3.5- and 4-years (e.g., Jensen & Neff, 1993; White, Dale, & Carlsen, 1990). In this type of task children are presented with three aural examples: a standard tone or short melody followed by two alternatives. Three identical colored shapes are presented with the tones/melodies and the child is required to select the one that sounds different (or the same) as the standard stimulus. This procedure has been shown to be a powerful method of non-verbal assessment of auditory discrimination in young children (Jensen & Neff, 1993; White et al., 1990).

The task was designed using E-prime software. To test whether children followed the format of the task, short and undemanding musical stimuli (i.e., three note melodies where the “change” stimulus included changes in both contour and pitch direction) were embedded into the tasks. Each auditory stimulus (either environmental or musical sound) was matched to the position of a colorful shape on the screen (all three shapes/colors were identical in each trial to avoid responses based on visual preference) and children were required to point to the shape that sounded “different”. To ensure that children understood the concepts of “same” and “different” a series of visual stimuli where the child had to identify the “same” and the “different” one was presented prior to the auditory task. More specifically the picture of e.g., a dog was presented at the top of a piece of paper while the picture of the same dog and the picture of a cat was presented at the bottom (see Figure 2.1). The child was then asked to point to the one that is the same and then the one that is different from the picture at the top.

Twelve participants (7 boys) between the ages of 3.4 and 4.7 years were tested in this format. According to the observations gathered during the exploration of this paradigm: [a] many of the children tested would appear to lose interest overtime and respond randomly, [b] positive verbal feedback provided by the experimenter and visual feedback on the screen (colorful “thumbs up” picture) did not appear to increase motivation or spark enthusiasm.

With the aim of creating a more appealing task with stimulating feedback the following format was conceived while all perception tasks (pitch, melody, rhythm and tempo perception) followed the same procedure: In each trial the child listened to a musical element corresponding to the drawing of a little girl named Maggie that appeared at the top of the computer screen (see Figure 2.2; Maggie’s picture appeared and the melody or pitch was heard simultaneously). Two identical shapes would then appear successively on the lower left and right sides of the screen corresponding to

another two melodies or pitches. One was always the same while the other was always different to Maggie's and the child was asked to point to the one that sounded the same. Position of appearance (whether the 'same' item would appear on the left or right) and order of appearance (whether the 'same' item would be heard first or second) was counterbalanced. All stimuli were presented at a standard volume of 75db. This volume was chosen to ensure that the stimuli would be well above the volume threshold for all participants and was similar to previous studies with young children (Jensen & Neff, 1993; Thompson, Cranford, & Hoyer, 1988). Stimuli in each trial were separated by 1-second silent intervals while inter-trial intervals varied in order to ensure that the child was attentive before each trial (each trial was initiated by the experimenter). Order of trials in all tasks was randomized across participants. Positive feedback included the image of Maggie clapping while little stars appeared out of her hands. Furthermore, children were provided with a small card at the beginning of the task on to which they were allowed to apply a star sticker of their choice each time they responded correctly. Negative feedback included the image of Maggie frowning slightly. The help of an expert animator (Middlesex Art & Design student Eleonora Quario) was sought for the creation and animation of the Maggie character. All tasks were designed and run using E-prime software. A score of 1 was assigned after each correct response and a score of 0 was assigned after an incorrect response.

To ensure that the children fully understood the procedure prior to the task, they were first administered four practice trials in the musical perception task format. The 4 practice trials included easily identifiable sound stimuli (e.g. a dog barking, cat going miaou) and the child had to complete 3 out of 4 trials correctly. Participants were excluded from the study if she/he did not meet this criterion on the first session. Only one child failed to reach the criterion. Moreover, three practice trials were included before each musical perception task. The child had to identify 2 out of 3 practice trials correctly in order to move on to the test trials.

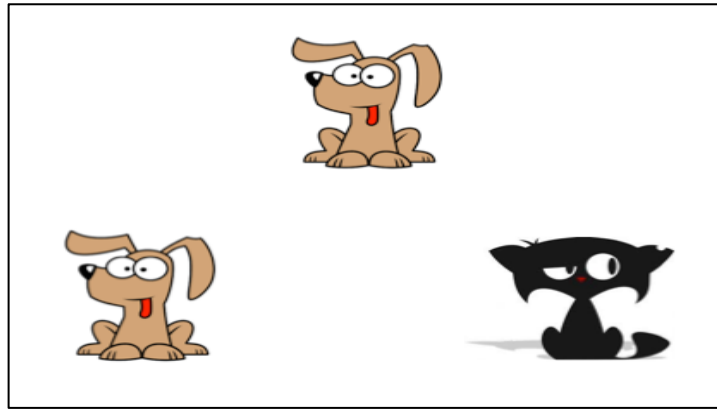


Figure 2.1. Example of picture presented to the child to ensure that the concepts of “same” and “different” are understood.

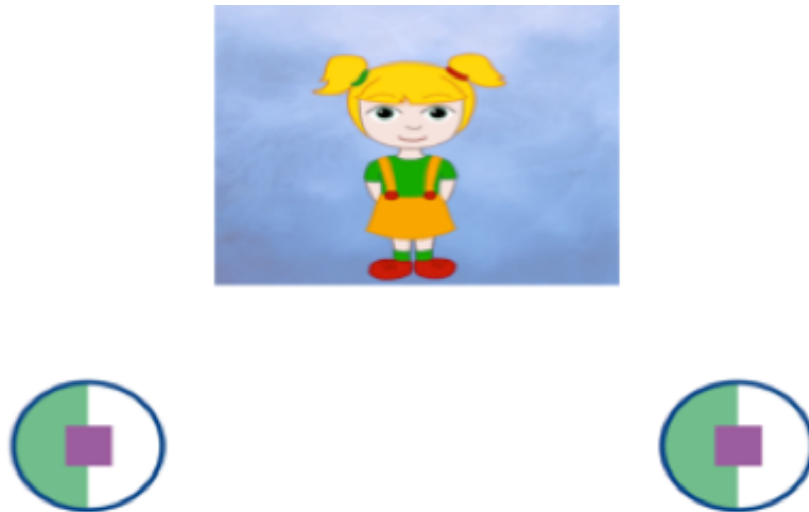


Figure 2.2. Visual configuration appearing in the four music perception tasks (shapes and colours differ among trials).

It is important to note that *Audie’s test* (Gordon, 1989) being the only published test suitable for this age group was piloted in the present investigation ($n = 10$) in parallel to the aforementioned tasks. An observation of children’s manner of responding to the task however, revealed a proneness to inattention and difficulty in maintaining interest (e.g., children often initiated conversations during the task). Furthermore, some of the children who exhibited good performance in the computerized odd-one-out task created for this study, responded randomly to *Audie’s test* (i.e., 5/10 correct). Given that *audiation* is a concept that has not been empirically tested, there is a possibility that contrary to Gordon’s prediction, this task requires children to hold a melody in memory across 10 trials and compare it to new stimuli thereby imposing a significant cognitive

load on young children, causing their attention to wane. This assumption can be corroborated by empirical research suggesting that the introduction of new tonal stimuli may mask recall of previously introduced tones and melodies (Allen, 2013; Deutsch, 1970; Massaro, 1970)

Design of stimuli

In the melody, rhythm and tempo perception tasks, computer-generated melodies composed by the author were used as stimuli. The piano sound from Garageband software was used due to its familiarity to most listeners of this age group and for its clear and brisk timbre. Individual pitches (pure tones) were used in the pitch task. During piloting, different versions of the stimuli in each task were presented to the children and approximately 5 to 10 children were tested on each version. This was done to ensure that the stimuli constructed would be neither too easy nor too difficult for the children, in other words, to ensure that the stimuli in each task would be sensitive enough to identify individual differences. More specifically, in each perception task we would expect most children to perform [a] above chance i.e., respond correctly to more than 50% of the trials and [b] the majority of children (60-70%) to respond correctly to 50% to 90% of the trials while a smaller number of children (10 to 20%) should respond correctly to >90% of the trials. This calculation was based on score distributions of several standardized subtests of the Wechsler Preschool and Primary Scale of Intelligence IV (WPPSI-IV, Wechsler, 2012) where the theoretical values of the normal distribution (i.e., percentile ranks) can be used to calculate the proportion of children scoring at different levels. Note that this was a rough calculation used in the pilot phase with the aim of determining test sensitivity based on very small samples. This calculation took into account the need to ensure that the children scored above chance in the tasks. Therefore only distributions of subtests where the majority of scores (80%) was above the .50 cut off representing chance performance were examined.

Final sets of stimuli for all music perception tasks are available in Appendix B.

Pitch perception stimuli. Ten stimuli were created based on previous pitch perception tasks for adults, young children and infants (Law and Zentner, 2012; Maxon & Hochberg, 1982; Olsho, 1982; 1984). The stimuli were sinusoids, or pure tones generated using the *Audacity* software. Pure rather than complex tones were used because pitch changes in complex tones can be perceived as a result of harmonics rather

than fundamental frequency (Licklider, 1954). Following Maxon and Hochberg's (1982) experiment with 4-year-old children, the duration of the pure tones was 400ms with a 25ms linear onset and offset ramp. The standard stimulus was 1000 Hz. This frequency was chosen based on previous work with infants indicating that discrimination ability is superior for high rather than low frequencies (Olsho, 1984). Furthermore, it has been used as a reference frequency in a number of experiments both with children (e.g., Agnew, Dorn, & Eden, 2004; Bobin-Bègue & Provasi, 2005; Thomson et al., 1999) and with adults (e.g., Paraskevopoulos, Kuchenbuch, Herholz, & Pantev, 2012; Tillmann, Janata, & Bharucha, 2003; Weiss, Granot, & Ahissar, 2014). Comparison stimuli differed in frequency (lower or higher) and were pivoted around 1000 Hz. Fifty per cent of the comparison stimuli were at a lower pitch, while 50% of the comparison stimuli were at a higher pitch compared to the standard stimulus. The first comparison stimulus represented the easiest trial and differed from the standard by 120 Hz while the difference between comparison and standard stimuli in the remaining nine trials ranged from 60 Hz to 12 Hz (the difference decreased across nine stimuli). Three training trials preceded the task where comparison stimuli differed by 200 Hz from the standard stimulus. This range of differences in pitch height represented a middle ground between a difference threshold range of 6 to 57 Hz for infants (Olsho, 1984; note that infants were tested with implicit head-turn procedures that are more sensitive in tapping perception) a threshold range of 25 to 64 Hz in 5-year-old children (Thomson et al., 1999) and a threshold of 12 Hz for 4-year-old children (Maxon & Hochberg, 1982). Adult levels of pitch discrimination can range from differences of 7 to 12Hz (Law & Zentner, 2012).

Thirteen children (7 girls, ages ranged from 3 years 6 months to 4 years 9 months) tested with this set of stimuli produced variability in their scores (nine children scored between 6 and 8 out of 10, two scored ≥ 9 out of 10 and three children scored ≤ 5 out of 10), suggesting that this set of stimuli is sensitive enough to differentiate between young children with different levels of pitch discrimination ability. Interestingly, 4 out of 13 children who failed to detect the easiest difference (120Hz) were at the lower end of the score distribution (≤ 6).

Melody perception stimuli. Twelve melodies were composed by the author for the melody discrimination task. Melodies were 3 to 5 tones long ranging from 1 to 3 seconds in overall duration. To make stimuli more engaging, each melody was

originally composed in C major but was then transposed into a different musical key (all major scales were used). Melodies were generated at a tempo of 140bpm, which is close to the spontaneous motor tempo (i.e., manual tapping task at the most comfortable tempo) of children in this age group (Gérard and Rosenfeld, 1995; Provasi & Bobin-Bègue, 2003). This is thought to coincide with an optimal sensitivity zone or referent period where processing of musical intervals becomes more accurate (Jones, 1976; Jones & Boltz, 1989).

Differences to be detected in the comparison stimuli consisted of one-tone changes. Difficulty was manipulated across two levels: [a] the length of the melodies (stimuli included six 3- and six 5-note melodies) and [b] changes in comparison stimuli were either contour-violating or contour-preserving. This was based on previous work showing that 4- to 6-year-old children can more readily identify contour-violating compared to contour-preserving transformations in short melodies (Morrongiello et al., 1985). Because children of this age might have acquired differential levels of key membership (i.e., understanding which notes belong in a key and which do not) and implicit harmonic knowledge (i.e., understanding which notes are more likely to follow others in a musical key; see Corrigan & Trainor, 2013) and to avoid any possibility that changes are more salient for some children due to out-of-key or out-of-harmony violations, all changes were kept within the key and harmony of the standard melody.

Another issue of concern was the position of changed tones within the melody. Research findings regarding the role of the position of tones in memory retention has been inconclusive, with some adult studies suggesting that initial and final tones are easier to remember than middle tones (Ortmann, 1926; Williams, 1975; Silverman, 2010) and other research demonstrating that memory in both children and adults is superior for final compared to initial tones (Bentley, 1966; Ross, Olson, Marks, & Gore, 2004; Siegel, 1974). Overall, it appears that the final position is clearly advantageous for memory retention, whereas it is less clear whether memory is facilitated for the first tone of a melody. Since changes in the last tone would interfere with the tonality of the sequence, changes in comparison melodies were limited to one tone in the middle of the melody (i.e., 2nd tone in 3-note melodies and 2nd, 3rd or 4th tone in the 5-note melodies).

Pitch interval changes ranged from 3 to 12 semitones and included both upward and downward changes. The average pitch interval changes were equivalent across 3- and 5-note melodies with a mean of 6.5 (range: 3-12) and 6.2 (range: 3-12) semitones respectively. Average pitch interval changes were, however, different between contour-

violating (mean of 9.3 and range of 8-12 semitones) and contour-preserving stimuli (mean of 3.8 and range of 3 to 5 semitones). Out of six children tested on the set of stimuli (5 boys, ages ranged from 3 years 5 months to 4 years 2 months), one child had very good performance (identified >90% of trials correctly), four identified 60% to 80% of the trials correctly and one child exhibited poor performance (<50%), suggesting that the stimuli might be sensitive in identifying different levels of melody discrimination ability.

Rhythm perception stimuli. The rhythm perception stimuli were created based on the Montreal Battery of Evaluation of Musical Abilities (MBEMA) (Peretz et al., 2013) for 6- to 8-year-old children. The same melodies as the melody discrimination task were used in this task. Differences to be detected in the comparison stimuli consisted of changes in the duration of adjacent tones. This manipulation altered the rhythmic grouping of the comparison melody while preserving the number of notes, overall duration and meter of the standard melody (see also Peretz et al., 2013). Difficulty of the stimuli was manipulated across three levels: [a] the length of the melodies (as in the melody discrimination task), [b] by changing duration of either two or three tones in a sequence and [c] changes in duration occurred either on the downbeat (easy trials, 50% of stimuli) or on the upbeat (more difficult trials, 50% of stimuli) of the melody's meter.

Out of the five children tested on this version of the stimuli (two boys, ages ranged from 3 years 7 months to 4 years 8 months), one child had very high performance (identified >90% of trials correctly), three children identified 60% -80% of the trials correctly and one child exhibited low performance (50%). This suggested that this set of stimuli might be sensitive in identifying variability in rhythm discrimination ability.

Tempo perception stimuli. Ten 4-note melodies were composed by the author for the tempo discrimination task. Four, rather than 3-note melodies (as in part of the rhythm and melody discrimination tasks) were used to ensure that the children adequately registered the tempo of each melody. All melodies were composed in the key of C major but were then transposed into different musical keys to make the stimuli more engaging (10 major scales were used). The difficulty level of this task was manipulated by varying the degree of the differences in tempo between the standard and the comparison stimulus. In other words, all standard stimuli were 100bpm whereas comparison stimuli were either slower or faster, with differences in tempo rates

decreasing linearly. The rate of 100bpm for the standard stimuli was chosen based on previous experiments showing that this is the optimal sensitivity zone for tempo discrimination in both infants (Baruch & Drake, 1997) and adults (Baruch, Panissal-Vieu & Drake, 2004). Furthermore, the only study that has so far explored tempo discrimination thresholds in children of 3- and 4-years of age has used 100bpm as a reference against which discrimination thresholds were estimated (Bobin-Bègue & Provasi, 2005). This is a very useful reference for the creation of the current task, given that it provides a guide for determining tempo differences in the comparison stimuli. According to the results of this study, an absolute difference of > 20 bpm can readily be detected by the majority of children between 3 and 4 years of age (both 3- and 4-year-olds performed above chance in detecting this difference) but children's success rates decreased with increasing difficulty (i.e., as differences in tempo decrease). Furthermore, 3-year-old children performed at chance in detecting an absolute difference of 15bpm but were above chance performance in detecting a 25bpm difference (Bobin-Bègue & Provasi, 2005). Based on these results, a first draft of stimuli was created where the differences in comparison stimuli ranged from 25bpm to 8bpm, revolving around a standard tempo of 100bpm. The rationale was that a set of stimuli with differences close to the discrimination threshold for this age group would efficiently identify variability in tempo discrimination ability.

The first draft of stimuli was tested on five children (4 girls, ages ranged from 3 years 7 months to 4 years 4 months). Their performance ranged from 30% to 60% correct (3 out of 5 children performed $\leq 50\%$) suggesting that this set might have been too challenging for children of this age group. Another set of stimuli was then created with differences in tempo between standard and comparison stimuli ranging from 18 to 50bpm. Seven children were tested in this version of the stimuli (1 girl, ages ranged from 3 years 5 months to 4 years 8 months) with 4 out of 7 children performing at chance or below ($\leq 50\%$) while no child responded correctly to 90% of the trials or above. This suggested that tempo discrimination in these groups of children might not follow the same thresholds as in the Bobin-Bègue & Provasi (2005) study, presumably because of differences in the nature of the tasks. Their task differed in the following ways: [a] the stimuli used were 10-tone sequences of identical tones rather than melodies, [b] each trial presented an individual sequence which was either faster or slower than 100bpm and the child had to respond by pressing the left or the right button. The left button had the picture of a rabbit attached to it representing "fast" sequences,

whereas the picture of a tortoise on the right button represented the “slow” sequences. Although creating a task similar to this for the current study would have allowed direct comparisons in tempo discrimination performance, it was deemed necessary that all musical perception tasks had an identical format to avoid burdening the children with additional training sessions.

Taking into account the pilot exploration described above, suggesting that tempo differences between 50 and 18bpm might still be challenging for young children, a final set of stimuli was created with differences in tempo ranging from 70bpm to 25bpm (pivoting around a standard tempo of 100bpm). Furthermore, trials with fast and slow comparison stimuli were presented in two separate blocks with two training trials preceding each block. This version of the stimuli was tested with six children (3 girls, ages ranged from 3 years 8 months to 4 years 4 months). One child had very high performance (identified >90% of trials correctly), 4 children identified 60% to 80% of the trials correctly and one child exhibited low performance (<50%). These results suggest that this set of stimuli achieved sufficient sensitivity in identifying variability in tempo discrimination ability.

2.2.2.2. Design of music production tasks.

Song production: For the evaluation of song production children were asked to sing a popular children’s song (“Twinkle Twinkle Little Star”) along with the voice of the experimenter that was pre-recorded and played through a portable JBL speaker⁹ (see Appendix B for a copy of the recording). This singing task was based on a review of the research on young children’s singing development, which implies that most children by the age of 3 and 4 are capable of integrating words, rhythm and pitch to sing a taught song, although not necessarily accurately (Dowling, 1999; Miyamoto, 2007; Moog, 1976). It was also inspired by Verney (2013) who, using a similar task to assess singing in 4- and 5-year-old children, had observed that young children felt more comfortable singing along to a recording. Furthermore previous research has demonstrated that developing rapport is desirable when assessing young children (Flowers & Dunne-Sousa, 1990; Verney, 2013). In the present study this was achieved in two ways: [a] the experimenter spent two days interacting with the children in their classroom before testing began and, [b] production tasks were always administered last; this allowed for

⁹ Please note that the instrumental part of the recording was taken from Verney (2013).

the children to spend time with the experimenter across 4 to 5 sessions before the singing session took place. Musical arrangement/accompaniment to the sung voice was taken from Verney (2013) and adjusted for the needs of the current research (tempo was adjusted to 100bpm). This tempo rate was chosen based on two observations during piloting of the task at three different tempo rates (80, 100 and 120bpm): [a] the faster tempi created more excitement for the children and they were more likely to perform the task and [b] in some cases the fast tempo (120bpm) made it more difficult for the children to remember and produce the lyrics, therefore slightly hindering their performance. Using the software *Audacity* and a Zoom H4n audio interface the child's voice was recorded on a MacBook Pro laptop while the song played through the speaker was re-recorded in a separate audio channel. This was necessary in order to avoid any latency problems associated with different types of recording and to facilitate data analysis.

Synchronization: The ability to tap along to a tempo was assessed with a synchronization measure. In this task, children were asked to tap along to two tempi (120bpm and 100bpm) across two trials. The beat (heard as metronome clicks) was played by an animated avatar (a teddy bear called Floyd, see Figure 2.3) on a computer screen. As with the "Maggie" character in the music perception tasks, animator Eleonora Quario (Middlesex Art & Design student) was recruited for the creation and animation of the Floyd character. The specific tempi were chosen based on previous work suggesting that preschool children synchronize with greater ease in faster tempi ranging from 100 to 150bpm (Provasi & Bobin-Bègue, 2003; Verney, 2013). As each child has a unique preference and ability that might not be accurately represented if a specific tempo is arbitrarily chosen, calculating the mean between two tapping rates was thought to be the most accurate way of reflecting the participants' performance (also based on Woodruff-Carr et al., 2014).

As in the song production task, the sound of the metronome that the children were asked to tap along to was re-recorded in a separate channel in *Audacity* to avoid any latency problems when comparing the standard tempo to the one produced by the child. Children's tapping was recorded using a custom contact microphone that was inserted inside a toy drum.



Figure 2.3. Animation of teddy bear (Floyd) appearing in the synchronization task (see Appendix B for videos as they were presented to children).

2.2.2.3. Analyses of music production tasks

Song production. Two independent raters (the experimenter and a musician working with young children) evaluated the performance of the children. For the song task, evaluation was based on the combination of two rating scales developed by Welch (*A revised model of vocal pitch-matching development*; 1998) and Rutkowski (*Singing Voice Development Measure*; 1997) (Welch, 2006)¹⁰ that involved identifying the specific pitch range produced by the child and comparing it to the recorded song. Pitch range was identified using the plot spectrum function in *Audacity* that gives precise information about pitch spectrum. In concert with the second rater, the Rutkowski (1997) scale was slightly adjusted to include an extra category that proved to be useful in the evaluation of the sample¹¹. Ratings on the two scales were summed to provide a score out of 10. A mean score of the two raters' evaluations was calculated and entered in all subsequent analyses.

Synchronization task. Of the 28 taps produced by the child accompanying the metronome, the first eight were removed from the analysis as the child was considered

¹⁰ Both of these rating scales can be found in Welch (2006).

¹¹ Extra category that was added by the author (between categories 2 and 3 of the Welch scale; Welch, 2006): "Melodic shape exists and follows the contour of the original. There is some variability in pitch not necessarily accurate but following the correct contour."

to be entraining/adjusting to the beat. The onsets of the last 20 taps that were subsequently used in the analysis were identified using a custom Matlab script originally devised by Goldsmith's University PhD student Jason Jiri Musil and implemented in collaboration with Nicolas Faruggia (University of Brest, <https://fr.linkedin.com/in/nicolasfarrugia>). The script initially produced three graphs (see Figure 2.4): [a] The 20 valid metronome clicks against which the performance of each individual was tested, [b] each participant's detected taps and, [c] the metronome clicks presented against the participant's detected taps. The graph also provided a summary of the parameters used to detect each participant's taps: *loudness threshold* and *refractory period*. Any drum hit that exceeded a certain loudness threshold (this was adjusted based on each participant's tapping volume) was considered to be a tap and was included in subsequent analyses. The script also excluded taps that occurred within a minimum refractory period. This was necessary because the contact microphone often detects touches or scratches on the surface of the drum immediately preceding or following the child's taps that can be mistaken for actual taps. To ensure that the script detected the correct number of taps for each participant, all recordings were replayed and compared against the data graph initially produced by Matlab. If an error occurred in any given participant's data (either an extra tap was detected or a tap was missing), loudness and refractory period thresholds were readjusted for this particular participant until the number and position of taps was accurately detected.

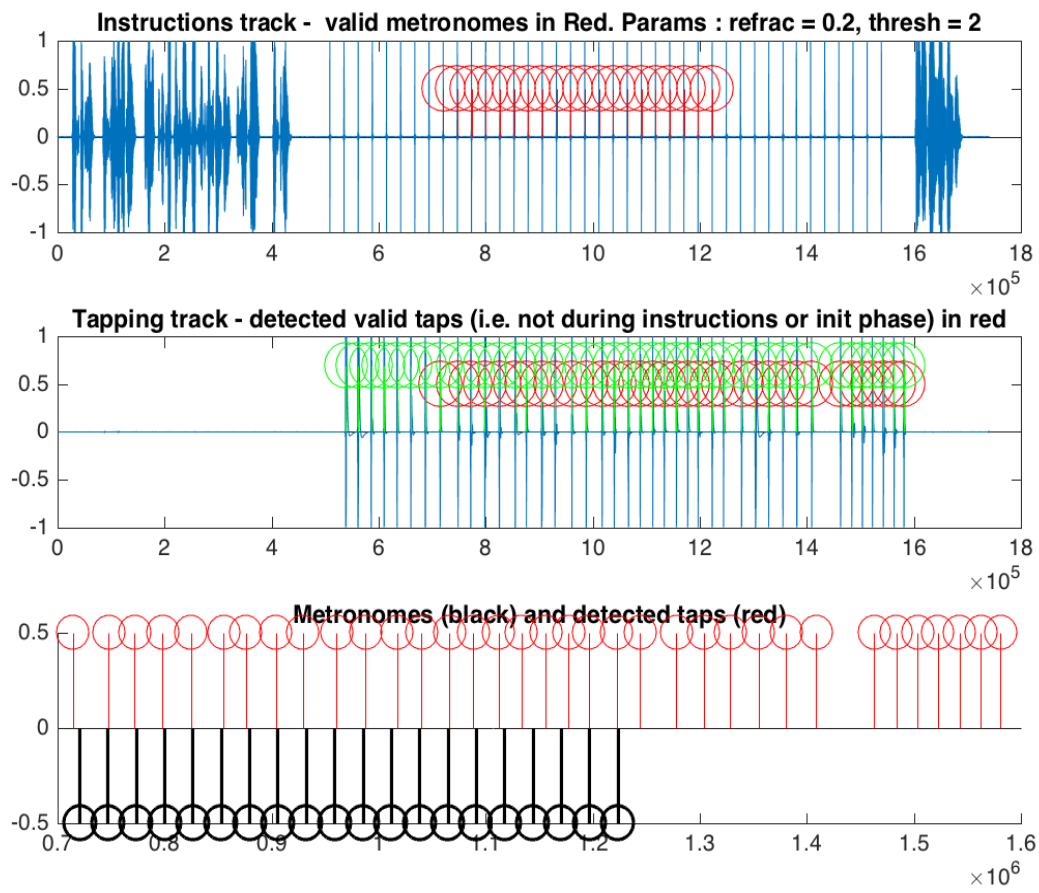


Figure 2.4. Graphs produced by Matlab representing: [a] The 20 valid metronome clicks [b] each participant’s detected taps, [c] the 20 metronome clicks presented against the participant’s detected taps.

Analysis of synchronization performance using linear and circular statistics

The standard method used to evaluate synchronization performance in adult tapping experiments is to align the metronome clicks and the participants’ taps to a linear time scale, and calculate the relative deviation of each response tap from the corresponding metronome click. Finally, the mean and variance of all deviations or asynchronies is calculated for each trial and entered into the statistical analyses (Kirschner & Tomasello, 2009). Therefore, linear analysis of tapping relies on participants producing one tap per metronome click. This is not the case with young children whose performance is inherently more diverse (Kirschner & Tomasello, 2009; Woodruff-Carr et al, 2014; Verney, 2009). With young children, it is almost impossible to couple each tap with a corresponding metronome click on a one-to-one basis (Kirschner & Tomasello, 2009). Circular statistics calculates accuracy and consistency

of synchronization to a beat without taking into account whether a given tap precedes or follows the metronome click and has therefore been used successfully in the analysis of young children's synchronization data (Kirschner & Tomasello, 2009; Woodruff-Carr et al, 2014; Verney, 2013). Circular statistics has also been used in the adult literature as it gives more accurate results in various groups where one-to-one correspondence of taps and metronome clicks can be challenging (e.g., patients with motor disorders; Bella et al., 2015)

In circular statistics the series of a group or Inter Stimulus Intervals (ISI's) is labeled as 'phase' or 'trial'. As mentioned earlier, in this study all the trials consisted of 20 beats with each child taking part in two trials with rates of 100bpm (600ms) and 120bpm (500ms). Circular statistics transforms each ISI into a unit circle, with the metronome clicks aligned at 0 (or 360) degrees. The relative time at which a specific response tap occurs within a given ISI can then be represented by a point on the circumference of the circle, by converting a positive (delayed) or negative (anticipated) asynchrony tap into degrees or radians. For example:

- The pulse rate has an ISI of 600ms.
- The participant taps 100ms after the beat
- This score is then converted into degrees (60°) by dividing the positive score of 100 by the trial's tempo (600ms) and multiplying it by 360 ($100 \div 600 \times 360 = 60$).
- Because the circumference of the circle is taken to be 2 radians then the response will be at 0.5 radians. (Example taken from Verney, 2013):

Absolute accuracy is at 0 degrees, taps at 359 degrees and at 1 degree are very close to accuracy while the greatest asynchrony is at 180 degrees from the point of absolute accuracy (see Figure 2.5). In order to assess the mean and variance of asynchronies for the tapping responses in a given trial the direction of points on the circumference of the circle needs to be summarized. This is done by calculating the mean vector rate. This consists of two non-parametric components: the mean direction θ (theta) that is analogous to the mean asynchrony in linear statistics, and R, the mean resultant length. R varies between 0 and 1 and is inversely related to the variance of asynchronies in linear statistics. An R of 1 implies that responses are perfectly synchronized with the metronome click. Therefore, while the mean direction θ reflects accuracy of phase (how close to the metronome click the child tapped) the mean vector length R is a

measure of consistency (i.e., a child can tap slightly out of phase with respect to the metronome click but still be consistent with respect to their own taps). Tapping responses that remain more or less stable throughout the trial result in a unimodal distribution of points on the circle represented by a high R value (see Figure 2.5 for an example of a unimodal distribution) whereas a uniform distribution of points reflects a high variance of asynchronies. A high variance of asynchronies is represented by a small R and indicates low synchronization accuracy (see Figure 2.5 for an example of a uniform distribution).

For this study, both linear and circular measures were calculated using a custom Matlab script originally devised by Simone Dalla Bella (Université de Montpellier, EuroMov Laboratory) and implemented with the help of Nicolas Faruggia. The following measures were calculated for each participant and for each trial (40 participants x 2 trials = 80 cases for each of the following measures):

- [a] **Coefficient of variation of the participants' inter-tapping intervals (CV-ITI; linear measure):** This is a standardized measure that indicates the variability of inter-tapping intervals (ITI). It is calculated by dividing the standard deviation by the mean of the ITI's.
- [b] **Mean relative asynchrony (linear measure):** the average of all deviations of the taps from the corresponding metronome clicks (asynchronies).
- [c] **Mean absolute asynchrony (linear measure):** a positive measure of the average of deviations from the metronome clicks.
- [d] **Standard error of asynchronies (SEA) (linear measure):** The SEA is used as a measure of the variance of the asynchronies and is analogous to the vector length R in circular statistics. Smaller SEA values indicate better synchronization performance.
- [e] **Vector direction θ (circular measure):** θ is analogous to the mean asynchrony in linear statistics.
- [f] **Vector length R (circular measure):** R varies between 0 and 1 and is inversely related to variance in asynchronies in linear statistics.
- [g] **Rayleigh p value:** Rayleigh's test tests the null hypothesis of circular uniformity of data points around the unit circle (no synchronization) against the alternative hypothesis of a unimodal distribution of data points (synchronization) (Fisher, 1993). A Rayleigh's p value of $p < .05$ (R is large) indicates that the null hypothesis can be rejected, thus the participant is synchronizing.

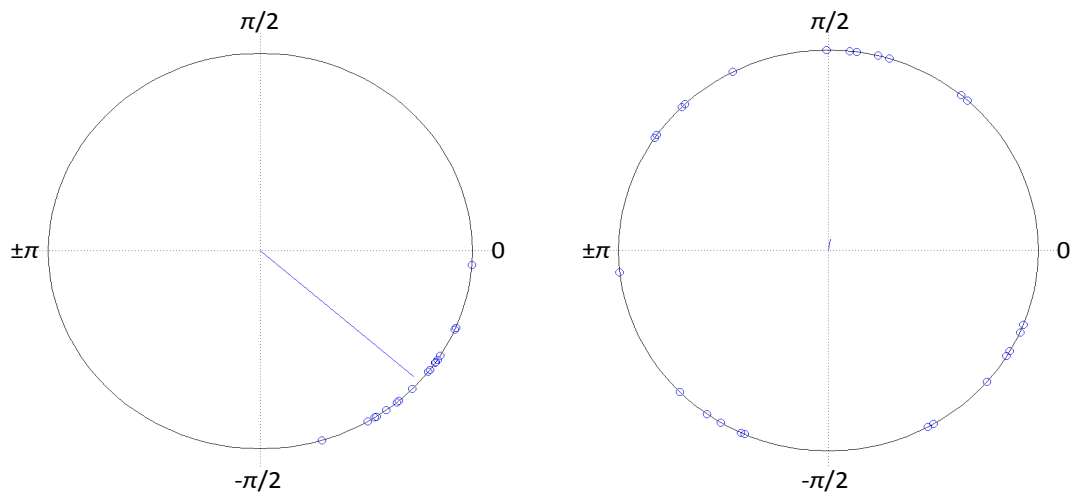


Figure 2.5. Left: example of a unimodal distribution of points on the circle represented by a high R value = high synchronization accuracy, Right: example of a uniform distribution of points on the circle represented by a low R value = low synchronization accuracy.

Selection of synchronization measure for further analyses using a linear model

The next step was to select the most suitable measure to enter into subsequent analyses. For each participant, an average score between the two trials (120bpm and 100bpm) was calculated for each measure. First a correlation matrix was produced for all continuous variables (i.e., all variables explained above except Rayleigh’s test) to examine patterns of relationships between measures. As can be seen in Table 2.1 most of the synchronization measures present significant correlations with two or more other measures, while the SEA is significantly associated with the greatest number of measures.

In order to select the most appropriate measure we created a linear model where all synchronization measures were entered as predictors and phonological awareness (see section 2.2.3 for details about how phonological awareness was measured and scored) was entered as a dependent variable. Manual backward elimination of variables was then used to select the synchronization measure that best predicted phonological awareness in our sample (see section 2.2.3 for a more detailed description of this

method). This rationale was based on previous studies with young children that have suggested a strong link between synchronization ability and the development of phonological awareness (Woodruff-Carr et al, 2014; Verney, 2013). This link is supported by the Temporal Sampling Framework (Goswami, 2011), which posits that analogies between musical meter and speech perception may arise from the fact that oscillations of networks of neurons entrain to an input rhythm. It was therefore expected that synchronization measures should predict phonological awareness in the current sample of 3- and 4-year-old children. However, as both linear and circular measures have been used in the research literature without providing a clear indication of which measure is the more appropriate, this investigation was deemed necessary.

Statistical analyses were conducted using R software. As a first step, all synchronization variables (CV-ITI, Mean relative asynchrony, Mean absolute asynchrony, SEA, Vector length R, Rayleigh's test) were entered into the model and multiple regression was conducted to examine which variables significantly predicted phonological awareness. Rayleigh's test score was entered as a categorical variable with two values: "synchronizer" for children who synchronized at both 120bpm and 100bpm rates and "non-synchronizer" for children that did not synchronize at both rates. Results showed that only the Standard Error of Asynchronies (SEA) significantly predicted phonological awareness ($Beta = -1.26$, $t(28) = -2.39$, $p < .05$) while all other variables did not [$F(1, 27) = 2.67$, $p < .05$, $R^2 = .37$]. Remaining variables were then eliminated iteratively. In the final model, only the SAE significantly predicted phonological awareness ($Beta = -0.47$, $t(32) = -3.01$, $p < .005$). This final model explained a significant amount of the variance in phonological awareness [$F(1, 32) = 9.10$, $p < .005$, $R^2 = .22$] and showed a good model fit ($AIC = -17.45$) compared to the first model where all variables were present ($AIC = -14.81$). Therefore the SAE was entered in all subsequent analyses as a measure of synchronization.

Residual plots were visually evaluated to test whether the assumptions of normal distribution, linearity and heteroscedasticity for the model were met. No obvious patterns were observed, suggesting that the assumptions of linearity and heteroscedasticity were met. Moreover, residuals did not appear to significantly deviate from a straight line therefore meeting the assumption of normal distribution.

Table 2.1. Pearson R correlation coefficients between different synchronization measures.

	CV-ITI	θ	R	MAA	MRA	SEA
CV-ITI	-	-.09	.48**	.45*	.08	.46*
θ	-.09	-	-.04	-.13	.90***	.16
R	.48**	-.04	-	.79**	-.31	-.93**
MAA	.45*	-.13	.79**	-	.23	.81**
MRA	.08	.90***	-.31	.23	-	.44**
SEA	.46*	.16	-.93**	.81**	.44**	-

CV-ITI = Coefficient of variation of inter-tapping intervals, θ = Vector direction, R = Vector length, MAA = Mean absolute asynchrony, MRA = Mean relative asynchrony, SEA = Standard error of asynchronies

Table 2.2. Summary of music perception and production tasks.

Musical tasks	Equipment	Stimuli	Participant task	No of trials	Scoring
Pitch Perception	Computer	Sinusoids	Identify which of two pitches is the same as the standard	10	% correct
Melody Perception	Computer	Melodies	Identify which of two melodies is the same as the standard	12	% correct
Tempo Perception	Computer	Melodies	Identify which of two melodies is the same as the standard	10	% correct
Rhythm Perception	Computer	Melodies	Identify which of two melodies is the same as the standard	12	% correct
Song Production	Computer, microphone	Song recording	Sing along to recording of <i>Twinkle Twinkle</i>	1	Scored by two independent raters
Synchronization	Computer, drum, contact mic	Metronome clicks	Tap along to metronome clicks	100, 120 bpm	Circular and linear statistics

2.2.3. Linguistic and cognitive measures

Language grammar. The *Language Structure Index* from the *Clinical Evaluation of Language Fundamentals - Preschool-2* (CELF-Preschool-2; Wiig, Secord, & Semel, 2004) was administered to assess language structure. The CELF-Preschool-2 evaluates a range of language skills in 3 to 6 year old children and has been standardized in the UK. The *Language Structure Index* (LSI) consists of three subtests:

Sentence Structure → In this task the experimenter reads out sentences of increasing structural complexity (22 trials) and children are required to point to the one of four pictures that corresponds to the sentence. A score of 1 is granted for each correct answer. Correct trials are summed to produce an overall raw score.

Word structure → In this task pairs of pictures are presented to the child in each trial (24 trials). The experimenter reads out a sentence that describes the first picture while the child is required to complete the sentence that describes the second. For example the experimenter says: “*Here Betty is giving a present to her (first picture), Here Betty is giving a present to ___ (the child has to provide the word him which corresponds to the second picture)*”. A score of 1 is granted for each correct answer and correct trials are added up to provide an overall raw score.

Recalling Sentences → In this task the experimenter reads out sentences of increasing complexity across 13 trials while the child is required to repeat them verbatim. A score of 3 is given for each correct verbatim repetition, a score of 2 is given if the child makes 1 error, a score of 1 is given if the child makes 2 to 3 errors and a score of 0 corresponds to ≥ 4 errors. Scores in each trial are added up to provide an overall raw score. The *Recalling sentences* subtest has also been used as a measure of verbal memory (Woodruff-Carr et al., 2014).

Scaled scores ($M = 10$, $SD = 3$) for each subtest were used in all analyses. A total score of language grammar is derived from summing the scaled scores of these three subtests. Standardized scores for the three subtests and the LSI were computed and used in all analyses.

Phonological awareness. Two subtests from the CELF-Preschool-2 were used to assess *word/syllable blending* and *sentence/syllable segmentation*. Two tests of rhyme and alliteration awareness – the *Phonological Oddity - Rhyme* and the *Phonological Oddity - Alliteration* task (Maclean, Bryant, & Bradley, 1987) - replaced the rest of the phonological awareness subtests of the CELF-Preschool-2 (*Rhyme*

perception and *Rhyme generation*), as during pilot testing these were deemed to be inappropriate for the younger, as well as some of the older children (note that there are no norms for 3-year-old children for these specific tasks in the CELF-Preschool-2).

Word/Syllable Blending. In the word-blending section of this task (4 trials) the experimenter reads aloud two words (e.g., *bed-room*) and the child is required to blend them together and say the word that they create. In the syllable-blending section (4 trials) the experimenter reads two parts of a word. A score of 1 is granted for each correct trial.

Sentence/Syllable Segmentation. In the sentence segmentation section of this task (4 trials) the child is required to repeat a sentence spoken by the experimenter and simultaneously clap for each word in the sentence. In the syllable segmentation (4 trials) section of the task the child is required to repeat a word and simultaneously clap for each syllable. A score of 1 is given for each correct trial.

Phonological Oddity – Rhyme. In this task the experimenter shows three pictures to the child while simultaneously reading the words that these depict. Two of the words in each trial rhyme, while one does not (e.g., *sail-nail-boot*). The child is required to point to the picture that represents the odd-one-out. The concept of rhyming was explained to the participants before the task and two practice trials were administered to ensure that the child understood the instructions.

Phonological Oddity – Alliteration. As in the rhyming task, the experimenter shows three pictures to the child while simultaneously reading the words that these depict. Two of the words in each trial alliterate (begin with the same sound) while one does not (e.g., *band-shell-shop*). The child is required to point to the picture that represents the odd-one-out. The concept of alliteration was explained to the participants before the task and two practice trials were administered to ensure that the child understood the instructions.

In order to derive a reliable composite score for phonological awareness and in absence of standardized scores, principal component analysis (PCA) was conducted on the four phonological awareness subtests using SPSS. The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis: KMO = .68 (acceptable according to Kaiser, 1974). Bartlett's test of sphericity, $\chi^2(6) = 33.1, p < .001$, indicated that correlations between variables were sufficiently large for PCA. One factor had an eigenvalue exceeding Kaiser's criterion of 1. All four subtests (*Phonological Oddity – Rhyme*, *Phonological Oddity – Alliteration* and *Word-Syllable Blending* and

Sentence/Syllable Segmentation) loaded adequately on to that factor, which explained 55.89% of the variance (loadings $\geq .39$). Therefore, factor scores for phonological awareness were used in subsequent analyses in addition to the separate subtests. Factor scores are considered to be reliable reflections of a participant's performance on a factor consisting of separate variables, as they take into account the relative importance of each variable to compute a composite score (Field, 2009). In SPSS, factor scores are calculated for each participant by using factor score coefficients in an equation (see example below). The factor scores are calculated using a regression method that adjusts the factor loadings to take into account the initial correlations between variables, thus stabilizing the variable variances (Field, 2009).

Example:

Phonological awareness Composite Score for any given participant = (0.301 x Word/Syllable Blending Raw Score) + (0.301 x Sentence/Syllable Segmentation Raw Score) + (0.353 x Phonological Oddity-Rhyme Raw Score) + (0.381 x Phonological Oddity-Alliteration Raw Score)

Memory and general ability. The *Digit Span* subtest from the British Ability Scales II (BAS, Elliott, 1996) was used to assess verbal memory (although this task is also influenced by auditory attention). In this task children are required to recall sequences of digits in the correct order. The sequences increase in length until the child fails to repeat all sequences within a block (each block includes 5 digit sequences of a certain length). A score of 1 is given for each correct trial. Correct trials are summed to provide the overall raw score.

The *Block Design* from the Wechsler Preschool and Primary Scale of Intelligence IV (WPPSI-IV, Wechsler, 2012)¹² was used as a proxy for non-verbal ability. Block design is primarily a measure of visual-spatial and organizational processing abilities, as well as nonverbal problem-solving skills. In this task, the child is presented with identical blocks with surfaces of solid red, surfaces of solid white, and surfaces that are half red and half white. Using an increasing number of these blocks, the child is required to reconstruct a pattern that the experimenter presents to them – first as a physical model, and then as a two-dimensional picture. The number of correct replications of the pattern constitutes the overall raw score for this test.

¹² This is designed for the age range 2 years 6 months – 7 years 7 months.

2.2.4. Procedure

All participants were tested during 6 or 7 individual sessions spread across 6 to 7 days, each lasting approximately 20 minutes. Number and duration of sessions depended on the child's individual characteristics such as attention span and mood on the given day. Testing for each participant was completed within 2 to 3 weeks of their first session. Individual sessions took place in specified quiet rooms in the participating nurseries. The first session included four practice trials of the music perception task format (see section 2.2.2.1) in order to determine whether the child understood the task. A child was excluded from the study if she/he did not meet the 3 out of 4 criterion in the first session. Order of administration was held constant for all children, alternating music and language tasks. However, the number of tasks completed in each session varied depending on the child's attention span and mood on the given day. The experimenter spent approximately two weekdays in classrooms playing with the children before testing, in order for the children to become acquainted with her and to feel comfortable. Before testing, parents were informed of the objectives of the study and the research procedure, and opt-out consents were handed out to allow parents to opt out if they wished.

The order of task administration was as follows: 1. Test Music Perception task, 2. BPVS, 3. Melody perception, 4. Sentence Structure, 6. Word structure, 7. Rhythm perception, 8. Expressive Vocabulary, 9. Pitch perception, 10. Recalling sentences, 11. Tempo perception, 12. Visual Memory (WPPSI), 13. Non-verbal intelligence (WPPSI), 14. Verbal intelligence (WPPSI), 15. Phonological awareness, 16. Tempo synchronization, 17. Rhythm production, 18. Song production.

2.3. Results

All data were analyzed using SPSS version 20.00 and R software environment (R Core Team, 2012).

A series of non-parametric comparisons (Mann-Whitney and Kolmogorov-Smirnoff) were then performed between monolingual ($n = 28$) and bilingual children ($n = 12$) to identify any differences in linguistic or cognitive performance resulting from bilingualism. Non-parametric tests were used to account for unequal sample sizes in the two groups. No statistically significant differences were found between monolingual and bilingual children in any of the tasks, thus one group including both monolingual and bilingual children was used for all subsequent analyses. Means and standard

deviations of participants' group performance in all linguistic and baseline cognitive tasks are presented in Table 2.3.

Table 2.3. Participants' performance in cognitive and linguistic tasks.

	Method of scoring	N	Min	Max	M	SD
BPVS	M = 100, SD = 15	40	86	129	107.80	10.03
CELF- LSI	M = 100, SD = 15	37	21	95	66.81	19.73
Phon Aw	Range of scores = 1-100	35	16.2	81.4	51.56	21.38
Block Design	Range of scores = 1-19	39	8	14	10.87	1.73
Digit Span	M = 50, SD = 10	38	22	92	69.63	20.16

BPVS = British Picture Vocabulary Scale, CELF-LSI = Clinical Evaluation of Language Fundamentals – Preschool – Language Structure Index, Phon Aw = phonological awareness composite score, M = mean, SD = standard deviation. Please note that N sizes differ, as 7 out of 40 children did not complete all the tasks included in the assessment (see section 2.2.1).

2.3.1 Exploring participants' performance in the musical tasks

A preliminary analysis was conducted to examine the possibility that either age or gender may influence performance in the musical tasks. To this end, a series of ANOVA were conducted with musical tasks as dependent variables and age group (3- and 4-year-olds) and gender as between-subjects factors. This series of analyses yielded no significant main effects of age group on any of the tasks, although the effect of age group on Tempo Perception approached significance [$F(1,36) = 3.80$, $p = .06$, $\eta^2 = .10$] with older children ($M = 7.7/10$, $SD = 1.30$) performing more accurately than younger ones ($M = 6.58/10$, $SD = 2.12$). For the remaining music perception and production tasks all F 's < 2.00 , all p 's $> .10$. No significant main effects of gender were observed on any of the tasks, except Song Production [$F(1,36) = 17.36$, $p < .001$, $\eta^2 = .35$], where girls ($M = 8.25/10$, $SD = 1.44$) performed significantly better than boys ($M = 5.70/10$, $SD = 2.10$) (for the remaining music perception and production tasks all F 's < 2.00 , all p 's $> .10$). No interactions between age group and gender were observed for any of the tasks (all F 's < 2.50 , all p 's $> .10$).

2.3.1.1. Musical perception tasks

To demonstrate that the children understood the procedure and were able to perform the music perception tasks, a series of t -test comparisons were conducted

comparing all participants' performance to chance (.50). Results showed that children did not give random responses in any of the tasks (see Table 2.4) clearly indicating that they were following the procedure. Next, a Kolmogorov-Smirnov's test was conducted to examine whether the scores in the performance tasks met the assumption of normal distribution. As shown in Table 2.4 scores in the Pitch, Tempo and Rhythm Perception tasks did not follow a normal distribution whereas the Melody Perception task met this assumption. To further explore the extent of non-normality of all the music perception tasks, Q-Q plots were generated and visually inspected (see Figure 2.6). Visual inspection of the Q-Q plots revealed moderate deviation from normality for the Rhythm and Tempo tasks. Furthermore, following the method suggested by Field (2009), *z*-scores for the values of skewness and kurtosis were calculated for each music perception task (see Table 2.4) and compared against the cut-off absolute value of 1.96. Skewness values were not significant for any of the musical perception tasks. However, Tempo Perception scores' distribution was slightly negatively skewed (skewness absolute value >1) suggesting that there was a build-up of high scores in this task. Finally, kurtosis values were not significant for any of the tasks. However, the kurtosis value for the Rhythm Perception task is close to the cut-off of -1.96, indicating that the distribution of scores in this task was relatively light-tailed.

To further explore the statistical properties of the scores' distributions, data were transformed into *z*-scores and screened for outliers. Three outliers above the absolute cut-off value of 1.96 were identified for the Pitch Perception task (two children exhibiting poor performance and one child exhibiting high performance in comparison to the mean) and one outlier was identified for the Tempo Perception task (one child performing poorly in comparison to the mean) indicating that deviation from normality in these tasks could be attributed to outliers. No outliers were identified for the Melody and Rhythm Perception tasks.

To test the assumption that deviation from normality in the Pitch and Tempo Perception tasks was a result of the outliers present in the data, the Kolmogorov-Smirnov's test was rerun for both those tasks after removing the outliers. Results indicated that both tasks still did not conform to the assumption of normality (Pitch Perception: $D(34)= 0.16$, $p < .05$; Tempo Perception: $D(36)= 0.18$, $p < .005$).

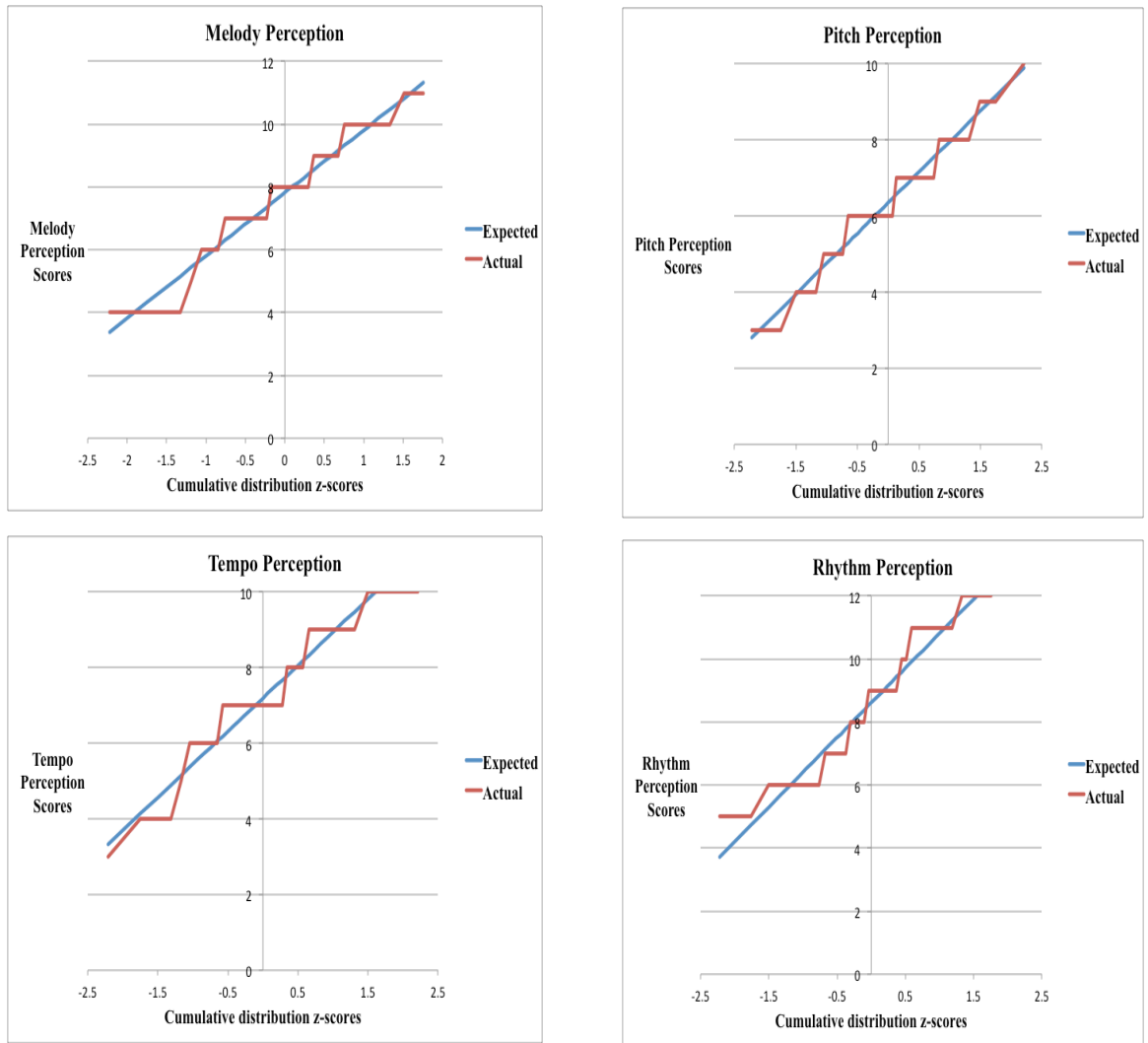


Figure 2.6. Q-Q plots for music perception tasks.

2.3.1.2. Music production tasks

As shown in Table 2.4 scores in the Song Production task met the assumption of normal distribution while the Kolmogorov-Smirnoff test for the Synchronization task was marginally significant (see Q-Q plots for music production tasks in Figure 2.7). As shown in Table 2.4 skewness and kurtosis of the scores' distributions for both tasks was not significant. However, the kurtosis value is above -1 for both tasks indicating that few extreme values were present in the Song Production and Synchronization data. Screening for outliers in the Song Production task identified one child who performed poorly in comparison to the mean (z -score = -2.09). No outliers were present in the Synchronization scores.

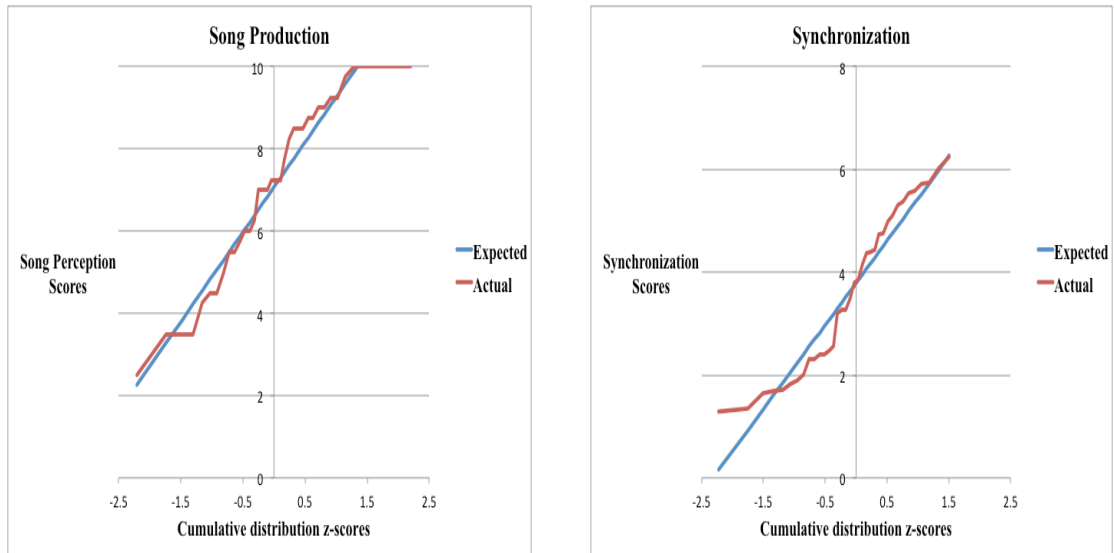


Figure 2.7. Q-Q plots for music perception tasks. Synchronization (standard error of asynchronies) is measured in seconds.

Table 2.4. Descriptives for musical abilities tasks, results of normality tests and comparison of task scores to random responses.

Task	Range of scores	<i>M</i>	<i>SD</i>	Comparisons between task and random scores (.50)	K-S test	Skewness	Kurtosis	
Perception				<i>t</i>	<i>p</i> <	<i>D(p)</i>		
Pitch	1 to 10	6.31	1.60	4.89	.001	.162(.024)	-.26	.10
Melody	1 to 12	7.72	1.98	5.60	.001	.131(.098)	.00	-.62
Tempo	1 to 10	7.37	1.76	7.36	.001	.186(.003)	-1.13	-.04
Rhythm	1 to 12	8.61	2.18	7.30	.001	.151(.024)	-.14	-1.70
Production								
Song	1 to 10	7.06	2.18	-	-	.134(.101)	-.97	-1.22
Synch (sec)	1.29-6.67	3.79	1.63	-	-	.143(.050)	.15	-1.80

Synch = Synchronization, *M* = Mean, *SD* = Standard Deviation, *K-S* = Kolmogorov-Smirnoff

In conclusion, both perception and production tasks did not present severe violations of skewness and kurtosis. Furthermore, children's performance on the music perception tasks was above chance, suggesting that they understood and performed the tasks adequately. To address the normality issues identified, the bootstrapping method was used for every subsequent test that relied on the assumption of normality.

Bootstrapping is a method for estimating the sampling distribution from a given sample of participants and it is a useful approach for circumventing violated assumptions and dealing with outliers in a dataset (Efron & Tibshirani, 1993; Field, 2009). The sampling distribution is estimated by deriving a number of smaller samples from a given dataset (the data are reinstated before a new sample is drawn), calculating statistics of interest (e.g. the mean) in each sample, and deriving a large number of samples (1000 is the default). The standard error of the statistic is estimated from the standard deviation of this sampling distribution, thus confidence intervals and significance tests can be computed (Field, 2009). For multiple regression models built in R the assumptions of normality, linearity and homoscedasticity were tested.

2.3.2. Bivariate and partial correlations between musical and linguistic tasks

Bivariate correlations were first performed between all musical and linguistic tasks to identify possible significant relationships between them. With respect to the associations between musical perception and production tasks (see Table 2.5), perception of tempo appears to be linked to the perception of melody, synchronization and rhythm perception. Melody perception is marginally associated with pitch perception ($p = 065$), rhythm perception ($p = 065$) and song production ($p = .056$), while song production is also associated with synchronization ability. As shown in Tables 2.6 and 2.7 a number of significant relationships were also observed between musical and linguistic measures. Specifically, tempo and rhythm perception and synchronization ability appear to be associated with phonological awareness. Rhythm perception is also significantly associated with one of the language grammar tasks (*Recalling Sentences*) while melody perception is significantly associated with one of the phonological awareness tasks (*Sentence/Syllable Segmentation*). Melody perception also showed a marginally significant association with the phonological awareness composite score ($p = 096$). Furthermore, song production appears to be marginally associated with the language grammar composite score ($p = 089$). Table 2.8 presents correlations between musical tasks, language composite scores and cognitive tests of general ability and memory.

Table 2.5. Bivariate correlations between musical abilities tasks.

	Perception				Production	
	Pitch	Tempi	Melody	Rhythm	Song	Synch
Perception						
Pitch	-	.09	.30 ¹	.18	.03	-.02
Tempi	.09	-	.44**	.32*	.27	-.36*
Melody	.30	.44**	-	.30 ¹	.33 ¹	-.13
Rhythm	.18	.32*	.30 ¹	-	.03	-.11
Production						
Song	.03	.27	.33 ¹	.03	-	-.41*
Synch	-.02	-.36*	-.13	-.11	-.41*	-

¹*marginally significant associations ($p < .1$), * $p < .05$, ** $p < .01$, *** $p < .001$. Negative correlation coefficients for the Synchronization task reflect the fact that smaller scores in the synchronization measure indicate better performance.*

Table 2.6. Bivariate correlations between musical tasks and subtests of phonological awareness and language structure.

Language tasks		Pitch	Tempi	Melody	Rhythm	Song	Synch
Grammar	SS	.16	.17	.27	.10	.19	.13
	WS	.09	.17	.35*	.02	.17	-.17
	RS	.25	.12	.37*	.33*	.12	-.15
Phon Aw	W/S	.15	.40*	.26	.36*	-.09	-.20
	S/S	.10	.41*	.41*	.31*	.04	-.36*
	Rh	-.27	.26	.17	.45**	.19	-.32*
	Alit	.09	.35*	.25	.67***	.21	-.38*

* $p < .05$, ** $p < .01$, *** $p < .001$, SS = Sentence Structure, WS = Word Structure, RS = Recalling Sentences, W/S = Word/Syllable Blending, S/S = Sentence/Syllable Segmentation, Rhyme = Phonological Oddity Rhyme, Alit = Phonological Oddity Aliteration

Table 2.7. Bivariate correlations between musical tasks and composite scores of phonological awareness and language grammar.

Musical tasks	Language Grammar	Phonological Awareness
	Total score	Total score
Pitch Perception	.09	.04
Tempo Perception	.23	.38*
Melody Perception	.43**	.29 ¹
Rhythm Perception	.24	.63***
Song Production	.29 ¹	.20
Synchronization	-.21	-.47**

¹marginally significant associations ($p < .1$), * $p < .05$, ** $p < .01$, *** $p < .001$

Table 2.8. Bivariate correlations between musical tasks and tests of non-verbal ability (WPPSI-Block Design) and verbal memory (Digit Span).

Musical tasks	WPPSI-Block Design	Digit Span
Pitch Perception	.14	.41**
Tempo Perception	.27	.16
Melody Perception	.18	.22
Rhythm Perception	.36*	.35*
Song Production	.23	.05
Synchronization	-.14	-.04
Language tasks		
Language Grammar	.54***	.58***
Phonological Awareness	.25	.56***

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

To ensure that any relationships between tasks are not driven by an underlying cognitive factor accounting for better performance in both linguistic and musical tasks, partial correlations were carried out between all musical and linguistic tasks while accounting for non-verbal intelligence and verbal ability composite measures (see Table 2.9).

With respect to the relationships between musical and linguistic tasks after non-verbal ability, verbal memory and age in months¹³ have been accounted for, the correlations between rhythm perception and phonological awareness (composite score), and synchronization ability and phonological awareness (composite score) remain significant, suggesting that these might be robust links independent of general cognitive ability. The correlation between melody perception and grammar also remains significant.

Table 2.9. Partial correlations between musical tasks and composite scores of phonological awareness and language grammar after non-verbal ability, verbal memory and age in months have been accounted for.

Musical tasks	Language Grammar	Phonological Awareness
	Total score	Total score
Pitch Perception	-.16	-.12
Tempo Perception	.08	.21
Melody Perception	.37*	.17
Rhythm Perception	-.11	.47**
Song Production	.24	.09
Synchronization	-.15	-.56***

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

2.3.3. Predicting linguistic abilities based on musical skills.

2.3.3.1. Statistical analyses

To investigate potential predictive relationships between musical and linguistic abilities, data were entered into two separate linear regression models with phonological awareness and language grammar as the dependent variables. In each model the measures of musical ability (Pitch, Rhythm, Tempo and Melody Perception, Song and Synchronization) were treated as predictors. Age and gender were also entered into the models in order to examine whether they contribute to the variance in linguistic abilities. In each case, the best-fitting and parsimonious model was selected via

¹³ Age-norms were only available for the language grammar tasks thus chronological age in months was also accounted for in the correlational analyses of the relationship between musical and linguistic tasks.

backward elimination of independent variables starting from the full model. All analyses were performed using *R* software. Gradual removal of variables was based on the Akaike Information Criterion (AIC) and the *p*-value. The AIC is a criterion of goodness of fit based on information theory that seeks the most parsimonious model with good fit to the data (Burnham & Anderson, 2002). The AIC is a comparative fit index and is meaningful only when two models are estimated and compared (lower values indicate a better fit; Burnham & Anderson, 2002). Therefore, given a set of candidate models for the data, the preferred model is the one with the minimum AIC value. The `drop1()` function in *R* was used to identify variables eligible for removal and gradually eliminate them. The `drop1()` function gives AIC and *p* values if each one of the variables is removed i.e., it tests whether each variable will improve the model if dropped. In every subsequent step, the variable that improved the model the most by being dropped was removed and multiple regression was re-run. This process was repeated until the variables left in the final models, significantly predicted the dependent variable and no further improvement was possible.

2.3.3.2. Musical abilities and phonological awareness

As a first step, all measures of musical ability were entered into the regression model while phonological awareness was included as the dependent variable. This first analysis indicated that only Rhythm Perception [$Beta = .53, t(19) = 3.54, p < .005$] and Synchronization [$Beta = -.38, t(19) = -2.30, p = <.05$] significantly predicted phonological awareness [$F(9, 19) = 3.23, p < .05, R^2 = .60$]. Independent variables eligible for removal were dropped in the following order: Gender, Tempo Perception, Song Production, Melody Perception, Pitch Perception and finally Age. In the final model, only Rhythm Perception and Synchronization significantly predicted phonological awareness (Model 1a, see Table 2.10). Given that Synchronization had a lower *beta* and *t* value an ANOVA was used to test whether a model where Synchronization is included (Model 2a) shows a better fit than a more parsimonious model where only Rhythm Perception is included (Model 1a). An ANOVA in this case compares the two models in terms of residual sums of squares; if the additional variable adds explanatory value to the model then the models differ significantly. Results indicated that the models differed significantly (see Table 2.10), suggesting that the Synchronization variable significantly contributes to the model.

In a further step, the strong association between rhythmic and synchronization

abilities and phonological awareness was examined to determine whether this could be driven by underlying cognitive factors accounting for better performance in both linguistic and musical tasks. To this end, Non-Verbal Ability (as measured by WPPSI-Block Design) and Verbal Memory (as measured by Digit Span) were entered into the linear model together with Rhythm perception and Synchronization¹⁴. Results indicated that Rhythm Perception [$Beta = .45, t(28) = 3.77, p < .001$], Synchronization [$Beta = -.38, t(28) = -3.40, p < .005$] and Verbal Memory [$Beta = .38, t(28) = 3.12, p < .005$] significantly predicted phonological awareness, while Non-Verbal Ability did not [$Beta = .53, t(19) = 3.54, p < .005$], [$F(4, 27) = 12.67, p < .001, R^2 = .65$]. Using backward elimination, all variables were then inspected to determine whether dropping any of them would improve the fit of the model. In the final model all variables significantly predicted phonological awareness (see Table 2.10) and based on the *AIC* criterion, no further improvement was possible. Finally, the model that included Verbal Memory (Model 3a) was compared to Model 2a to ensure that Verbal Memory adds explanatory value to phonological awareness. Results showed that the two models differed significantly, suggesting that all variables predict phonological awareness significantly and independently from each other. As shown in Table 2.10, Model 3a explained a significant amount of variance in phonological awareness and showed a better model fit compared to Model 2a.

Residual plots were visually evaluated to test for the assumptions of normal distribution, linearity and heteroscedasticity of the data. No obvious patterns were observed and residuals did not appear to deviate from a straight line therefore meeting the assumptions. Three cases were identified as outliers through visual inspection of the residual plots. To assess whether these outliers were influential cases leading to changes in the interpretation of the model, leave-one-out diagnostics (or *DFbeta* values) for each data point were produced. These are the values with which each coefficient has to be adjusted if a particular data point is excluded. If a beta coefficient has to be adjusted by more than half of its absolute value then this data point warrants special attention (Winter, 2013). *DFbeta* values for all data points in the sample did not differ by more than half the absolute value of the independent variables' beta coefficients, suggesting that the outliers did not cause drastic changes in the model.

¹⁴ Please note that the `lm()` function in R used to test linear models returns individual coefficients for each independent variable after having accounted for other independent variables in the model.

Table 2.10. Summary and comparisons between Models 1a, 2a and 3a predicting phonological awareness.

	β	t	p	R^2	AIC	F	p	Model Comparisons
Model 1a				.400	-24.57	20.56	<.001	
Rhythm								
Perception	.630	4.530	<.001					Model 2a vs Model 1a F(1,29) = 8.72, p <.05
Model 2a				.530	-31.03	16.29	<.001	
Rhythm								
Perception	.570	4.440	<.001					
Synch	.380	-2.950	<.05					Model 2a vs Model 3a F(1,29) = 9.75, p <.005
Model 3a				.650	-38.58	17.38	<.001	
Rhythm								
Perception	.450	3.770	<.001					
Synch	-.380	-3.410	<.005					
Verbal								
Memory	.370	3.120	<.005					

2.3.3.3. Musical abilities and language grammar.

As with phonological awareness, all measures of musical abilities (Pitch, Rhythm, Tempo and Melody Perception, Song Production and Synchronization), as well as Age and Gender, were entered into a liner model as predictors and language grammar score was treated as the dependent variable.

The first analysis indicated that none of the variables significantly predicted language grammar [$F(8, 22) = .94, p = \text{n.s.}, R^2 = .25$]. In subsequent steps, the variable that improved the model the most by being dropped was removed and the multiple regression was re-run. Independent variables were dropped in the following order: Song

Production, Synchronization, Tempo Perception, Age, Pitch Perception, Rhythm Perception and finally Gender. In the final model (Model 1b), only Melody Perception significantly predicted language grammar (see Table 2.11). As shown in Table 2.11, Model 1b explained a notable amount of variance in language grammar scores.

Next, the possibility that underlying cognitive factors can drive the association between melody perception abilities and language grammar was explored. Non-Verbal Ability (as measured by WPPSI-Block Design) and Verbal Memory (as measured by Digit Span) were entered into the regression model (Model 2b). Results indicated that all variables significantly predicted language grammar (see Table 2.11). All variables were then inspected to determine whether dropping any of them would improve the fit of the model. Based on *AIC* and *p* values, dropping any of these values would not improve the fit of the model. Finally, Model 2b was compared to a Model where only Non-Verbal Ability and Verbal Memory were included (Model 3b) (Melody Perception had the lowest *beta* and *t*-value of all three variables). This was necessary in order to ensure that Melody Perception adds explanatory value to language grammar. Results showed that the two models differed significantly, suggesting that Melody Perception predicts language grammar, over and above general cognitive abilities. As shown in Table 2.11, Model 3b explained a significant amount of variance in language grammar scores and showed a better model fit compared to Model 1b.

Residual plots were visually evaluated to test for the assumptions of normal distribution, linearity and heteroscedasticity of the data. No obvious patterns were observed in the residual plots and residuals did not appear to deviate from a straight line therefore meeting the assumptions. Three cases were identified as outliers through visual inspection of the residual plots. However, *DFbeta* values for all data points in the sample did not differ by more than half the absolute value of the independent variables' beta coefficients, suggesting that the outliers did not cause significant changes in the model.

Table 2.11. Summary and comparisons between Models 1b, 2b and 3b predicting language grammar.

	β	t	p	R^2	AIC	F	p	Model Comparisons
Model 1b				.190	205.64	7.7	<.01	
Melody	.440	2.780	<.05					
Model 2b				.560	188.42	13.04	<.001	
Melody	.290	2.320	<.05					
NVA	.390	2.970	<.05					
VM	.360	2.710	<.05					
								Model 2b vs Model 3b
								$F(1,32)=$
Model 3b				.480	196.77	15.26	<.001	5.39, $p < .05$
NVA	.390	2.920	<.05					
VM	.440	3.260	<.005					

Melody = Melody Perception, NVA = Non-Verbal Ability, VM = Verbal Memory

2.4. Discussion

The present study aimed to examine the associations between a range of musical skills and the development of phonological awareness and language grammar in 3- and 4-year-old children. To this end, a group of 3- and 4-year-old children were recruited from three nurseries in Greater London and underwent a thorough assessment of their musical and linguistic abilities. A range of musical skills such as pitch, tempo, rhythm and melody perception, song and synchronization ability was tested, using age appropriate measures specifically designed for this research. Standardized measures were used for the assessment of phonological awareness and language grammar.

In line with the first prediction, results from correlational analyses showed that both melodic and rhythmic aspects of musical processing were significantly associated with tasks measuring phonological awareness and grammar. More specifically, timing abilities such as tempo and rhythm perception and synchronization were significantly associated with phonological awareness. Rhythm perception was also significantly associated with one of the language grammar tasks (*Recalling Sentences*) while a

significant correlation between melody perception and one of the phonological awareness tasks (*Sentence/Syllable Segmentation*) was found. In addition, melody perception showed a trend towards significance with the phonological awareness composite score. Finally, song production appeared to be marginally linked to the language grammar composite score. These findings suggest that shared auditory processing mechanisms come into play in both music and language learning and that this can be found early in development. They are also broadly in agreement with previous research reporting music-language links in older preschoolers (e.g., Anvari et al., 2002; Degé & Schwarzer, 2011; Norton et al., 2005; Gordon et al., 2014; Verney, 2013).

As expected, results from the regression analyses revealed that some associations were stronger than others, with specific musical skills differentially predicting linguistic abilities in young preschoolers. First, synchronization and rhythm perception were found to be the most significant predictors of phonological awareness, over and above the influence of cognitive skills such as verbal memory and non-verbal ability. These findings corroborate research in older children (4 and 5 year olds; Anvari et al., 2002; Verney, 2013) and suggest that links between rhythm perception, entrainment to a beat and phonological awareness are already active from 3 years of age. Only one study so far has shown that synchronization ability in 3- and 4-year-old children is associated with early reading skills (Woodruff-Carr et al., 2014). The present study however provides the first evidence that this link also extends to rhythmic pattern perception in children younger than 4 years.

Indeed, phonological awareness has been argued to depend in part on the entrainment of networks of neurons to an input rhythm, marked by syllable rise times in speech predicting a specific and unique association between the processing of metrical structure¹⁵ in language and in music (Goswami, 2011). According to the ‘rise time hypothesis’ posited within the Temporal Sampling Framework, associations between timing skills and phonological processing in development partly depend on shared underlying neural processing of the patterns formed by strong and weak beats. Although metrical structure in language is non-periodic compared to music, strong and weak syllables alternate in order to avoid stress clashes. Thus metrical structure in language,

¹⁵ **Metrical structure** refers to the pattern of beats in a piece of music, including meter, tempo, and all other rhythmic aspects. Metrical structure also refers to the pattern of stressed and unstressed syllables in speech.

as in music, relates to strong and weak syllable “beat” patterns (Goswami et al., 2013). In the present study, as predicted by the rise time hypothesis, both the perception of rhythmic patterns within a melody and the ability to synchronize to an external beat strongly predicted phonological awareness skills.

Given the above hypothesis, it was anticipated that the tempo perception task, which also reflects sensitivity to the metrical structure of a melody, would be associated with phonological awareness. Indeed, correlational analyses revealed that the tempo perception task was moderately associated with this linguistic skill. However, the relationship between tempo perception and phonological awareness did not remain significant after non-verbal ability and verbal memory were controlled for, indicating that cognitive skills might have partly accounted for better performance in this task. Furthermore, tempo perception did not predict phonological awareness when entered into a linear model along with other musical skills. It is possible that in this model where the predictive power of independent variables is measured over and above the influence of other independent variables, both rhythm perception and synchronization overshadowed tempo perception. This implies that these tasks may be measuring timing skills more critical to language than the sensitivity to changes in tempo. Specifically, the rhythm perception task manipulated the duration of both accented and un-accented tones affecting rhythmic temporal structure and altering the patterns of beat distribution. Pattern beat distribution is most relevant to the perception of phonology in speech according to the Temporal Sampling Framework (Goswami, 2011; 2013). It is also worth mentioning that comparable same-different tasks that manipulate the duration of adjacent tones have been used in studies that have revealed links between metrical structure perception and phonological awareness in typical development (Anvari et al., 2002; Huss et al., 2011). The synchronization task, in addition to entrainment to the tempo and beat of a sequence, requires auditory-motor coordination, a skill thought to have emerged as an evolutionary product necessary for vocal and linguistic learning (Patel, 2008). Indeed, studies have reported impairments in rhythmic tapping in children and adults with developmental dyslexia, a language disorder related to specific deficits in phonological awareness and reading (Thomson, Fryer, Maltby, & Goswami, 2006; Wolff, 2002; Wolff, Michel, Ovrut, & Drake, 1990).

Interestingly, rhythm perception and synchronization ability predicted phonological awareness independently from each other suggesting that these timing skills might be, at least in part, dissociable. This is further supported by the fact that the

correlation between scores on these two tasks was non-significant. In line with these results, two recent studies have reported cases of individuals demonstrating poor perception of changes in rhythmic patterns despite unaffected synchronization ability (Bégel, et al., 2017; Dalla Bella & Sowiński, 2015). The opposite pattern has also been observed. Fries and Swihart (1990) report the case of a patient with right hemisphere damage who demonstrated preserved performance in rhythm discrimination but was unable to entrain to a rhythm. These findings suggest that separate mechanisms might underlie perceptual and sensorimotor timing skills while these abilities might relate to phonological awareness via distinct neural pathways (Bégel, et al., 2017). For example, Goswami (2011) has proposed that the tracking of the amplitude envelope in speech that is crucial for perceiving individual phonemes relies on phase-locking of neurons to slow oscillations (1.5 – 7 Hz) in the auditory cortex, while the same neural mechanism has been proposed for perceiving rhythmic structure in music (Large, 2008). On the other hand, it has been argued that both synchronization and phonological skills depend on the accurate representation of timing in the subcortical auditory system (Tierney & Kraus, 2014). In support of this notion, studies have shown that both individuals who exhibit variability in moving to a metronome (Tierney & Kraus, 2013) and children with developmental dyslexia (Hornickel & Kraus, 2013) show poor subcortical processing of timing information as reflected in delayed responses to sound and greater trial-by-trial timing variability in the auditory brainstem. It is therefore, a distinct possibility that rhythm perception and synchronization may impact on phonological awareness through different neural (cortical versus subcortical) pathways.

The second music-language link arising from the present results was that between melody perception and language grammar. More specifically, melody perception predicted language grammar score even when verbal memory and non-verbal ability had been accounted for. These results strongly suggest that similar auditory perceptual mechanisms may be responsible for both melody perception and language grammar, at least at this stage in development. They also imply that these mechanisms might be partly separated from those underlying the association between rhythmic abilities and phonological awareness. Pitch and melody discrimination have previously been associated with phonological awareness in 4 to 6-year-old children (Anvari et al., 2002; Forgeard et al., 2008; Norton et al., 2005; Lamb & Gregory, 1993) however, the connection with language grammar is a novel finding. Why melody discrimination skills appear to have an association with language grammar is less clear. One possibility is

that melodic aspects of prosody are particularly important for the acquisition and development of grammar. Indeed, it has been suggested that pitch changes in continuous speech appear to mark boundaries between different syntactic clauses and phrases, thereby assisting the extraction of grammatical information (Speer & Ito, 2009; Brooks & Kempe, 2012; Xie, 2012). Consistent with this view, Cohrdes et al. (2016) showed that melodic discrimination in 5- to 7-year-old children was associated with the processing of emotional prosody in linguistic phrases, suggesting that low-level auditory skills may work to strengthen more fine-grained aspects of language.

In addition, statistical learning, a mechanism thought to underlie the internalization of melodic patterns of one's musical culture (François & Schön, 2014) as well as the extraction and internalization of grammar constructions (Gómez & Lakusta, 2004; Saffran, 2003; Saffran & Wilson, 2003), may play a crucial role in both melody perception and grammar acquisition at this specific stage of development. With respect to the role of statistical learning in the acquisition of grammar, Saffran (2002) showed that both school-aged children and adults rely on distributional information in the sequencing of words (i.e., type A words always preceding type B words) to learn an artificial grammar, while Gomez and Lakusta (2004) found that even 12-month-old infants can categorize words based on distributional information. As suggested by Saffran and Wilson (2003), infants and children may use statistical regularities to acquire different levels of structure in language and this can occur in a cascaded manner. In their experiment, 12-month-old infants were exposed to multi-word sentences organized according to a finite-state grammar while transitional probabilities of syllables were lower between words compared to within words. Results showed that infants learned to distinguish between grammatical and ungrammatical sentences, suggesting that they were able to initially segment words from continuous speech and later use this knowledge to acquire grammatical rules in an artificial language (Saffran & Wilson, 2003). Given that the acquisition of grammar is a long and complex process that continues into the late preschool years (Brooks & Kempe, 2012; Brown, 1973) it is possible that 3- and 4-year-old children continue to rely on the distributional properties of input speech to internalize the structures of their native grammar. At the same time, between the third and fourth year of age, children are in the process of internalizing melodic and harmonic structures from the musical environment (Corrigall & Trainor, 2009; 2013) a process that has been argued to rely on extracting regularities from musical input (Tillmann, Bharucha, & Bigand, 2000).

Overall, it appears that the commonalities between distinct language and music skills can be based on shared underlying mechanisms while the operation of these mechanisms may at least in part determine the developmental sequence of the music-language connections. Given that developmental theories have supported the idea that the acquisition of language is a gradual process moving from the awareness of language phonemes in infancy (Jusczyk & Aslin, 1995) to more complex skills such as recognizing the meaning and functions of words in sentences (Cohrdes et al., 2016), it seems plausible that distinct musical skills that rely on common learning mechanisms will develop in parallel and in a similar fashion. Indeed, accounts in which musical skill acquisition develops in a gradual manner have also been proposed (Dowling, 1999; Welch, 1985). The findings of the present study bring together these accounts to suggest specific mechanisms that may operate in different manners across development to underlie both the acquisition of distinct language and music skills but also the connections between them. Specifically, it is proposed that sensitivity to metrical structure in 3- and 4-year-old children may contribute both to the acquisition of phonological awareness in language and to skills necessary for perceiving and producing rhythm structures in music. On the other hand, as demonstrated above, preschoolers may make use of sensitivity to statistical regularities to process melodies as well as grammatical structures at this specific point in development. Although the extraction of statistical regularities from speech also plays an important role in phonological awareness, evidence has shown that infants make use of this mechanism to become accustomed to phonological aspects of their native language within the first year of life (Kuhl et al., 1992; Mugitani et al., 2009, Werker & Tees, 2005). Therefore, 3- and 4-year-olds may well rely on other auditory and cognitive skills to refine their knowledge of phonological structure. Similarly, the internalisation of regularities in rhythmic patterns may take place earlier than in melodic sequences (Hannon and Trehub (2005). Indeed, studies have shown that 12-month-old infants are already facilitated by the isochronous meter typical in Western music when detecting changes in musical sequences (Hannon & Trehub, 2005) whereas 6-month-old infants in North America can detect variations in both Western and Balkan music meters equally well (Hannon & Trehub, 2005a; Hannon & Trehub, 2005b). Broadly in support of these findings, it has been suggested that rhythmic skills such as rhythm discrimination (Anvari et al., 2002) and production of rhythmic structures may develop earlier than melodic skills (see also Tafuri & Villa, 2002).

This idea of specific intersections between distinct language and musical skills is also consistent with theoretical accounts according to which there are shared but also dissociable features in the cognitive processing of speech and music (Patel, 1998; 2003; Peretz, 2006; Saffran, 2003; see also Asaridou, 2013 for a review of the evidence regarding this issue). For instance, in his highly influential theory Patel has proposed that the online memory process of integrating new items in unfolding sequences in language (i.e., sentences) and in music (i.e., chord progressions) may rely on common cognitive and neural resources (Patel, 1998; 2003) while linguistic and musical long-term memory systems may be independent (Peretz et al., 1994). Indeed, a number of behavioural and neuroscientific studies in adults and children have supported the idea of shared online processing (Fedorenko et al., 2009; Jentschke & Koelsch, 2009; Jentschke et al., 2008; Kunert et al., 2015; Sammler et al., 2013; Slevc & Reitman, 2013) while other evidence has suggested that brain damage can impair the processing of harmonic relations while linguistic syntactic processing remains intact (Peretz et al., 1994). Similarly, a number of other studies have shown overlap in brain areas and cognitive resources processing specific features language and music (e.g., Koelsch et al., 2002; Schön et al., 2010; Slevc & Reitman, 2013) while other features such as semantics appear to be processed independently (e.g., Brown, Martinez, & Parsons, 2006; Slevc et al., 2009). Accommodating the plethora of evidence, Peretz (2006, p. 25) has argued: *“What I suggest, is that music is an autonomous function, innately constrained and made up of multiple modules that overlap minimally with other functions such as language”*. Overall, although there is evidence to suggest that musical skills are modular and specialized, this view does not exclude the use of domain-general mechanisms for the processing of music and the acquisition of musical skills (Oram & Cuddy, 1995; Peretz, 2006; Saffran, 2003). The present study informs influential accounts such as the above first by identifying specific connections between distinct language and music skills in a younger age than previously studied and second by proposing domain-general learning mechanisms responsible for these links.

It is important to note that, contrary to studies that have reported links between pitch processing and language areas such as phonological awareness and reading (e.g. Forgeard et al., 2008; Lamb & Gregory, 1993) the pitch discrimination task used in the present work had very low correlations with both domains of linguistic development. This is an intriguing finding given that pitch perception is a fundamental aspect of

prosody, carrying crucial information for language learning (Marie et al., 2011). It is possible that the use of sinusoids in this task instead of more ecologically valid instrument sounds was more demanding and less pleasant for this age group, therefore relying on attentional and memory resources to a greater extent. This possibility is further supported by the fact that pitch perception showed a significant correlation with digit span, a task thought to measure verbal memory and attention. Furthermore, pitch perception did not exhibit any significant associations with any of the other musical tasks, further suggesting that it may not have accurately measured the skill it was intended to measure.

A related issue is the fact that the link between song production, a melody-related skill, and language grammar was only marginally significant. Perhaps singing along to a recording, which involves monitoring and matching vocal production with an external stimulus while recalling the words of the song, required children to draw more heavily on cognitive resources than the other musical tasks.

It is worth noting that links were also observed among different musical skills. Specifically, melody perception was significantly linked to tempo perception and marginally associated with pitch perception and song production. It appears that, apart from singing, which has previously been associated with accurate pitch and melody perception in preschoolers (Apfelstadt, 1984; Ramsey, 1983), tempo perception might also be essential for tracking, extracting and following melodic events. Furthermore, singing along to a recording was related to synchronization ability, possibly because both singing and tapping to a beat require sensory-motor coordination and motor control (Dala Bella et al., 2015; Hutchins et al., 2014; Woodruff-Carr et al., 2014). In addition, entrainment to a beat may have been particularly relevant in the present singing task where children were asked to sing along to a recording: ease of tracking and extracting melodic events might have facilitated the child's internal feedback monitoring system that matches sung production with an external model (Welch, 1985; 2005). Interestingly, rhythm perception was linked to tempo perception and marginally linked to melody perception (perhaps because all of these perception tasks made use of short melodies) but not to synchronization. This is in agreement with a recent case study demonstrating that poor rhythm perception can occur despite unaffected synchronization ability, suggesting that separate pathways may in some cases underlie perception and action (Bégel, et al., 2016). In the present study this result is further supported by the fact that rhythm perception and synchronization ability independently

predicted phonological awareness. Although links among musical skills was not the focus of the present research, these findings add to on-going research examining the cognitive and biological bases of musical abilities (see Peretz, 2006; Honing & Ploeger, 2012 for reviews) and provide initial insights regarding their separate developmental trajectories.

Overall, these results indicate that musical and linguistic skills are linked in young preschoolers, adding to previous research with older children (e.g., Norton et al., 2005; Gordon et al., 2014) and providing further support for the idea that shared mechanisms underlie learning in both domains. Critically, rhythmic and melodic aspects of musical ability differentially predicted phonological awareness and language grammar, while these links were not accounted for by individual differences in non-verbal ability and/or verbal memory. These results reveal part of the developmental trend of the music-language relationships and inform existing theoretical accounts of these associations.

CHAPTER 3: THE ROLE OF INFORMAL MUSICAL EXPERIENCE IN EARLY MUSICAL AND LINGUISTIC DEVELOPMENT (STUDY 2)

Abstract

Study 2 sought to investigate whether informal musical experience in the home predicts musical or/and linguistic development. A second, related aim was to explore whether informal musical experience in the home plays a role in the associations between specific musical and linguistic abilities as these were identified in Study 1. The *Musical Experience in the Family questionnaire* (Franco, Brunswick, & Kiakides, 2014) was administered to parents with the aim of exploring the frequency of musical interactions in the family and the *Goldsmiths Musical Sophistication Index* (Gold-MSI; Müllensiefen, Gingras, Musil, & Stewart, 2014) was used to explore the parents' musical background. A strong association between informal musical experience and the development of language grammar was observed while no consistent relationships were found between this type of environmental input and children's musical skills. With respect to the second question, interactions between the frequency of musical experience in the home and musical ability predicted both phonological awareness and language grammar even when the parents' musical background had been accounted for. This finding opens a new area of exploration regarding how environmental experience can affect the development of language.

3.1. Rationale and aims of Study 2

With the purpose of elucidating possible environmental factors influencing early musical and linguistic development, the aim of Study 2 was to explore whether informal musical interactions and experience within the family might have an impact on children's musical and linguistic skills as assessed in Study 1. Although much is known about formal musical experience as a contributor to linguistic and musical skills in children and adults, the type of informal musical experience examined in this study is a largely unexplored area of research. As outlined in the literature review (section 1.5.3) only two studies so far (Putkinen et al., 2013; Williams et al., 2015) have directly assessed the effect of informal home musical experience (that is not limited to maternal singing) on language-related developmental outcomes. Based on their findings

suggesting enhanced auditory processing (Putkinen et al., 2013) and improved vocabulary (Williams et al., 2015) in young precoolers with higher levels of home musical experience, it is hypothesised that this aspect of environmental input will have a specific influence on the development of key linguistic areas (i.e., phonological awareness and grammar) and musical abilities as these were assessed in Study 1.

Another aim of Study 2 was to investigate the possibility that informal musical experience in the home could play a role in the development of links between the musical and linguistic skills that were identified in Study 1. In other words, the possibility that home musical experience could interact with musical abilities in predicting language grammar and phonological awareness was explored.

Therefore, Study 2 asks two questions: [i] does informal musical experience in the home predict musical or/and linguistic development? [ii] does informal musical experience in the home play a role in the relationship between music and language?

3.2. Materials and methods

3.2.1. Participants

Thirty-four parents/guardians of children participating in Study 1 completed a short demographics section and two self-report questionnaires regarding informal musical experience in the family and personal experience with music. Mean age of the parents was 36.4 years and in 44 % of the families at least one parent had received a Bachelor's degree or above.

3.2.2. Materials

The Musical Experience in the Family questionnaire (henceforth MEF; Franco et al., 2014) was used to assess frequency and type of musical engagement in the child's home environment. The MEF includes questions about frequency of musical engagement in the child's home environment (singing and music making) as well as richness of musical exposure. The Goldsmith's Musical Sophistication Index (henceforth Gold-MSI; Müllensiefen et al., 2014) was also administered to assess level of musical sophistication of the parents (see Appendix B for demographics, Gold-MSI and MEF as they were administered to parents). Musical sophistication is

conceptualized as the capacities necessary for successfully engaging with music besides being skilled at playing a musical instrument (Müllensiefen et al., 2014).

3.3.3. Procedure

At the launch of the Study 1, parents of participating children were informed of the objectives of the project and the research procedure and a questionnaire including the materials above was handed out to them. Completed questionnaires were collected at different times during the course of the Study 1.

3.3. Results

3.3.1. Associations between Musical Experience in the Family, Musical Sophistication of parents, parental education, and musical and linguistic abilities.

Correlations were performed between scores on the Gold-MSI (Musical sophistication score), the MEF (frequency of musical interactions and exposure in the family), parental education expressed as educational level, and children's musical perception and production tasks¹⁶. As can be seen in Table 3.1, a significant association was observed between the MEF scores and Song Production. Significant associations were also found between Gold-MSI and MEF scores indicating that parents' engagement with music, combined with the amount of musical training they had received, can be reflected in the way they interact musically with their children. No significant associations were found between parental education and any of the music perception or production tasks, the MEF or the Gold-MSI.

Interestingly, apart from the significant link between the MEF and song and the marginally significant association between the Gold-MSI and song ($p = .062$), no associations were found between home musical environment variables and the development of musical abilities, possibly suggesting that the development of musical abilities might be strongly affected by additional factors (e.g. individual characteristics

¹⁶ Preliminary non-parametric comparisons indicated that there were no significant differences between children receiving musical or dancing training outside the nursery/home ($n = 5$) and the rest of the sample ($n = 29$) in the linguistic composite scores, the MEF or the Gold-MSI. No significant differences were found for any of the musical tasks apart from Rhythm Perception where non-musically trained children performed higher than their counterparts ($U = 26.5, p = .031$).

and disposition of the child towards music, engagement of the child with music) not assessed by the instruments used in this study.

Table 3.1. Bivariate correlations between MEF, Gold-MSI-Musical Sophistication, parental education and musical abilities tasks.

	MEF	GoldMSI	Parental Education
MEF	-	.44**	-.05
Gold-MSI	.44**	-	.07
Parental Education	-.05	.07	-
Pitch Perception	.13	-.11	-.17
Tempo Perception	.17	-.03	-.06
Melody Perception	.02	-.19	-.02
Rhythm Perception	-.03	.16	.18
Song Production	.41*	.33 ¹	.01
Synchronization	-.17	.23	-.14

¹*marginally significant association ($p < 1$), * $p < .05$, ** $p < .01$*

Bivariate correlations between the home musical environment variables, parental education and all linguistic tasks were then performed (see Table 3.2). Both the MEF and the Gold-MSI were significantly correlated with the Sentence Structure subtest while the Gold-MSI was also significantly correlated with Recalling Sentences. The relationship between the MEF and the Recalling Sentences subtest was marginally significant ($p = .083$). Furthermore, there was a marginally significant association ($p = .076$) between the Gold-MSI and one of the phonological awareness subtests (Phonological Oddity-Aliteration). Next, bivariate correlations between the MEF, the Gold-MSI and composite scores of language grammar and phonological awareness were performed. As seen in Table 3.3, both the MEF and the Gold-MSI were significantly associated with language grammar scores. Interestingly, no associations were found between parental education and scores on the linguistic abilities tasks, although there was a trend towards significance in the relationship between parental education and the Phonological Oddity-Rhyme ($p = .095$) and Alliteration ($p = .103$) subtests.

To answer the question of whether musical characteristics of the parents or parent-child musical interactions *per se* can exert an influence on the development of grammar, partial correlations between the MEF and grammar were conducted after

controlling for the Gold-MSI scores. Results showed that the association between the MEF and grammar did not remain significant after controlling for the Gold-MSI ($r = .243, p = .195$). Similarly the association between the Gold-MSI and grammar was rendered non-significant when the MEF was accounted for ($r = .265, p = .157$).

Table 3.2. Bivariate correlations between MEF, Gold-MSI - Musical Sophistication and all linguistic tasks.

		MEF	Gold-MSI	Parental Education
Language Grammar	SS	.47**	.34*	-.04
	WS	.05	.09	.24
	RS	.31 ¹	.46**	.13
Phon Aw	W/S Blend	.14	.08	.06
	S/S Segm	-.01	-.05	.11
	Rhyme	.14	.16	.30 ¹
	Alit	.120	.26 ¹	.29 ¹

¹marginally significant associations ($p < .1$), * $p < .05$, ** $p < .01$

PhonAw = phonological awareness, SS = Sentence Structure, WS = Word Structure, RS = Recalling Sentences, W/S Blend = Word/Syllable Blending, S/S Segm = Sentence/Syllable Segmentation, Rhyme = Phonological Oddity Rhyme, Alit = Phonological Oddity Aliteration. As phonological awareness scores were not age-normed, age in months was controlled for in all relevant correlations.

Table 3.3. Bivariate correlations between home musical experience variables and composite scores of phonological awareness and language grammar.

Home Musical Environment	Language Grammar	Phonological Awareness
	Total score	Total score
GoldMSI	.37*	.30
MEF	.36*	.18
Parental Education	.14	.26

* $p < .05$, ** $p < .01$. Since phonological awareness scores were not age-normed, age in months was controlled for in all relevant correlations.

3.3.2. The role of informal musical experience in the family on the development of musical and linguistic abilities.

The possibility that Musical Experience in the Family (MEF) could interact with musical abilities in predicting language grammar and phonological awareness was then explored. In other words, although MEF did not appear to be related to musical abilities in young children, it is conceivable that the relationship between musical and linguistic abilities varies as a function of MEF. To this end, two linear regression models were built with language grammar and phonological awareness as dependent variables. Interactions between the musical abilities found to be the strongest predictors of these linguistic abilities and MEF were entered as predictors in each model separately. All analyses were conducted in R.

3.3.2.1. Informal musical experience in the family, musical abilities and phonological awareness

A linear model was built where phonological awareness was entered as a dependent variable. Two interactions were entered into the model as predictors: an interaction between MEF and Rhythm Perception and the interaction between MEF and Synchronization.

Multiple regression analysis indicated that both the interaction between MEF and Rhythm Perception and the interaction between MEF and Synchronization significantly predicted phonological awareness (see Table 3.4). To ensure that the model where both interactions are included (Model 2c) shows a better fit than a more parsimonious model where only the strongest predictor is included (Model 1c), an ANOVA comparison was performed. Results indicated that the models differed significantly, suggesting that both interactions add notable explanatory value to the model (see Table 3.4).

In order to explore whether these interactions would still predict phonological awareness over and above another important environmental factor presumably linked to musical experience in the home, notably, the parents musical sophistication including level of musical training, an average of maternal and paternal musical sophistication (as measured by the Gold-MSI) was entered into the model. Results indicated that both interactions as well as the Gold-MSI significantly predicted Phonological Awareness (see Table 3.4). The model that included the Gold-MSI (Model 3c) was then compared to Model 2c using ANOVA, to ensure that the Gold-MSI also explained notable

variance in the dependent variable. Results showed that the two models differed significantly, suggesting that all variables significantly and independently from each other predict phonological awareness (see Table 3.4).

Visual evaluation of residual plots for Model 3c, suggested that the final model met the assumptions of linearity, heteroscedasticity and normality. Three cases were identified as outliers through visual inspection of the residual plots. However, inspection of DFBeta values for all data points in the sample indicated that the outliers did not cause drastic changes in the model.

To plot the effects of the interactions on phonological awareness scores two separate models were built with phonological awareness as the dependent variable and interactions between Rhythm and MEF (Model 1d) and Synchronization and MEF (Model 2d) respectively, as predictors¹⁷. Both models were significant predictors of phonological awareness [Model 1d: $F(1, 25) = 7.38, p < .05, R^2 = .22$, Model 2d: $F(1, 27) = 4.32, p < .05, R^2 = .13$]. As can be seen in Figure 3.1, higher levels of MEF contribute towards a stronger link between the child's musical abilities and phonological awareness.

¹⁷ This was to ensure that the visual depiction of the interactions would be clear enough to have interpretative value, given that a visual depiction of the final model (Model 3c) would have to include four different levels corresponding to the four different independent variables.

Table 3.4. Summary and comparisons between Models 1c, 2c and 3c predicting phonological awareness.

	<i>Beta</i>	<i>t</i>	<i>p</i>	<i>R</i> ²	<i>AIC</i>	<i>F</i>	<i>p</i>	Model Comparisons
Model 1c				.220	-14.15	7.39	<.01	
Rhythm:MEF	.006	2.75	<.05					
Model 2c				.450	-21.37	9.87	<.001	Model 1c vs Model 2c F(1,24) = 9.76, p < .005
Rhythm:MEF	.007	3.65	<.005					
Synch:MEF	-.012	-3.16	<.005					
Model 3c				.600	-27.84	11.46	<.001	Model 2c vs Model 3c F(1,23) = 8.48, p < .05
Rhythm:MEF	.005	2.79	<.05					
Synch:MEF	-.017	-4.48	<.001					
Gold-MSI		2.91	<.05					

Rhythm: MEF = Interaction between Rhythm Perception and MEF, Synch: MEF = Interaction between Synchronization and MEF

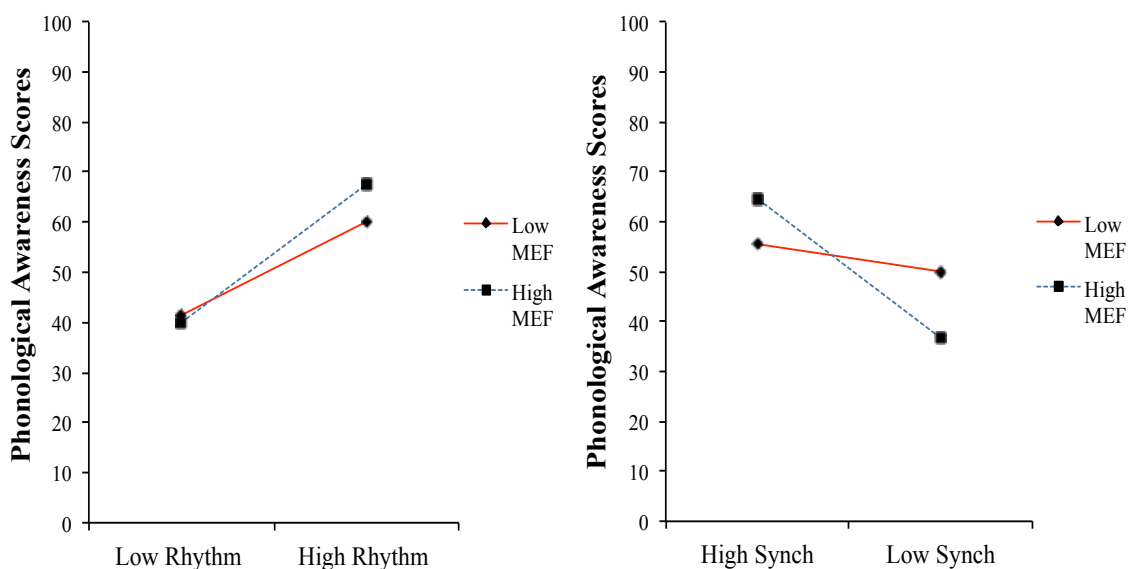


Figure 3.1. Interactions between Musical Experience in the Family and musical abilities in predicting phonological awareness scores. Rhythm = Rhythm perception, Synch = Synchronization (N.B. smaller scores in the Synchronization task indicate better synchronization performance).

3.3.2.2. Informal musical experience in the family, musical abilities and language grammar.

A multiple regression analysis model was built where language grammar was entered as a dependent variable while the interaction between MEF and Melody Perception was entered as predictor.

Results of the multiple regression showed that the interaction between MEF and Melody Perception significantly predicted language grammar (Model 1e) and explained a significant amount of the variance in language grammar (see Table 3.5). A plot of the effect of the MEF - Music Perception interaction on language grammar scores is presented in Figure 3.2. Similar to what was observed in the case of phonological awareness, the association between Melody Perception and language grammar is stronger in children with higher levels of MEF.

The next step was to add the average of maternal and paternal musical sophistication (as measured by the appropriate Gold-MSI subscale) into the model. Results indicated that the interaction between MEF and Melody Perception still predicted language grammar significantly while the Gold-MSI did not. To confirm that the Gold-MSI did not add explanatory value to the model, Model 2e where all predictors were present, was compared to Model 1e using ANOVA. Results showed that the two models did not differ significantly, confirming that the Gold-MSI did not explain a significant amount of variance in language grammar (see Table 3.5).

Table 3.5. Summary and comparisons between Models 1e and 2e predicting grammar.

	<i>Beta</i>	<i>t</i>	<i>p</i>	<i>R</i> ²	<i>AIC</i>	<i>F</i>	<i>p</i>	Model Comparison
Model 1e				.31	167.59	12.45	<.001	
Melody:MEF	.19	3.53	<.001					Model 1e vs Model 2e F(1,27) = 2.65, p = n.s.
Model 2e				.37	-21.37	7.91	<.005	
Melody:MEF	.17	3.12	<.005					
Gold-MSI	.33	1.63	n.s.					

Melody:MEF = Interaction between Melody Perception and MEF

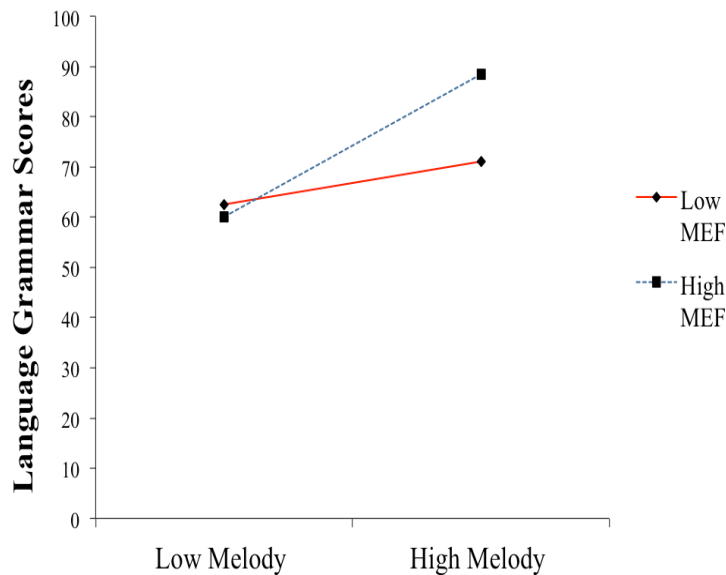


Figure 3.2. Interaction between Musical Experience in the Family and Melody Perception in predicting language grammar scores.

3.4. Discussion

The aim of Study 2 was to examine associations between informal musical experience in the home and early musical and linguistic development. A related goal was to explore the potential role of this type of experience in the relationship between musical and linguistic skills. To these ends, an instrument assessing frequency and type of informal musical experience in the home (Musical Experience in the Family Questionnaire or MEF; Franco et al., 2014) was administered to parents. In addition, parents completed the Goldsmith’s Musical Sophistication Index (Gold-MSI; Müllensiefen et al., 2014) with the aim of controlling for their own musical sophistication (i.e., musical experience and personal engagement with music).

With respect to associations between the home musical environment and children’s musical skills, the only significant relationship observed was between MEF scores and the children’s ability to sing in tune. This association is not surprising for two reasons: [a] children’s singing skills might have benefited from sufficient practice at home and [b] children who frequently engaged in singing activities may have felt more comfortable about performing in the presence of the experimenter. Furthermore, singing is the only activity of those tested that was likely to be performed outside the

testing room. Contrary to expectations, no other musical skills were significantly correlated with the measures of home musical environment (neither the MEF nor the Gold-MSI). One possibility is that the development of musical skills might be influenced by extraneous variables that were not measured in this study. For example, there was no assessment of personal engagement of the child with music, or quality of parent-child singing and music-making (e.g., singing in or out of tune, keeping a steady beat), factors that could potentially affect musical development. It is also highly likely that the focus of these spontaneous interactions in the home is not to practice music in a consistent manner, rather it is an opportunity for pleasant joint activities between parents and children and a means for enhancing the emotional bond between them (Custodero, 2006; Custodero & Johnson-Green, 2003). Not surprisingly, research has shown that informal musical activities in the home often play a supportive role to other learning goals (e.g., singing counting songs to learn the numbers), accompany everyday activities to make them enjoyable (Barrett, 2009; Custodero & Johnson-Green, 2006) or serve other purposes such as soothing, providing distraction or regulating behavior (Barrett, 2009; Custodero & Johnson-Green, 2006; Young et al., 2008).

Consistent with this notion of the supportive role of musical engagement to enhance other learning goals, correlational analysis revealed that MEF scores were significantly associated with children's development of language grammar, supporting the view that higher levels of engagement with singing, music making and greater exposure to music in the home can serve as scaffolding for the acquisition of verbal skills. Perhaps the rhythmic and melodic properties of music when combined with speech in everyday interactions, offer additional cues for children to successfully extract and internalize linguistic structures and information from their environment. Indeed, infants as young as 6- to 8-months old appear to benefit from complex input (i.e., melody and lyrics) with information from one modality facilitating learning in the other (Thiessen & Saffran, 2009). Furthermore, given that musical interactions among groups in early childhood have been linked to pro-social attitudes and socio-emotional bonding, (Cirelli et al., 2014; Custodero, 2006; de Vries, 2005; Kirschner & Tomasello, 2010) music making in the home might facilitate emotion regulation and cooperation in the context of learning complex information. Indeed, it has been argued that affective and social aspects of musical engagement affect cognitive performance and learning in young children as well as infants (Franco et al., 2014; Kuhl, 2011). In a highly influential study, Kuhl and her colleagues (2003) have also highlighted the role of social

engagement in language learning. Specifically, these researchers showed that 9-month-old English-learning infants exposed to Mandarin native speakers who vividly interacted with them across 12 sessions learned to discriminate Mandarin phonemes, as opposed to a control group who were exposed to the same amount of foreign language sounds only via audio-visual and audio recordings (Kuhl, Tsao, & Liu, 2003). Therefore, it seems plausible that pro-social and emotional aspects of musical interactions may play an important role in promoting the acquisition of language.

Whether it is predominantly the socio-emotional functions of music-making that contribute to language learning or simply the perception-facilitating (e.g., rhythmic and melodic) properties of music that are important is a crucial question that deserves specific investigation. With regards to song, previous evidence appears to suggest that both perceptually facilitating and motivational properties of sung speech may work together to promote word learning (Schön et al., 2008). In their experiment these researchers compared word segmentation performance of a spoken versus a sung language where each syllable was sung on a specific pitch and the statistical structure of the musical and linguistic dimensions matched. While 7 minutes of familiarization were not enough to segment a spoken language, they were sufficient to learn the sung language, suggesting a perceptual facilitation of speech in song. To exclude the possibility that song is simply more arousing than speech, a further experiment was run using another sung language where the statistical distributions of linguistic and musical structures were mismatched. The participants' performance was exactly in between those of the spoken and the sung stimuli observed in the previous experiment, suggesting that it is a combination of perceptual and motivational properties of music that is beneficial for language learning (Schön et al., 2008). Based on these findings it can be suggested that a combination of emotional and perceptual characteristics of musical engagement could drive children's enhanced learning. Investigating whether this is the case is an interesting question for future studies.

The extent to which musical sophistication of the parents might contribute to the child's linguistic development is unknown. In the present study, significant associations were found between the parents' Gold-MSI scores and children's grammar skills. These findings indicate that musical characteristics of the parents such as personal engagement with music and musical knowledge can also, perhaps indirectly, contribute to gains in children's linguistic development. Indeed, parents with a greater interest in music might be more likely to engage musically with their children (see also Custodero & Johnson-

Green, 2003). This idea is further supported by the significant correlation between Gold-MSI and MEF scores found in the present study. Furthermore, given that the Gold-MSI assesses rather more stable characteristics of the parents, this measurement might reflect musical engagement with the child over time, including earlier times in development when the brain is highly plastic and receptive to environmental influences (Trainor, 2005). This further validates the link between informal musical experience and developmental outcomes.

Given the above findings, the question arises as to whether it is parental characteristics related to music, or active musical interactions *per se* that affect language development. To approach this question, partial correlations were carried out, which revealed that the relationship between MEF scores and grammar scores does not remain significant after controlling for parent's level of musical sophistication. Similarly, the association between Gold-MSI score and grammar is rendered non-significant when musical interactions in the home are controlled for. These findings suggest that the two variables are interlinked, and that musically sophisticated parents are indeed more likely to provide a rich musical environment for their children. Future studies could attempt to delineate the degree to which the child might benefit from indirect exposure to music (e.g., parent's personal engagement with music) versus the degree to which active musical interaction might benefit cognition.

Perhaps the most intriguing finding was that the interaction between informal musical experience in the family and musical skills was predictive of language development. Specifically, although MEF score did not appear to be related to the musical skills of children in our sample, the observed predictive relationships between musical and linguistic skills (i.e., the link between rhythm and phonological awareness and the link between melody perception and grammar) varied as a function of musical experience in the home with children from more musically active families, showing a stronger connection between musical and linguistic skills. This is consistent with findings by Forgeard et al., (2008) who found that predictive relationships between music perception skills and reading competence were stronger for musically trained 6-year-old children compared to their untrained counterparts. Perhaps the fact that informal musical play usually brings together speech and music within a context of positive interpersonal interaction enhances interconnectivity between the areas of cognition that are engaged during this process. Such interconnections may later facilitate music to language transfer if children acquire formal musical training.

Although this study was not designed to directly address these possibilities, the present findings generate interesting ideas for future exploration.

Furthermore, the interactions between MEF scores and musical skills significantly predicted both grammar and phonological awareness skills even when the parents' level of musical sophistication was taken into account. This finding further underlines the important role of active parent-child musical engagement in mediating the music-language link. It is important to note however, that the Gold-MSI had a contribution in predicting phonological awareness independent of the interaction between MEF score and musical ability, suggesting that the parents' musical sophistication might also reflect a level of musical engagement with their children at home possibly not captured by the MEF Questionnaire.

In sum, it is apparent that informal musical experience in the family and the development of grammar are linked in 3- and 4-year-old children. This finding adds to previous research on the contribution of informal musical experience to young preschooler's auditory perception (Putkinen et al., 2013) and vocabulary development (Williams et al., 2015), by providing new evidence about the positive influence of this type of environmental experience on more complex areas of language learning. Furthermore, the finding that musical experience in the family interacts with musical abilities in predicting language development suggests that this type of environmental experience may work to strengthen connections between musical and linguistic skills, opening new possibilities for future research to explore. Given the significant potential of informal musical input in supporting language development in both typical and disadvantaged groups, further research is needed to elucidate the exact nature of these relationships and their underlying mechanisms.

CHAPTER 4: A NOVEL INSTRUMENT FOR THE MEASUREMENT OF INFORMAL MUSICAL EXPERIENCE IN THE HOME IN THE EARLY YEARS (STUDY 3)

Abstract

The findings from Study 2, which suggested an influence of the informal home musical experience on the development of key language areas, warranted the creation of an appropriate tool to develop systematic research in this understudied area. The aim of Study 3 was therefore to develop the brief *Musical Experience in the Family Questionnaire* as a comprehensive instrument with good psychometric properties. The new questionnaire (*Music@Home Questionnaire*) was designed for both infants and preschoolers, with the ultimate aim of addressing the origin of the developmental trajectory of the relationship between the informal musical experience in the home and language development. An initial pool of items was first generated and incorporated into an online survey and responses were collected from a wide audience of parents with children within the age range of 0 to 5 years. Exploratory factor analysis was used to identify different dimensions that corresponded to sub-scales of the questionnaire and these sub-scales were refined with the aim of reducing items (stage 1). Confirmatory factor analysis was subsequently employed with data collected from a different set of participants (stage 2), to consolidate the factor structure in the reduced-item version of the questionnaire. Convergent and divergent validity, internal and test re-test reliability of the newly developed instrument were also established.

4.1. Background, rationale and aims of Study 3

Even though much is known about the positive language-related outcomes of formal musical training in adults (Kraus et al., 2009; Lee et al., 2009) and children (Barac et al., 2011; Francois et al., 2013; Moreno et al., 2009), very little is known about whether musical experience in more informal contexts could have equally empowering effects. The majority of young children do appear to show spontaneous enjoyment of singing, dancing and interacting with musical instruments, but whether variations in engaging in such activities in the home could contribute to different developmental outcomes is still largely unexplored.

The findings of Study 2 indicated a relationship between informal musical experience in the home (as measured by the Musical Experience in the Family Questionnaire; MEF) and language development. Specifically: [a] significant associations were found between MEF scores and the development of language grammar and [b] MEF scores interacted with children's musical abilities in predicting both language grammar and phonological awareness. These findings, combined with two previous proposals of how frequency of musical interaction in the home at a young age can boost language-related areas of development (Putkinen et al., 2013; Williams et al., 2015) warranted the creation of a novel tool to investigate in depth this promising and unexplored area of environmental experience.

A number of parental report tools have been used in the past to assess parent-child musical engagement at home. The first parent self-report instrument designed to explore the musical environments of school-aged children (7-years-old), the Home Musical Environment Scale (HOMES), was published by Brand in 1985. The HOMES comprised of 4 factors relating to different aspects of parent and child involvement with music (i. parents' attitude toward music and musical involvement with child, ii. parental concert attendance, iii. parent-child ownership and use of records/tapes and iv. parent plays a musical instrument) and displayed good reliability and concurrent validity. The main motivation for its development was for music educational purposes such as nourishing the musical potential of primary school students or exploring associations between scores on the HOMES and children's musical attainment (Brand, 1985; 1986). Another validated instrument recently created to map the musical behavior of children under the age of five is the Children's Musical Behavior Inventory (CMBI; Valerio, Reynolds, Morgan, & McNair, 2012). The CMBI is an 8-factor, 97-item parental report designed to assess the frequency with which children engage in a number of musical behaviours such as music-listening, singing and dancing, with the aim of identifying and meeting their musical needs in preschool education settings. While seven of the eight factors in the CMBI are associated with child-initiated musical behaviours, one factor also assesses the frequency of parent-initiated musical activities. The CMBI dimensions show good reliability (Cronbach's α ranged from .77 to .97) and adequate construct validity as tested with confirmatory factor analysis (Valerio et al., 2012).

Other studies have used *ad-hoc* questionnaires and/or parental interviews to explore how parents use music at home with children younger than 6 years, either for

descriptive purposes (Barrett, 2009; De Vries, 2009; Gingras, 2012; Illari, 2005; Young, 2008) or to examine how the parents' previous experience with music can affect current musical engagement with their children (Custodero & Johnson-Green, 2003; Mehr, 2014; Shoemark & Arnup, 2014). All of the instruments used in the studies above explored musical experience in specific age groups focusing on either the infant or the preschool range. The *ad hoc* frequency items that were used in another two studies examining the effect of informal musical experience on language-related developmental outcomes (seven items in Putkinen et al., 2013, one item in Williams et al., 2015) were valuable in identifying associations between frequency of musical interactions and individual differences in auditory processing (Putkinen et al., 2013) and cognitive and socio-emotional aspects in early development (Williams et al., 2015). However, the home experience with music can consist of a number of different dimensions (e.g., parental singing, the child's engagement with music) differentially relating to aspects of early development. A small number of items broadly evaluating musical experience in the home might fail to capture these associations.

Indeed, given their music educational perspective or descriptive focus, most of the home musical environment measurements used so far have addressed specific aspects of this experience, such as frequency of musical interactions, while neglecting others, such as richness of musical exposure or parental beliefs regarding music and development. Combined with the fact that psychometric properties have been examined for only two of the aforementioned instruments (HOMES; Brand, 1985; CMBI; Valerio et al., 2012) focusing on preschool and school-aged children, the creation of a systematic, easily administered and cost-effective research tool encompassing a range of parent and child musical behaviors was deemed necessary. Crucially, with the aim of drawing a complete picture of informal musical experience for children under the age of 5, as well as exploring the developmental trajectory of the relationship between this experience and aspects of development, the new instrument was designed for both infants and pre-schoolers.

Study 3 therefore aims to develop a valid and reliable instrument, i.e., Music@Home Questionnaire, that can be used in the exploration of the informal musical experience in the home from infancy to the preschool years and in research examining potential effects of this type of environmental experience on a range of developmental outcomes. Within the development of this instrument, another aim was to elucidate potentially different dimensions comprising informal musical experience in

the home for infants and pre-schoolers, that is, for different developmental levels. This study was designed as follows: Stage 1 involved the generation of 67 items for the preschool and 60 items for the infant version. These were administered to a large sample of parents and exploratory factor analysis was used to [a] identify underlying dimensions within the items and [b] reduce the initial pool of items to a smaller number of meaningful questions. In Stage 2, data from a different sample of participants was used for confirmatory factor analysis to corroborate the factor structure of the new questionnaire. Convergent and divergent validity and test-retest reliability of the new instrument were also tested. Given that informal musical experience in Study 2 was significantly associated with musical sophistication of the parents, we also assessed whether the Music@Home Questionnaire would be associated with musical characteristics of the parents, such as their musical education and personal engagement with music.

4.2. Stage 1: Creation of the Music@Home questionnaire; exploratory and confirmatory factor analysis

4.2.1. Preparatory stage – Creation of survey

The preparatory stage came about from collaboration between the author, Fabia Franco (Middlesex University), Lauren Stewart, Daniel Müllensiefen and Olivia Brancatisano (Goldsmiths, University of London). A total of 67 items were compiled covering a broad definition of musical experience at home, which was conceived as: “informal interactions or/and indoor/outdoor activities involving music”. Items were selected based on a review of relevant pre-existing items (e.g., Franco et al., 2014; Mehr, 2014; Putkinen et al., 2013; Willams et al, 2015), as well as from a series of notes collected from parents of infants and preschoolers of their personal experiences with their children at home. The initial 67-item list covered 12 different aspects of musical experience at home, which were considered by the team as relevant to the working definition. These dimensions were: *Structured musical activities*, *Parental attitudes towards music*, *Music use for child's emotion/mood regulation*, *Child listening to music*, *Child moving to music*, *Child music making*, *Infant and child directed singing*, *Child singing*, *Richness of musical exposure*, *Daily routine and home activities*, *Child music preferences*, *Beliefs on music and development*. The majority of items were applicable to both infants and preschoolers. However, seven items relevant to preschoolers (and

deemed necessary in the description of informal musical experience in this age group) did not apply to infants (e.g., *My child sings along to music on the television*). Therefore, two versions of the questionnaire were created; an infant version containing 60 items, and a preschool version containing an additional seven items.

All items were entered into an online survey tool (*Qualtrics*, Provo, UT) and a 7-point agreement-disagreement scale was used for all items. Half of the items were negatively phrased, in order to minimize extreme responses and/or compliance bias. One survey was created for both Infant and Preschool versions, while each participant was directed to the appropriate version according to the age group of the child for whom they completed the survey. An additional 20 items assessing demographic information appeared at the beginning of the survey. The Music@Home Questionnaire was intended for the primary caregiver (i.e., the caregiver who spends more time with the child); in case of equal parenting, either caregiver could complete the questionnaire (see Appendix B for a copy of the Stage 1 survey).

4.2.2. Participant recruitment

English-speaking participants (including advanced, fluent and native speakers) from English-speaking and other countries (UK, USA, Ireland, Australia, Canada and New Zealand) were recruited via social media, parent networks, participant databases and public mailing lists. Dissemination of the survey included: [a] posting the survey link on parent networks on Facebook and UK nationwide networks such as www.netmums.com, [b] distributing it through personal contacts and social media (Twitter and Facebook), [c] sending the link via public mailing lists (e.g., JISCMail lists such as Parenting Research list and Child Studies list) and [d] accessing participant databases from Middlesex and Goldsmith's Babylabs.

4.2.3. Participants

Music@Home Questionnaire - Preschool version

A total of 347 participants completed the survey between October and December 2015. The primary caregiver completing the survey was predominantly the mother ($n = 312$), while in a few cases it was the father ($n = 34$) or another relative ($n = 1$). Demographic information for participating parents and children is presented in Tables

4.1 and 4.2 respectively. With respect to their level of English, participants were primarily native speakers. The majority of the participants were UK residents, while a number resided in other English-speaking countries such as United States of America, Australia, Canada, Ireland, and New Zealand. Other countries of residence included Belgium, China, Croatia, Cyprus, Denmark, Finland, France, Germany, Greece, Kenya, Mexico, Netherlands, Nigeria, Qatar, Spain, Sweden, Switzerland and United Arab Emirates. The mean age of participants was 36.56 years ($SD = 4.78$). The mean age of the children for whom the survey was completed was 3.58 years ($SD = .98$).

Table 4.1. Demographic information for Music@Home-Preschool participants.

	n	%
Level of English		
Native	314	90.5%
Fluent	20	5.8%
Advanced	13	3.7%
Country of Residence		
United Kingdom	254	73.2%
United States of America	25	7.2%
Australia	19	5.5%
Canada	4	1.2%
Ireland	2	0.6%
New Zealand	1	0.3%
Other	42	12.1%
Level of Education		
Did not complete school qualification	1	0.3%
First School Qualification (e.g. GCSE/Junior High School)	11	3.2%
Second qualification (e.g. A levels/ High School)	32	9.2%
Undergraduate Degree or professional qualification	141	40.6%
Master's degree or above	162	46.7%
Level of Family Income		
£40.000 or lower	49	14.1%
£40.000-£60.000	80	23.1%
£60.000-£90.000	93	26.8%
£90.000 or higher	125	36.0%

Table 4.2. Demographic information for children for whom the Music@Home-Preschool was completed.

	n	%
Gender		
Female	165	47.6%
Male	182	52.4%
Language		
English Monolingual	287	82.7%
English Bilingual	27	7.8%
Monolingual other	27	7.8%
Bilingual other	6	1.7%
Number of children in the family		
Only child	125	36.0%
2 children	169	48.7%
3 children	36	10.4%
4 or more children	17	4.9%

Music@Home Questionnaire - Infant version

A total of 302 participants completed the survey between October and February 2015. Although initially the infant version was conceived as appropriate for infants from birth to 1 year and 11 months, comments from a number participants regarding the unsuitability of some of the items for their young infants (< 4 months) led to a reconsideration of the age range that the Music@Home Questionnaire-Infant version should be intended for. Clearly, some of the items required a degree of interactivity that is not common in very young infants. Therefore, all participants with infants under the age of 4 months were excluded from subsequent analyses, leaving a sample of 287 participants. Demographic information for participating parents and infants is presented in Tables 4.3 and 4.4 respectively. The primary caregiver completing the survey was predominantly the mother ($n = 265$) while in 22 instances it was the father who completed the survey. With respect to their level of English, participants were mainly native speakers. The majority of participants were UK residents, while a number resided in other English-speaking countries such as United States of America, Australia and Ireland. Other countries of residence included Austria, China, Finland, Germany, Greece, Guatemala, Israel, Italy, Netherlands, Portugal, Qatar, Singapore, Spain and Sweden. The mean age of participants was 35.13 years ($SD = 5.29$). The mean age of the children for whom the survey was completed was 14.52 months ($SD = 6.54$ months).

Table 4.3. Demographic information for Music@Home-Infant participants.

	n	%
Level of English		
Native	255	88.9%
Fluent	24	8.4%
Advanced	8	2.8%
Country of Residence		
United Kingdom	203	70.7%
United States of America	22	7.7%
Australia	14	4.9%
Ireland	16	5.6%
Other	32	11.1%
Level of Education		
Did not complete school qualification	1	0.3%
First School Qualification (e.g. GCSE/Junior High School)	6	2.1%
Second qualification (e.g. A levels/ High School)	30	10.5%
Undergraduate Degree or professional qualification	99	34.5%
Master's degree or above	151	52.6%
Level of Family Income		
£40.000 or lower	53	18.5%
£40.000-£60.000	73	25.4%
£60.000-£90.000	73	25.4%
£90.000 or higher	88	30.7%

Table 4.4. Demographic information for children for whom the Music@Home-Infant was completed.

	n	%
Gender		
Female	155	54.0%
Male	132	46.0%
Language		
English Monolingual	224	78.0%
English Bilingual	30	10.5%
Monolingual other	21	7.3%
Bilingual other	10	3.5%
Trilingual	2	0.7%
Number of children in the family		
Only child	204	71.1%
2 children	62	21.6%
3 children	11	3.8%
4 or more children	10	3.5%

4.2.4. Materials and Procedure

Parents of children between the ages of 0 and 5 were invited to complete the 67-item questionnaire by clicking on an online link. As explained in section 4.2.1, the questionnaire had to be completed by the primary caregiver (i.e., the caregiver who spends more time with the child). The demographic information section included 20 items assessing general information such as age and ethnicity, education and level of income of the parents. These were completed before the participant was directed to either the Infant or the Preschool version of the survey depending on the age of their child. Completion of the survey took approximately 15-20 minutes.

4.3. Stage 1 –Exploratory and confirmatory factor analysis

All data were analyzed using the R software environment (R Core Team; 2012). Exploratory factor analysis (EFA) was employed in both infant and preschool versions of the questionnaire. In both versions, items with a highly skewed distribution were excluded from further analyses. The remaining items were used for further analyses with the aim of identifying a coherent factor structure.

4.3.1. Music@Home Questionnaire Preschool version - Results from exploratory and confirmatory factor analysis

First, 17 items were excluded from further analyses as they were found to have highly skewed distributions (> 1.0). As the main aim of this stage of the analysis was to identify different dimensions within the set of items that would correspond to sub-scales of the questionnaire, dimensionality of the data was further explored. An initial EFA was run on the 12 dimensions that were identified in the preparatory stage. Two factor extraction methods, typically used in exploratory factor analysis were implemented i.e., maximum likelihood estimation and minimum residual factor analysis. The criteria employed for factor extraction included: parallel analysis (Horn, 1965), Kaiser's criterion (only factors with eigenvalues >1 are retained; Dinno, 2009), visual inspection of the screeplot (Cattell, 1966), Velicer's Minimum Average Partial (MAP) criterion (Velicer, 1976), and Revelle and Rocklin's Very Simple Structure (VSS; Revelle & Rocklin, 1979). Different criteria indicated solutions where the optimal number of factors ranged from 1 to 12. Furthermore, when performing parallel analysis the first factor yielded an eigenvalue 7 times larger than the second factor. The results above indicated the presence of a model where a general factor existed in parallel with domain-specific sub-factors (Chen, West, & Sousa, 2006; Beaujean, 2014). In other words, it was suggested that all items of the Music@Home Questionnaire Preschool measure a general construct (presumably musical experience in the family) while in addition facets of this construct may exist that are independent of each other after accounting for the general construct.

A test using McDonald coefficient omega (McDonald, 1999), which is a sensitive and reliable measure for the detection of a general factor (Revelle & Rocklin, 1979; Revelle & Wilt, 2013), confirmed the presence of a hierarchical or bi-factor model for all factor solutions that were tested (i.e., the presence of a general factor was tested for different possible numbers of sub-factors; numbers ranged from 2 to 12). For each one of these solutions values of omega ranged from .75 to .79 (values above .6 indicate the presence of a general general factor; McDonald, 1999). Furthermore, hierarchical factor analysis models that included sub-factors showed a better fit than a 1-factor model, as assessed from smaller values of the Root Mean Square Error of Approximation or RMSEA index. The RMSEA index assesses how well the collected data fit the proposed model and a cut-off close to or less than 0.06 has been recommended (Hu & Bentler, 1999).

To control for this general factor in the search of the correct number of sub-dimensions in the data, a factor analysis was performed with maximum likelihood estimation extracting only one factor and then used the matrix of residuals for further analysis (Müllensiefen, Gingras, Musil, & Stewart, 2014). A parallel analysis on the residual matrix using the Kaiser's criterion (i.e., only factors with eigenvalues above 1 are retained) suggested the existence of 6 sub-factors while the MAP criterion suggested that four was the optimal number of sub-factors. This result signaled the need for further exploration in order to identify the correct number of factors.

Subsequently, the Schmid-Leiman solution with maximum likelihood estimation and oblique rotation (Schmid & Leiman, 1957; Wolff & Preising, 2005) was used to explore the factor structure of the items. This solution is considered suitable for both higher-order and bi-factor models (Schmid & Leiman, 1957) as it calculates direct relations between individual items and sub-factors after accounting for the impact of the general factor and direct relations between individual items and the general factor after accounting for the impact of sub-factors (direct relations are reflected on factor loadings) (Wolff & Preising, 2005). To perform the Schmid-Leiman procedure in R the number of sub-factors to be extracted needed to be determined. Since parallel analysis and the MAP criterion suggested different factor solutions (6 and 4 respectively), both of these numbers of sub-factors were entered in R to test which one gave the best model fit. The best RMSEA value (.06) was found for the model including 6 sub-factors (RMSEA index was .06, compared to .068 in the 4-sub-factor solution).

One of the main aims was to reduce the number of items in order to obtain a coherent, meaningful and quick-to-administer tool. Therefore, items were screened and removed at each stage of the analysis if [a] they had high uniqueness values (a high uniqueness value indicates that a high proportion of the item's variance is not explained by any of the factors in the model; Beaujean, 2014), [b] they had very low loadings on the general general factor or each one of the sub-factors or [c] they had similar loadings on more than one factors (values between .20 and .40). Each time a number of items was removed, the analysis was re-run based on the optimal number of sub-factors suggested at the previous stage (this was based on the RMSEA index as well as on the meaningfulness of the factor solution). In subsequent stages, 4 items with high uniqueness values (>.7) and 27 items with either very low loadings (>.2) or similar loadings on two rather than one factor (loadings between .2 and .4) were removed and the procedure was re-run until 19 items that had adequate loadings on the general and

on one of the sub- factors remained. A subsequent analysis using the Schmid-Leiman procedure on those 19 items yielded a 4-sub- factor solution with an acceptable fit to the data¹⁸ (RMSEA = .067) and a high omega value (.07 = .7). All factors had eigenvalues >1. All items except one had adequate loadings on the general Musical Experience in the Family factor (loadings >.30) and all items loaded adequately on one of the sub-factors (>.20) and weakly on all the others (<.20). One item that did not adequately load on the general factor was retained because it significantly contributed to one of the sub-factors (loading = .48) and removing it would weaken this particular factor's eigenvalue. Note that the loadings on the sub- factors in this case have lower values than they would have if the general general factor had not been accounted for. Details of the 4 factors, their items and their loadings are presented in Table 4.5.

The model can be specified as either a higher-order (i.e., a model where a general factor accounts for the covariance between lower-level sub- factors) or a bi-factor model (i.e., a model where a general factor exists in parallel with domain-specific sub- factors considered to be unrelated to the general factor). A bi-factor approach was deemed more appropriate in this case for two reasons:

[a] In the bi-factor model a general factor accounts for the conceptual commonality between the items by having a direct influence on them, while in a higher-order model the general factor influences the items indirectly via the sub- factors (Beaujean, 2014). In this case, the Music@Home general construct was considered to directly derive from the items while domain-specific dimensions of this construct also existed.

[b] The bi-factor model is particularly useful when the researcher's interest is to examine predictive relationships between the domain-specific dimensions of for example, a scale and other variables, after accounting for the general factor (Chen et al., 2006). This is particularly relevant in this case as one of the aims of constructing the Music@Home instrument was to identify dimensions within this construct that could have differential effects on aspects of development.

Suitable labels were assigned to the 4 sub- factors. The items that loaded on the first factor included statements about musical activities (singing and music-making with either real or toy instruments) that were initiated by the parent. Therefore, the first factor

¹⁸ According to MacCallum, Browne and Sugawara (1996) values between .50 and .80 indicate a mediocre fit to the data while Hu and Bentler (1999) suggest that a value close to .06 indicates an acceptable fit.

was labelled *Parent Initiation of Musical Behaviour*. The items that loaded on the second factor concerned the child's musical activities. The second factor was therefore named *Child Active Engagement with music*. The third factor reflected parental beliefs about music and development and was therefore named *Parental Beliefs*. The fourth factor included items concerned with the range of musical styles that the child is exposed to within the home. It was therefore labelled *Breadth of Musical Exposure*.

Table 4.5. Structure of factors and item loadings for the Music@Home - Preschool

M@H - Preschool Items	M@H-GF	PB	CAE	PIn MB	BME
1. I believe that children should learn to play an instrument	.49	.60			
2. I believe that music is part of a well-rounded education	.44	.20			
3. My child was deliberately sung to/exposed to music whilst in the womb	.43	.22			
4. I believe music has an impact on my child's intelligence	.52	.44			
5. I think musical activities are important for learning to communicate	.51	.24			
6. My child enjoys making sounds/interacting with musical instruments (including toy ones)	.60		.57		
7. My child rarely makes music	.58		.45		
8. My child does not use objects to intentionally produce sounds	.56		.52		
9. My child enjoys toys with musical features	.46		.37		
10. I sing in playful contexts to/with my child at least once a day	.57			.55	
11. I sing to/with my child in many different situations (e.g. during playtime, with friends and family)	.62			.48	
12. I sing to/with my child several (e.g. 5 - 10) times a day.	.56			.70	
13. I do not feel comfortable singing to my child in public or when others are around.	.46			.23	
14. I make music with my child (including toy instruments) almost everyday	.58			.49	
15. I do not make music with my child (including toy instruments) more than once or twice per week	.59			.42	
16. My child is exposed to a broad range of musical styles at home (e.g. pop, rap, dance, classical etc)	.53				.60
17. I sing all different types of songs to my child (e.g. adult songs, traditional folk songs)	.63				.53
18. I would only expose my child to "children's music"	.38				.43
19. I sing mostly children's songs or lullabies to or with my child	<.20				.48

M@H-GF = Music@Home-General Factor, PB = Parental Beliefs, CAE = Child's Active Engagement with Music, PInMB = Parent Initiation of Musical Behavior, BME = Breadth of Musical Exposure.

As a final step, a confirmatory factor analysis (CFA) procedure was employed to examine the factorial validity of the model we had constructed using the Schmid-Leiman procedure. Analysis was carried out using the R package *lavaan*. A bi-factor model was tested which, as suggested by the EFA, comprised of: [a] a general factor

defined by all the items in the reduced version except item 19 which did not load adequately on the general factor and, [b] 4 sub- factors corresponding to the groupings above. When the model was run in the first instance, it was observed that two items had weak loadings on one of the sub- factors (both loadings $< .2$) indicating that these should be removed. The model was then re-run without these two items. All factor residual variances were set to 1 and all factors were set to be uncorrelated as suggested in Beaujean (2014). According to the RMSEA, CFI and SRMR fit indices the model had a good confirmatory fit to the data (see Table 4.7) while the TLI index was close to the cut-off of .95 (Hu & Bentler, 1999).

4.3.2. Music@Home Questionnaire Infant version - Results from exploratory and confirmatory factor analysis.

First, 10 items were excluded from further analyses as they were found to have highly skewed distributions (> 1.2). Not all items with skewness values >1 were removed because a number of them were considered to be conceptually meaningful for the infant group. Furthermore, exclusion criteria of skewed variables range from cut-off values >1 (Floridou, Williamson, Stewart, & Müllensiefen, 2015) to cut-off values >2 , (Biddle, Wang, Chatzisarantis, & Spray, 2003), therefore, a cut-off value of >1.2 can be considered acceptable. Next, dimensionality of the data was explored. As with the preschool version, different criteria suggested solutions where the optimal number of factors varied from 1 to 8. This result, as well as the fact that the first factor extracted yielded an eigenvalue 5 times larger than the second factor suggested the presence of a model where a general factor existed in parallel with domain-specific sub-factors (Chen, West, & Sousa, 2006; Beaujean, 2014). The McDonald coefficient omega (McDonald, 1999) value confirmed the presence of a hierarchical model for all possible numbers of sub-factors; these numbers ranged from 1 to 12. For each one of these solutions values of omega ranged from .68 to .77. Hierarchical factor analysis models that included sub-factors showed better fit than a 1-factor model.

As before, a one-factor analysis was first performed, and the matrix of residuals was extracted (Müllensiefen et al., 2014). A parallel analysis on the residual matrix combined with the Kaiser's and the MAP criterion suggested the existence of 5 sub-factors. This was taken as clear indication that five was the optimal number of sub-factors. Following the analysis of the Preschool version and since both versions were

part of the same instrument, the model was conceptualized as bi-factor. The Schmid-Leiman procedure with maximum likelihood estimation and oblique rotation was then used to explore the factor structure of the items.

The procedure was re-run until 23 items remained. Overall, 14 items with high uniqueness values ($>.7$) and 13 items with either very low loadings ($>.2$) or similar loadings on two rather than one sub-factor (loadings between $.2$ and $.35$) were removed. A subsequent analysis using the Schmid-Leiman procedure on those 23 items yielded a five-factor solution (all factors had eigenvalues >1) with a very good overall fit to the data (RMSEA = $.049$) and a high omega value ($.7$). Twenty out of 23 items had high loadings on the general Musical Experience in the Family factor ($>.40$) (see Table 4.6). The 3 items with weaker loadings on the general factor had very high loadings on one of the sub-factors ($>.60$). All items loaded adequately on one of the sub-factors ($>.20$). Two items that were loading on two sub-factors rather than one were kept because [a] their loading on one factor was much higher than the other [b] they were conceptually relevant to the factors they loaded more highly on, and [c] removing them would weaken the respective factors' eigenvalues.

Table 4.6. Structure of factors and item loadings for the Music@Home - Infant

M@H - Infant Items	M@H-GF	PB	ER	CAE	PInS	PInMM
1. I believe that children should learn to play an instrument	.46	.50				
2. I believe that music is part of a well rounded education	.48	.60				
3. My child was deliberately sung to/exposed to music whilst in the womb	.44	.49				
4. I believe music has an impact on my child's intelligence	.46	.46				
5. I sing to soothe my child	.44		.37		.21	
6. I find music does not influence my child's mood or emotional state	.44		.42			
7. I find my child is not soothed by music or singing	.41		.76			
8. My child displays no physical signs of engagement when there is recorded music on (e.g. bouncing or tapping)	.37		.22	.61		
9. I encourage my child to move along to music	.43			.46		
10. I have noticed my child moving in time with the beat of the music	.25			.74		
11. My child does not dance/move to music on the stereo or television	.32			.87		
12. Music does not evoke a physical response from my child	.45			.72		
13. My child rarely makes music	.47			.48		.29
14. I sing in playful contexts to/with my child at least once a day	.64				.47	
15. I sing to/with my child several (e.g. 5 - 10) times a day	.66				.50	
16. I teach my child new songs	.60				.37	
17. I do not usually choose to play games that involve singing/music with my child	.58				.29	
18. I sing to/with my child in many different situations (e.g. during playtime, with friends and family)	.67				.41	
19. During our daily routine, I do not spend much time singing about what we are doing	.56				.43	
20. Our daily routines often involve music (e.g. during tooth brushing, bath time)	.58				.21	
21. Making music with my child (including toy instruments) is a regular part of playtime at home	.63					.54
22. I make music with my child (including toy instruments) almost everyday	.67					.55
23. I do not make music with my child (including toy instruments) more than once or twice per week	.67					.45

M@H-GF = Music@Home-General Factor, PB = Parental Beliefs, ER = Emotion Regulation
 CAE = Child's Active Engagement with Music, PInS = Parent Initiation of Singing, PInMM =
 Parent Initiation of Music Making.

The next step was to designate appropriate labels to the 5 groupings suggested by the sub- factors. The first grouping (as in the Preschool version) included items that reflected parent’s attitudes towards music and development. The first factor was therefore named *Parental Beliefs*. The second grouping of items concerned parental activities and attitudes about regulating the child’s emotion through music and singing. It was therefore labelled *Emotion Regulation*. The third grouping of items was related to the child’s engagement with musical activities and was therefore named *Child’s Active Engagement*. The fourth grouping included statements about singing activities that were initiated by the parent and was therefore labelled *Parent Initiation of Singing*. The fifth factor included items concerned with parent-child music-making and was therefore named *Parent Initiation of Music-Making*. It is important to note that analogies, but also differences are observed between groupings in the Preschool and Infant versions. Implications and possible interpretations of these analogies and differences are discussed in section 4.7.

Finally, a CFA procedure was employed to examine the factorial validity of the model. A bi-factor model was tested which, as suggested by the EFA, comprised of: a general factor defined by all the items in the reduced version of the questionnaire and 5 sub- factors. When the model was first run, it was observed that two of the items had weak loadings on one of the sub- factors (Parent Initiation of Singing; loadings was $<.2$) suggesting that they should be removed. After removing these two items, the model was re-run. All factor residual variances were set to 1 and all factors were set to be uncorrelated. This model showed a good fit to the according to the RMSEA, CFI and SRMR fit indices while the TLI index was close to the cut-off of .95 (see Table 4.7).

Table 4.7. Fit indices for the two versions of the Music@Home tested in CFA.

CFA models	χ^2	<i>df</i>	RMSEA	CFI	TLI	SRMR
Music@Home- Preschool	208.89	103	.054	.945	.927	.045
Music@Home- Infant	2606.47	168	.051	.947	.934	.049

4.4. Stage 2 – Methods

The purpose of Stage 2 was twofold: [a] to test the factor structure suggested by the EFA employed in Stage 1 using a different sample of participants and [b] to establish reliability and validity of both versions of the Music@Home Questionnaire (Infant and Preschool). A further aim was to assess whether the instrument would be associated with characteristics of the parents such as personal engagement with music and musical training.

4.4.1. Participants

Music@Home Questionnaire - Preschool version

A total 213 participants completed the Preschool version of the Music@Home Questionnaire. The primary caregiver completing the survey was mainly the mother ($n = 194$), while in few cases it was the father ($n = 19$). Demographic information for participating parents and children are presented in Tables 4.8 and 4.9 respectively. The overwhelming majority of participants were native speakers of English. The majority of the participants were UK residents, while a number resided in other English-speaking countries (see Table 4.8). Other countries of residence included France, Romania, Germany, Denmark, Luxembourg, Switzerland, Russian Federation, Pakistan, Malaysia, Jordan and Burma. The mean age of participants was 37.02 years ($SD = 4.49$). The mean age of the children for whom the survey was completed was 3.34 years ($SD = 11.64$ months). As a proxy for socioeconomic status, rather than using the level of income, National Statistics Socio-economic Classification (NS-SEC) was used, which is the latest revised socio-economic classification recommended by the Economic and Social Research Council (ESRC) and commissioned by the Office for National Statistics (ONS) (Rose, Pevalin, & O'Reilly, 2005). The NS-SEC derives information from occupation (8 occupational categories see Appendix B) and employment status/size of organization to classify individuals in 5 classes (see Table 4.8). The NS-SEC is an internationally accepted classification and has been validated as a good predictor of educational outcomes (Rose et al., 2005).

Table 4.8. Demographic information for Music@Home-Preschool participants.

	n	%
Level of English		
Native	183	85.9%
Fluent	15	7.0%
Advanced	15	7.0%
Country of Residence		
United Kingdom	163	76.5%
United States of America	21	9.9%
Australia	6	2.8%
Canada	1	0.5%
Ireland	2	0.9%
New Zealand	1	0.5%
Other	19	8.9%
Level of Education		
Did not complete school qualification	-	0%
First School Qualification (e.g. GCSE/Junior High School)	4	1.9%
Second qualification (e.g A levels/High School)	8	3.8%
Undergraduate Degree or professional qualification	65	30.5%
Master's degree or above	136	63.8%
SES (NS-SEC)		
Managerial and professional occupations	191	89.7%
Intermediate occupations	7	3.3%
Small employers and own account workers	10	4.7%
Lower supervisory and technical occupations	2	0.9%
Semi-routine and routine occupations	3	1.4%

Table 4.9. Demographic information for children for whom the Music@Home-Preschool was completed.

	n	%
Gender		
Female	84	39.4%
Male	129	60.6%
Language		
English Monolingual	186	87.3%
English Bilingual	14	6.6%
Monolingual other	11	5.2%
Bilingual other	2	0.9%
Number of children in the family		
Only child	99	46.5%
2 children	90	42.3%
3 children	16	7.5%
4 or more children	8	3.8%

Music@Home Questionnaire - Infant version

A total 213 participants initially completed the Infant version of the Music@Home Questionnaire. The primary caregiver participating was predominantly the mother ($n = 206$), while in few cases it was the father ($n = 6$) or another relative ($n = 1$). Demographic information for participating parents and children is presented in Tables 4.10 and 4.11 respectively. Most of the participants were English native speakers. The majority of the participants were UK residents, while a number of them resided in other English-speaking countries (see Table 4.10). Other countries of residence included China, Spain, France, Italy, Greece, Netherlands, Norway and Czech Republic. The mean age of participants was 35.14 years ($SD = 4.60$). The mean age of the children for whom the survey was completed was 12.81 months ($SD = 5.71$ months).

Table 4.10. Demographic information for Music@Home-Infant participants.

	n	%
Level of English		
Native	187	87.8%
Fluent	15	7.0%
Advanced	11	5.2%
Country of Residence		
United Kingdom	183	85.9%
United States of America	9	4.2%
Canada	2	0.9%
Australia	3	1.4%
Ireland	1	0.5%
Other	15	7.0%
Level of Education		
First School Qualification (e.g. GCSE/Junior High School)	10	4.7%
Second qualification (e.g A levels/High School)	7	3.3%
Undergraduate Degree or professional qualification	85	39.9%
Master's degree or above	109	51.2%
Missing	2	0.9%
SES (NS-SEC)		
Managerial and professional occupations	185	86.9%
Intermediate occupations	8	3.8%
Small employers and own account workers	10	4.7%
Lower supervisory and technical occupations	4	1.9%
Semi-routine and routine occupations	5	2.3%
Missing	1	0.5%

Table 4.11. Demographic information for children for whom the Music@Home-Infant was completed.

	n	%
Gender		
Female	108	50.7%
Male	105	49.3%
Language		
English Monolingual	176	82.6%
English Bilingual	16	7.5%
Monolingual other	17	8.0%
Bilingual other	4	1.9%
Number of children in the family		
Only child	130	61.0%
2 children	62	29.1%
3 children	17	8.0%
4 or more children	4	1.9%

4.4.2. Materials

As in Stage 1, all items were entered into the *Qualtrics* online survey tool (*Qualtrics*, Provo, UT). A 7-point agreement-disagreement scale was used for all items of the reduced-item versions of the Infant and Preschool Music@Home Questionnaire. The demographic information section included 22 items that were completed before the participant was directed to either the Infant or the Preschool version of the survey (see Appendix B for a copy of the Stage 2 survey).

With the aim of testing the convergent and divergent validity of the newly developed instrument and to examine whether there would be associations with parental characteristics relevant to musical engagement (as measured with the Gold-MSI) the survey included:

[a] Two subscales from the Goldsmith's Sophistication Index (Müllensiefen et al., 2014), namely the Musical Training and Musical Engagement subscales.

[b] Five items derived from the Parent Music Activities subscale of the Children's Music Behavior Inventory (CMBI; Valerio et al., 2012) to test for convergent validity. These items were selected from a subset of 10 items that had the highest loadings on the Parent Music Activities factor of the CMBI (Valerio Wendy, personal communication

03/06/2016). Their selection was based on their applicability for both infants and preschoolers.

[c] Two subscales the Stim-Q Cognitive Home Environment (Dreyer, Mendelsohn, & Tamis-LeMonda, n.d.) were used to test for divergent validity, namely the Reading and Parental Involvement in Developmental Advance scales. The Stim-Q assesses the quality of the home learning environment and similarly to the Music@Home Questionnaire, different versions have been developed for infants and preschoolers. Therefore, both the Stim-Q Infant and the Stim-Q Preschool were used in our Stage 2 survey.

4.4.3. Procedure

As in Stage 1, English-speaking participants (including native, advanced and fluent speakers) were recruited via social media, parent networks, participant databases and public mailing lists. Given that there was a considerable time lag (approximately 1.5 months) between data collection for Stages 1 and 2, an overlap with some participants from Stage 1 taking the survey again was possible. A total of 12 individuals participating in the Preschool version completed the survey both in Stages 1 and 2. All participants completed the survey between June and November 2016.

For the test-retest reliability phase all participants who had agreed to be involved in future research by providing their email addresses received an email invitation to re-complete the reduced-item version of the infant and preschool questionnaires within 1 month of completing the Stage 2 survey. A total of 27 participants for the Preschool version ($M_{age\ of\ children} = 3.30$ years, $SD = 11.95$ months) and a total of 31 participants for the Infant version ($M_{age\ of\ infants} = 10.87$ months, $SD = 4.75$ months) took the survey on both occasions.

4.5. Stage 2 – Results from reliability and confirmatory factor analyses.

As a first step the internal reliability of each subscale corresponding to each factor of the Music@Home questionnaires was assessed, using four different measures, namely Cronbach's alpha, MacDonald's omega total, and Guttman's lambda 6. As can be seen in Table 4.12, all subscales of the Preschool version showed moderate to very good reliability estimates. Similarly, all subscales in the Infant version apart from *Emotion Regulation* showed moderate to very good reliability (see Table 4.12). Table 4.12 also presents test-retest reliability correlations. All subscales in both versions apart

from the *Emotion regulation* subscale of the Music@Home Questionnaire-Infant, display high test-retest correlations (.647 to .871) significant at the $p < .001$ level. The test-retest correlation for the *Emotion Regulation* subscale is non-significant.

Given that the CFA run in stage 1 rendered very good fit indices for a Music@Home Questionnaire-Infant model that included the *Emotion Regulation* subscale (see Table 4.7), and that the *Emotion Regulation* individual items loaded highly on their associated factor in addition to the general factor (all loadings significant at the $p = .001$ level), it is surprising that this subscale showed low internal and test-retest reliability with a new sample of participants. These results however suggest that the correspondence of these items to a sub-scale named *Emotion Regulation* is questionable. Thus, this subscale and its items were excluded from further analyses. Reliability of the Music@Home Questionnaire –Infant general factor was then recalculated. This analysis returned very good internal and test-retest reliability (internal reliability: $\alpha = .873$, $\omega_{tot} = .879$, $\lambda_{G6} = .909$, test-retest reliability: $r = .695$, $p < .001$).

Table 4.12. Estimates of internal reliability and test-retest reliability correlations for the Music@Home-Preschool and Music@Home-Infant factors.

	alpha	omega.tot	G6	test-retest
M@H-Preschool general factor	.851	.871	.895	.83***
Parental beliefs	.710	.735	.674	.87***
Child's active engagement	.765	.781	.746	.68***
Parent initiation of musical behaviour	.799	.804	.766	.82***
Breadth of musical exposure	.662	.676	.602	.81***
M@H-Infant general factor	.876	.883	.911	.65***
Parental beliefs	.693	.717	.637	.82***
Emotion regulation	.569	.584	.480	.21
Child's active engagement	.835	.842	.832	.67***
Parent initiation of singing	.808	.820	.793	.64***
Parent initiation of music-making	.857	.861	.803	.68***

M@H = Music at Home

For both Preschool and Infant versions, four different factor models that differed in their factor structure and specification of inter-factor correlations were examined.

Model 1 was the one identified in Stage 1, which was specified as a bi-factor model with a general factor impacting directly on all items (i.e., all items loaded directly on the general factor) while the sub- factors also impacted on the items associated with them (i.e., individual items also loaded on their respective factors). Model 2 was specified as a hierarchical model where the general factor impacted on the sub- factors, which in turn impacted on their associated items. Model 3 replicated the factor structure of Model 2 but allowed for group factors to inter-correlate. Model 4 did not include a general factor and items only loaded on group factors. It is important to note that when items are summed to provide sub-scale overall scores (as in both Music@Home questionnaires) it is not recommended to have item weights within each sub-scale that are higher than others (Comrey, 1988). To meet this recommendation all item loadings were constrained within the general factor and each of the sub- factors were set to be equal.

Fit indices for both versions of the Music@Home questionnaire are presented in Tables 4.13 and 4.14. In both Music@Home-Preschool and Infant versions, Models 1, 2 and 3 which included a general factor that either impacted directly on all the items of the questionnaire (Model 1) or on the sub- factors (Models 2 and 3), showed better confirmatory fit to the data when compared to Model 4 which did not include a general factor.

Table 4.13. Fit indices for the four Music@Home-Preschool models assessed with CFA.

Models	χ^2	df	RMSEA	SRMR	CFI	TLI	AIC	BIC
Model 1	342.601	131	.087	.108	.768	.759	10868.26	10999.35
Model 2	336.554	131	.086	.105	.775	.766	10864.74	10995.83
Model 3	319.126	121	.088	.102	.783	.756	10878.52	11043.23
Model 4	485.626	131	.112	.217	.612	.601	11052.21	11179.94

Table 4.14. Fit indices for the four Music@Home-Infant models assessed with CFA.

Models	χ^2	df	RMSEA	SRMR	CFI	TLI	AIC	BIC
Model 1	371.841	148	.084	.142	.815	.808	11493.81	11631.63
Model 2	356.990	148	.081	.117	.827	.821	11478.81	11616.62
Model 3	310.879	138	.077	.102	.857	.841	11459.30	11630.73
Model 4	495.029	149	.104	.222	.713	.706	11636.05	11770.50

In light of these results it was concluded that for both questionnaires, models that include a general factor representing a general home musical experience construct in addition to four sub- factors reflecting different facets of this construct, show the best fit to the data. It is worth noting that differences in fit indices between Models 1, 2 and 3 have no consequences for the practical application of the questionnaire.

4.6. Stage 2 - Results from convergent and divergent validity

Regarding convergent validity, high correlations between the newly developed instrument and items from an already validated questionnaire (CMBI; Valerio et al., 2012) were predicted, capturing frequency of parent-child musical activities. In terms of divergent validity low to moderate correlations were expected between the Questionnaire and two subscales of an instrument measuring general engagement of parents in learning activities with their children, namely the Reading and Parental Involvement in Developmental Advance (PIDA) subscales of the Stim-Q (Dreyer et al., n.d.).

As shown in Table 4.15, both versions of the Music@Home and their associated subscales show highly significant correlations with the CMBI, establishing convergent validity of the scale. Furthermore both the Preschool and Infant versions of the new instrument exhibit low to moderate associations with the Reading and PIDA subscales of the Stim-Q, suggesting that the Music@Home Questionnaire measures a unique form of engagement that is separate from general engagement of parents with their children. Interestingly, one subscale of the Music@Home-Infant i.e., the *Child engagement with music* subscale shows high correlations with both the Reading and PIDA subscales. As it is unlikely that this subscale, which refers to the child's behaviour, measures general parental engagement, this result might indicate a connection between the quantity and quality of parent-child engagement in various activities and the child's attitude towards these activities (see section 4.7 for a more detailed discussion). Finally, the Music@Home Preschool and Infant versions and their corresponding factors showed differential associations with the Gold-MSI subscales, raising interesting questions regarding the development of parent-child patterns of musical interaction as the child grows older.

Table 4.15. Convergent and divergent validity of the Music@Home Preschool and Infant versions and associations with Gold-MSI subscales.

	CMBI	StimQ- Reading	StimQ- PIDA	Gold-MSI -Act Eng	Gold-MSI - MusTrai
M@H-Preschool general factor	.49***	.09	.04	.40***	.05
Parental beliefs	.45***	.11	.03	.39***	.05
Child's active engagement	.37***	-.02	-.02	.17*	.03
Parent init of mus behavior	.46***	.07	.03	.36***	.05
Breadth of musical exposure	.24***	.13	.08	.34***	-.00
M@H-Infant general factor	.53***	.12	.20**	.24***	.23***
Parental beliefs	.40***	-.11	.03	.38***	.37***
Child's active engagement	.32***	.27***	.33***	.07	.06
Parent init of singing	.38***	.03	.08	.18*	.14*
Parent init of music-making	.48***	.06	.07	.14*	.17*

M@H = Music@Home, Parent init = Parent initiation, CMBI = Children's Music Behavior Inventory, PIDA = Parental Involvement in Developmental Advance, Gold-MSI-MusTrai = Gold-MSI-Musical Training.

4.7. Discussion

The purpose of the present study was to develop and evaluate a comprehensive and systematic parent report instrument to assess informal musical experience in the family for children under the age of 5. Given the qualitative differences in the way parents may engage musically with infants relative to preschoolers, two versions of the novel Music@Home Questionnaire were developed i.e., Preschool and Infant versions.

Stage 1 of this study included the generation of an initial pool of items for the Music@Home Preschool and Infant Questionnaires, and the use of exploratory and confirmatory factor analysis to identify the underlying factor structure of the questionnaires. Subsequently, the initial pool of items was reduced to provide an easy-to-administer tool. In Stage 2, data from a different sample of participants were used to evaluate the reliability of the new instrument and to validate its factor structure. Using data from the sample collected in Stage 2, convergent and divergent validity of the Music@Home Questionnaire were also tested. Finally, given that an association between informal musical experience and the Gold-MSI emerged in Study 2,

correlational analyses were conducted to test associations between the Music@Home factors and two subscales of the Gold-MSI assessing musical training and active engagement with music.

Results showed that the Music@Home experience for both infants and preschoolers was best described as comprising a general factor corresponding to musical experience in the family, while dimensions or sub-factors of this construct existed in parallel (Chen, West, & Sousa, 2006; Beaujean, 2014). These sub-factors quantify a range of dimensions relevant to informal musical experience in the home. The factor structures of the Infant and the Preschool versions differed in terms of sub-factors they included, reflecting variations in the musical engagement and nature of parent-child interactions between the two age groups. The dimensions identified and the similarities and differences between the Infant and the Preschool versions outlined below provide new insights about early musical experience in the home.

With respect to the Music@Home Questionnaire-Preschool, four factors were identified corresponding to the following dimensions: Parental Beliefs, Child Engagement, Breadth of Musical Exposure and Parent Initiation of Musical Behavior. A variant of this structure was identified for the infant version, the five factors of which were assigned the following names: Parental Beliefs, Child Engagement, Emotion Regulation, Parent Initiation of Singing, and Parent Initiation of Music-making. Notably, the Emotion Regulation subscale exhibited low internal and test-retest reliability in the Stage 2 data analysis and was subsequently discarded.

“Parental beliefs” represents notions of the parents with regards to the beneficial effects of music on their child’s general development. Importantly, the same cluster of questions that reflected parental beliefs in the Music@Home Questionnaire - Preschool were also uncovered during the Infant version analysis, suggesting that this is a facet of informal musical experience consistent across ages. The Preschool version however, included an extra item (“*I think musical activities are important for learning to communicate*”) reflecting the expanded communicative repertoire of preschoolers. This aspect has previously been addressed in studies looking into the musical home environment of infants and preschool children (Custodero & Johnson-Green; 2003; Illari, 2005; Mehr, 2014) or exploring music-related parental attitudes in relation to music educational outcomes (Brand, 1986; Cho, 2015; Driscoll et al., 2015; Dai & Schader, 2002; Sichivitsa, 2007). These studies have shown that parents whose children participate in music classes usually have positive beliefs towards the general

educational benefits and significance of music practice (Cho, 2015; Dai & Schader, 2002), and that parental attitudes can be positively associated with children's musical attainment and motivation (Brand, 1986; Driscoll et al., 2015; Sichivitsa, 2007). Furthermore, the majority of parents of preschoolers who expressed positive beliefs about the benefits of music education also reported high frequency of singing and listening to music with their children (Mehr, 2014). Taken together, the findings indicate that parental attitudes and beliefs are important factors influencing children's musical experience in formal or informal settings. Therefore, this sub-scale provides a consistent measurement of a dimension that will contribute to providing a complete picture of informal musical experience in the home.

The "Child engagement" subscale, which represents children's active participation and initiation of musical activities, was a factor that emerged in both infant and preschool versions of the Music@Home Questionnaire. Musical behaviours that emerged as important for each version reflected characteristics of the different age groups (e.g., from the infant version: "*Music does not evoke a physical response from my child*"; example item from the preschool version: "*My child enjoys making sounds/interacting with musical instruments, including toy ones*"). Children's musical engagement and participation has been thoroughly addressed in the work of Valerio et al., (2012) who constructed a parent-report questionnaire with the specific aim of documenting preschool children's musical behaviour (the Children's Musical Behaviour Inventory; CMBI) in order to best meet their musical needs in childcare and school settings. Although this is the only existing validated measurement of children's musical engagement, the importance of observing and documenting aspects of the child's music-related behaviour in musical development research and music education has long been recognized (Custodero, 2006; Custodero, Britto, & Brooks-Gunn, 2003; Custodero & Johnson-Green; 2003; Moog, 1976; Rainbow, 1981; Rutkowski, 1990; Welsch, 2006). Including a relevant subscale in a systematic instrument assessing informal musical experience such as the Music@Home Questionnaire opens new avenues for exploring, in experimental contexts, how the interplay of parent-child characteristics may affect the child's experience as well as their developmental outcomes.

The "Parent Initiation of Musical Behaviour" subscale of the Music@Home Questionnaire-Preschool, indexes parent-triggered musical engagement, such as singing and making music with the child. Undoubtedly, parent-child musical interactions are a crucial aspect of the home musical experience and a higher frequency of parent-child

involvement in music during the early years has previously been associated with positive outcomes, such as enhanced auditory sensitivity (Putkinen et al., 2013) and better vocabulary skills (Williams et al., 2015). Along with parental beliefs and attitudes, parental musical involvement with their children at home has long been recognized as an important influence in children's musical attainment (Brand, 1986).

Although in the Music@Home Questionnaire-Preschool singing and music-making comprised a single factor exhibiting very good internal reliability, these two activities emerged as separate factors in the Music@Home Questionnaire-Infant. The distinction between the two versions' factor structure, is likely to reflect differences in the extent to which parents of different age groups engage in the two activities. Clearly, infants up to the age of 2 years engage in active music-making to a lesser extent, while parental singing appears to hold a central role in regulating arousal (Shenfield et al., 2003) and in building emotional interaction in infancy (Nakata & Trehub, 2004; Van Puyvelde et al., 2014). Furthermore, approaching singing in infancy as a separate dimension highlights the importance that this activity may carry for developmental outcomes such as socio-emotional development and language learning (Lebedeva & Kuhl, 2010; Thiessen & Saffran, 2009; Van Puyvelde & Franco, 2015). Indeed, due to the rhythmic and melodic properties of song that emphasize and exaggerate speech elements, singing has been shown to facilitate phonetic learning in 6- to 8- and in 11-month-old participants (Lebedeva & Kuhl, 2010; Thiessen & Saffran, 2009). Another possibility is that infants benefit from the combined input of music and lyrics, since a second source of information (music) provides additional cues to help them identify structure in the first source (i.e., words and syllables) (Thiessen & Saffran, 2009). In addition, Van Puyvelde and Franco (2015) have proposed that the melodic patterns and moments of 'tonal synchrony' observed in parent-infant vocal interactions (Van Puyvelde et al., 2010), which facilitate affective co-regulation (Van Puyvelde et al., 2014) may well be a prerequisite for later social development. Therefore, since one of the key aims of developing the Music@Home Questionnaire is its future use in experimental research addressing the potential effects that aspects of informal musical experience may have on development, including parental singing as a separate subscale for the infant version is well motivated.

Another dimension that emerged in the Music@Home Questionnaire-Preschool but not in the Infant version refers to the breadth of musical exposure in the home, including music that is sung or listened to. This grouping of items reveals an aspect of

the home experience with music that has not previously been addressed as a separate dimension of potential importance. Questionnaires or interviews in previous studies have embedded items about the quantity of music heard in the home or the number of musical resources such as CD's, musical and toy instruments (Brand 1985; 1986; Illari, 2005; Young et al., 2008). However, exposing the child to a broad range of musical styles either via song or music listening may reflect qualitative differences in individuals' appreciation of music and motivation to include their children in their musical interests. Not surprisingly, this factor was associated with personal engagement of parents with music. However, it was not correlated with musical training, suggesting that it does not represent formal experience but potentially reflects a unique type of musical sophistication that may extend to how parents interact musically with their children. Exploring the associations of this dimension with other potential variables such as personality characteristics is an interesting question for future studies.

It is important to note that one of the factors that was initially revealed as relevant to the Music@Home Questionnaire-Infant experience, namely "Emotion Regulation", showed low reliability when evaluated with a new sample of participants. This is surprising, given that mood regulation appears to be a central function of music and singing in the infant years (Barrett, 2009; Custodero & Johnson-Green, 2006; Young et al., 2008). One possibility is that a very small number of items were included in this subscale contributing to low reliability of the factor. Another possibility is that the negative items in the subscale (two of three items were negatively worded) were unclear to participants, leading them to respond erratically thus affecting intercorrelations between items and compromising internal reliability. As test-retest reliability of this subscale was also low, it was subsequently removed from further analysis.

Strong associations were observed between all subscales of the Music@Home Questionnaire-Preschool and Infant versions, and a subscale of the CMBI (Valerio et al., 2012) measuring parental involvement with music (i.e., *Parent Music Activities*). This establishes convergent validity of the Music@Home questionnaires. Notably, although highly significant, correlation coefficients were not higher than .60, suggesting that Music@Home measures a relevant but not identical construct to the CMBI-*Parent Music Activities*. Divergent validity of the questionnaires was also established, as weak to moderate associations were found between most of the dimensions of the Music@Home Preschool and Infant versions, and two subscales from a validated

instrument (i.e. Stim-Q) assessing the cognitive environment of young children at home (*Reading and Parental Involvement to Developmental Advance* or PIDA). These results suggest that the experience of music at home as assessed with our newly developed questionnaire can be separated from general engagement of parents with their children. A moderately significant correlation that was observed between the Music@Home-Infant general factor and the PIDA subscale suggests that in the case of infants, there is a stronger coupling between engaging in musical activities and promoting learning in all domains.

Interestingly, stronger associations were observed between the *Child Engagement* subscale of the Music@Home Questionnaire-Infant and both the *Reading* and *PIDA* subscales. However, since this subscale reflects infants' attitudes and behaviours towards music, it is unlikely that it assesses a concept similar to general parental engagement. Rather, it is possible that this finding hints at an association between the level of parent-child engagement in various activities and the child's attitude towards these activities. In line with this view, Kuhl (2003; 2011) has argued that interpersonal engagement can have determinant effects on infant attention and arousal.

Further supporting this argument, *Child Engagement* from the infant version was the only factor that was not related to parental musical characteristics as measured with the Gold-MSI subscales (*Active Engagement* and *Musical Training*). This suggests that on one hand young infants are not yet in a position to imitate or be influenced from their parents' personal interests while on the other hand, that they may benefit more from active participation in joint activities.

Differential associations emerged between the subscales of the Gold-MSI and the two versions of the Music@Home Questionnaire. Specifically, the general factor and all subscales of the Music@Home Questionnaire-Preschool showed strong associations with parent's personal engagement (*Active Engagement factor*) with music but not musical training (*Musical Training factor*). Conversely, consistent with Custodero & Johnson-Green (2003) who found that musically trained parents were more likely to engage musically with their infants, the Music@Home-Infant general factor and most of the subscales showed strong associations with both parental engagement with music and parent's musical training. These findings possibly reflect differences between the two age groups' characteristics and modes of interaction. In the case of preschoolers, where there is a more limited time window for parent-child

engagement and a broadening of external influences due to changes in everyday activities (e.g., parents may be back at work, children may be attending nursery), it is the parents' level of personal engagement with music that affects the mode of interactions with their children, whereas musical training (which may have been received some years ago) does not determine their current level of joint activities to the same extent. In the case of infants however, there might be a greater opportunity for parental characteristics to be reflected in the way they interact with their young ones, either due to spending a greater amount of time at home with infants relative to preschoolers (see <http://www.oecd.org>) for statistics on children attending day care in function of age), or because personal inclinations may weigh more in orienting the choice of activities at developmental stages in which children have more limited vocal and motor abilities. Future studies need to address these alternatives more specifically in order to elucidate their potential role in shaping everyday musical experiences at the start of the developmental path.

To summarize, the Music@Home Preschool and Infant questionnaires provide researchers and educators with a quick-to-administer, valid and reliable instrument for the systematic assessment of informal musical experience in the home. Importantly, this new instrument brings together for the first time novel dimensions such as breadth of musical exposure, and combines them with more typically studied aspects of informal musical experience, allowing for a comprehensive tool to capture the extent of musical activities occurring informally within the home. Future studies can make use of this instrument to explore the nature of the home musical experience, examine its associations with individual and parent characteristics and investigate its potential contribution to various developmental outcomes.

CHAPTER 5: LINKS BETWEEN MUSIC AND LANGUAGE STRUCTURE: THE ROLE OF INFORMAL MUSICAL EXPERIENCE (STUDY 4)

Abstract

Study 4 was designed to address the hypothesis that language and music structural processing are related in preschoolers and that home experience with music, as assessed with the questionnaire developed in Study 3, is associated with these skills. The assessment of preschool children's musical ability focused on melodic structural processing, namely the degree of expectedness of endings in simple Western musical phrases. Children were tested on a newly developed melodic priming task that used melodies with either "expected" or "unexpected" endings according to rules of Western music theory. The stimuli in this task were constructed using the Information Dynamics Of Music or IDyOM system (Pearce, 2005), a probabilistic model estimating the level of "unexpectedness" of a note given the preceding context. The main findings from Study 4 revealed that children processed melodic structures in an adult-like manner. Processing of language structure (i.e., grammar skills) was only marginally associated with processing of music structure. Dimensions of informal musical experience in the home were associated with music structural processing. Critically, a strong relationship between informal musical experience in the home and the development of language grammar emerged, a significant finding corroborating the results from Study 2.

5.1. Background, rationale and aims of Study 4

As discussed in the literature review (section 1.2.2.1), the study of the processing of musical structure has recently made advancements within the field of developmental research, although few questions still remain. One such question is whether young children can process melodic structures in an adult-like manner.

Another question is whether structural processing in music is associated with processing of language structure (i.e., grammar skills). Although a specific relationship between structural processing in music and language is supported by a number of behavioural and neuroscientific studies in adults (Patel et al., 1998; Slevc et al. 2009; Fedorenko et al., 2009; Sammler et al., 2009; 2013) and children (Jentschke & Koelsch, 2009 with 10- and 11-year-olds; Jentschke et al., 2008 with 4- and 5-year-olds), researchers have so far used electrophysiological testing and artificial music stimuli to

explore this link. Whether the relationship between music and language structural processing holds true when using behavioural measures and ecologically valid musical stimuli remains unknown.

It would also be interesting to explore whether home experience with music, as measured with the newly developed Music@Home Questionnaire, is linked to this type of musical processing in young children. The findings from Study 2 did not reveal any links between musical experience in the family and musical perception skills, as measured by tasks of auditory discrimination and music production. However, the type of implicit processing introduced in this chapter has been previously conceived of as being directly linked to learning through everyday informal exposure to the music of one's culture (see Hannon & Trainor, 2007 for a review).

Processing of musical structure from a developmental point of view has been conceptualized as the gradual acquisition of key membership (knowing which notes belong to a given key) and harmonic relations (having an understanding of which notes and chords are more likely to follow others in a musical piece). With regards to the development of music structural processing, 4- and 5-year-old children already appear to possess implicit knowledge of both key membership and harmonic rules when tested with indirect measures such as EEG (Corrigall & Trainor, 2013; Jentschke et al., 2014) and harmonic priming paradigms presenting them with chord progressions (Marin, 2009; Schellenberg et al., 2005; see section 1.2.2.1 for a review of enculturation to one's musical environment).

In the present study, the assessment of children's musical ability focuses on the degree of expectedness of endings in simple melodic phrases. Unlike previous tasks for children that used chord sequences specifically composed for each experiment (Schellenberg, 2005; Marin, 2009), this task incorporates folk melodies from an existing database of folk tunes (*i.e.*, *the Essen Folk Song Collection*). Therefore, although stimuli are carefully controlled, they also resemble to a greater extent what the child would hear in the everyday environment, contributing to ecological validity of the task. One reason to focus on melodies is that they constitute an important part of Western as well as non-Western musical traditions. Therefore, the results may generalise more naturally cross-culturally. It also offers a new perspective in the study of musical expectations in children, as it includes melodies rather than harmonic progressions. As discussed in the literature review, listeners can build up expectations for the following note in melodies, probed by an implied harmonic structure (*i.e.*, implied chord progression underlying the

melody's notes) (Trainor & Unrau, 2012), while the formation of expectations is considered to reflect enculturation to one's musical environment (Bigand & Poulin-Charronnat, 2006; Tillmann, 2005; Tillmann et al., 2000).

Given this rationale and the greater sensitivity of implicit tasks in tapping the early understanding of harmonic relationships, a melodic priming task was presented to young participants via a child-friendly application with colourful graphics. The task included melodies with either "expected" or "unexpected" endings according to rules of Western music theory (see section 5.2). The stimuli in this task were constructed using the Information Dynamics Of Music or IDyOM model (Pearce, 2005), a probabilistic model estimating the likelihood of a note given the preceding context. This model is based on information theory and statistical learning and has been inspired by the view that listeners form musical expectations via a process of internalizing musical patterns, which ultimately leads to a refined knowledge of musical structure (Tillman et al., 2000).

The IDyOM models the formation of melodic expectations using a process of unsupervised learning and comprises two components: a long-term component exposed to a large corpus of Western tonal melodies, which simulates the formation of expectations through long term exposure to music, and a short-term component trained incrementally for each melody. The short-term component represents immediate influences on expectations that are formed through online processing of the unfolding melody. The predictions of the long and short-term components of the model are combined to provide a prediction for the pitch of the next note. The expectedness of each pitch in the melody is expressed in units of information content (IC). The IC (the negative logarithm, to the base 2, of the probability of an event occurring) is a tool provided by information theory. It is inversely proportional to probability (MacKay, 2003) and reflects the unexpectedness of a given note within a melodic context (Hansen & Pearce, 2012). In brief, a high probability note in a melodic context corresponds to low IC, and should appear as 'expected' to the listener whereas a low probability note corresponding to high IC, should appear as 'unexpected'.

The IDyOM model forms predictions closely simulating cognitive processes that generate expectations based on previous experience and learned regularities, just as statistical learning theory predicts. This process operates over two time scales as predictions also take into account the dynamic formation of expectations during the

unfolding of a melody. This renders the IDyOM model a more elegant option compared to previous accounts (Narmour, 1990; Shellenberg, 1997).

In Narmour's *Implication-Realization* theory (Narmour, 1990) it is suggested that melodic expectations are influenced by two independent perceptual systems: a *bottom-up* system comprising of innate, Gestalt-like principles and a *top-down* system that is acquired through exposure to a specific musical culture. Support for at least some of the principles comprising the bottom-up system was provided by a number of experimental studies (e.g., Cuddy & Lunny, 1995; Krumhansl, 1995). Shellenberg (1996) however, argued that both the Narmour and Krumhansl models are redundant due to collinearities between their constituent principles and may be expressed in a more parsimonious manner. Indeed, Schellenberg (1997) proposed a model to account for the formation of expectations that was arguably simpler. According to this model, two principles can adequately explain the formation of expectations, namely the *principle of proximity* (successive notes tend to be close in pitch) and the *pitch reversal* (itches tend to change direction). Despite exhibiting considerable predictive power, the Schellenberg model made predictions based on a limited number of preceding notes (one or two). In contrast, the IDyOM model can predict the probability of a note occurring based on preceding melodies of variable lengths (Pearce, 2005; Omigie et al., 2013). Furthermore, it has been shown to be superior to the Schellenberg model in predicting individuals' expectations (Pearce et al., 2010).

In summary, the present study used a novel task to probe melodic expectations in preschool children addressing three research questions:

1. Do preschool children already process knowledge of Western musical structure by exhibiting the melodic priming effect in an adult-like manner?
2. Is there an association between young children's processing of musical structure (as reflected in the strength of their melodic expectations) and age-appropriate standardized measures of language grammar?
3. Is informal musical experience and exposure to music in the home associated with the development of these abilities, possibly mediating the relationship between them?

With regards to the first research question, the implicit task including ecologically valid stimuli should provide evidence of melodic expectations in preschool children. With respect to the second research question, music and language processing are expected to be linked, extending the findings of previous studies with children to ecologically valid musical stimuli and systematic measures of linguistic development.

Regarding the third research question, it is anticipated that home musical experience will be linked to both linguistic and musical skills for two reasons: [a] previous findings have suggested effects of formal musical experience on preschoolers' linguistic abilities including processing of language structure (Marin, 2009) while the findings from Study 2 showed strong effects of informal musical experience on the same linguistic skills and [b] as explained above, implicit processing of musical structure has been argued to emerge from learning through everyday informal exposure to a given musical environment. Given that findings in Study 2 indicated that the interaction between melody perception and home musical experience predicted language grammar, in other words, that home musical experience mediated the relationship between musical and linguistic development, it is predicted that a similar model may emerge when considering this aspect of musical processing.

5.2. Materials and methods

5.2.1. Participants

Forty-six participants (24 girls) between the ages of 4 years 9 months and 6 years 10 months were recruited from one of the London schools that participated in Studies 1 and 2. Mean age of participants was 5 years and 9 months ($SD = 7.54$ months). Half of the children ($n = 23$) were attending reception class ($M_{age} = 5.22$ years, $SD = 2.78$ months) and half ($n = 23$) were attending year 1 ($M_{age} = 6.30$ years, $SD = 4.49$ months). All participants had English as their first language (i.e., English was the main language spoken in the household as reported by the parents). The British Picture Vocabulary Scale (Dunn et al., 1997) was administered to all participants with the aim of determining whether they all possessed an adequate level of English. Thirty-nine children were monolingual English speakers while seven children also spoke a second language at home. The sample recruited initially consisted of 48 children. Two children were however excluded from the study: one boy was suspected of attention difficulties by the nursery teachers and one boy had been officially diagnosed with language difficulties.

It is important to note that the implicit task designed to probe melodic expectations in preschoolers was first piloted in a group of 3- and 4-year-old children. However, a considerable proportion of these children (35%) failed to reach the criterion for participation in the study (see section 5.2.4). Furthermore, young children who reached

criterion and completed the task made several errors, thus minimizing the number of trials that could be used in the analyses. It was therefore concluded that an age group > 4 years was more suitable for inclusion in the study.

5.2.2. Ethical approval

Ethical approval for the study was granted by the Middlesex University Psychology Department's Ethics Committee (application no PG011). An acceptance letter was obtained from the participating school and the opt-out consent procedure was used following all necessary regulations (see details on opt-out procedure and Enhanced Certificate in the corresponding section in chapter 2 - Study 1). The information letter distributed to parents is provided in Appendix A.

5.2.3. Materials

Music structural processing – The TimpreApp

A child friendly application (*TimbreApp*) featuring a timbre identification task was created in collaboration with Goldsmiths University PhD student Pedro Kirk (supervisor prof. Lauren Stewart) and was run on an iPad 2. Stimuli for this task were created and arranged by Dr Marcus Pearce (Queen Mary University). Forty five-note melodic phrases were taken from a corpus of folk melodies, the Essen Folk Song Collection and were rendered in piano timbre using the Steinway grand piano sound from *Garageband* software. The melodies had a length of 5 notes each and the last note of each stimulus is always the target, preceded by a context of four notes to ensure that a clear melodic context was established before the child had to respond. Given that the focus was on melodic expectations, the rhythmic structure of the melodies was removed so that each note within the melody had a duration of 500ms while the last note had a duration of 1000ms. The tempo of the stimuli was 120bpm and was chosen based on previous work with young children indicating that preschool children synchronize with greater ease at faster tempi ranging from 100 to 150bpm (Provasi & Bobin-Bègue, 2003; van Noorden et al., 2009; Verney, 2013). It has been proposed that this range, which is close to the preferred and spontaneous motor tempo for young children (Gérard & Rosenfeld, 1995; McAuley et al., 2006; Provasi & Bobin-Bègue, 2003), coincides with an optimal sensitivity zone where processing of musical intervals becomes more accurate (Jones, 1976; Jones & Boltz, 1989).

The average pitch across all melodies was 69.50 in MIDI number¹⁹ (approx. 440 Hz). Half of the stimuli were original melodic phrases taken from the corpus and had high probability endings (i.e., low IC) as calculated using the IDyOM model (Pearce, 2005). The other half of the stimuli had low probability endings (i.e., high IC) chosen by randomly sampling from the distribution returned by IDyOM notes that had a lower probability than the original target note. Therefore, the IC for the target notes was either within the low (IC: $M = 12.34$, $SD = 1.84$, range = 8.01–14.40) or the high range of values (IC: $M = 1.62$, $SD = 0.96$, range = 0.14 – 4.09). Different original melodies were used for the stimuli with low and high probability endings.

Half of the high probability and half of the low probability target notes were altered to a trumpet timbre using *Garageband* software and participants were asked to make speeded judgments about the timbre of the target note by tapping on the image of either a piano or a trumpet on a touch screen. High probability and low probability notes rendered in piano constituted the main targets of interest and high probability and low probability notes rendered in trumpet constituted the foils. Response times and accuracy of responses were measured. Response times were expected to be shorter for high versus low probability target notes. In other words, if children have implicit knowledge of Western musical structure, high probability endings will prime their responses and response times will be shorter, echoing the pattern of adult responses in a similar task making use of the IDyOM (Hansen & Pearce, 2014; Omigie, Pearce, & Stewart, 2012).

Each child completed 40 trials (corresponding to 40 melodies) spread across two sessions. Order of presentation was counterbalanced across participants with half of the children completing trials 1-20 (Block A) and half of the children completing trials 21-40 (Block B) in their first session. Order of trials was randomized within each block. Half the children were presented with a piano left/trumpet right configuration (Configuration 1) and the other half were presented with a piano right/trumpet left configuration (Configuration 2). This way any laterality bias remained constant across all trials for individual participants. Overall, four Block/Configuration combinations were created (see Table 5.1) and participants were assigned to either an A1-B1, B1-A1, A2-B2 or B2-A2 order.

¹⁹ Convention for numbering notes in MIDI instruments such as synthesizers.

Table 5.1. Timbreapp Block/Configuration combinations that participants were assigned to.

Block	Configuration
A = melodies 1-20	1 = piano on the right/trumpet left
A = melodies 1-20	2 = piano left/trumpet right
B = melodies 21-40	1 = piano on the right/trumpet left
B = melodies 21-40	2 = piano left/trumpet right

The IC of the melodies was balanced between different timbres and blocks of trials. A 3-way ANOVA with IC as the dependent variable and Block (A/B), Timbre (piano/trumpet) and Target-type (high/low) as independent variables yielded a significant main effect of Probability [$F(1,36) = 610.89, p < .001, \eta^2 = .944$] and no other main or interaction effects. This confirms that IC differs significantly between the high and low-probability conditions but does not differ between the various combinations of timbre and block.

The size and direction of the final interval of each melody was balanced within the low-probability condition. Specifically, there were an equal number of large (six or more semitones) and small ($N = 10$) and descending and ascending intervals ($N = 10$). Balancing large and small intervals for the high-probability condition was not possible given that these were actual phrases taken from folk songs. There were however an equal number of ascending and descending intervals within the high-probability condition ($N = 10$). A 3-way ANOVA with pitch interval as the dependent variable and Block (A/B), Timbre (piano/trumpet) and Probability Condition (high/low), yielded no significant effects of Block and Probability Condition but a significant effect of Timbre [$F(1,36) = 4.84, p < .05, \eta^2 = .119$]. These results demonstrate that pitch interval did not differ between the two main conditions of interest (high/low probability). The fact that pitch interval significantly differed between the two timbre conditions (piano/trumpet), was not of great concern for this study as previous work with melodic priming in adults (Marmel & Tillmann, 2008; Omigie et al., 2012) has demonstrated that only trials where target notes/chords that are the same timbre as the preceding context provide facilitation in speed of response. Therefore, trials ending with trumpet and trials ending with piano timbre will be examined separately.

The timbre identification task was presented to the children as a game: each trial was presented along with the drawing of a bear-conductor Mr Giles and children were told that Mr Giles needs help with identifying the sound of the instruments, as he cannot hear very well. Participants were therefore asked to “tell Mr Giles what the last sound of each song is” by tapping on the image of the correct instrument as fast as possible. Audio-visual positive and negative feedback for correct and incorrect timbre identification were given at the end of each trial to increase motivation. Positive feedback included the recording of a female voice saying “Well done!” while applause was heard in the background and colourful stars appeared on the screen. Negative feedback included the recording of the same female voice saying “Oh-oh” while the sound of broken glass was heard in the background and disintegrating grey stars fell down from the top of the screen (see Fig. 5.1 for pictures of Mr. Giles, positive and negative feedback). Furthermore, before each block of test trials children were told that they would receive a number of star stickers as a reward (either 5 or 6 stickers) depending of how fast they responded. This ensured that they performed to their best ability in terms of speeded responses throughout each block of trials.



Figure 5.1. Pictures of Mr. Giles, positive and negative feedback from the melodic priming task (*Timbreapp*).

Non-verbal ability and memory

Block Design from the Wechsler Preschool and Primary Scale of Intelligence IV (WPPSI-IV, Wechsler, 2012) was used as a proxy measure of non-verbal ability and the *Digit Span* subtest from the British Ability Scales II (Elliott, 1996) was used to assess verbal memory (see section 2.2.3 for detailed descriptions of the tasks).

Language grammar

The *Language Structure Index* from the *Clinical Evaluation of Language Fundamentals - Preschool-2* (CELF-Preschool-2; Wiig, Secord, & Semel, 2004) was administered to assess language grammar (please refer to section 2.2.3 for a detailed description of the tasks). Standardized scores for the three subtests and a total standardized score for language structure were used in all analyses.

Self-report questionnaires for parents

Parents were asked to complete [a] the newly developed reduced-item version of the Music@Home Questionnaire – Preschool (see chapter 4 for a detailed description) [b] seven ad-hoc items asking about the frequency of the child’s musical activities outside the home, [c] the Reading subscale from the Stim-Q Cognitive Home Environment - Preschool (Dreyer et al, n.d) which assesses the availability of reading materials and the frequency of reading to children between the ages of 3 and 6 years. (the Reading subscale was used as a proxy for the quality of the home learning environment) and [d] the Gold-MSI (Müllensiefen et al., 2014) was administered to assess level of musical sophistication of the parents (see Study 3- Parental Questionnaire in Appendix B).

In order to control for exposure to music of different cultures that might follow different structural rules than the Western melodies included in the task administered, parents completed two additional items assessing: a) types of music the child is most frequently exposed to in the household and, b) types of songs most frequently sung to/with the child. For both items the participant was requested to tick one or more out of six types of musical styles. All children met the requirements of adequate exposure to Western music in the household, i.e., no child was frequently exposed to non-Western musical styles.

It is important to note that 4 out of 46 families did not complete the self-report questionnaires due to parents being unavailable during the times when the questionnaires were handed out and collected. Therefore, the number of participants in statistical analyses involving the variables derived from the self-report instruments (i.e., Music@Home, Reading to child, Musical Activities outside the home and Gold-MSI – Musical Sophisticstion) was $N = 42$.

5.2.4. Procedure

Participants were tested across 3 or 4 sessions each lasting approximately 20 to 30 minutes. Sessions were held on different days and duration of each session depended on child individual characteristics such as attention span and processing speed. The first session was designed to establish that participating children were able to perform the *TimbreApp* task, which requires speeded responses and correct sound/image matching for each instrument (trumpet/piano). Therefore, to ensure that participants can identify the piano and trumpet instruments by their sound and image, 6 trials of a timbre recognition task were first administered. In this task, children listened to a trumpet or a piano sound and had to respond by tapping on the correct instrument. If children responded correctly to 5 out of 6 trials they moved on to the next stage that required them to complete 4 practice trials in the actual task format with a 3 out of 4 inclusion criterion. Two children who did not reach this criterion were excluded from further testing. The *TimbreApp* 40 trials (divided into two sets of 20 trials each, including two practice trials before each set) and the language and cognitive measures were administered in the remaining two test sessions. Order of administration was held constant for all children, but the number of tasks completed in each session varied depending on the child's cognitive profile and mood on the given day. The order of tasks was as follows: Practice session for Timbre app – Screening vocabulary test (BPVS) - Timbre app test session 1 – Sentence Structure – Word structure - Sentence Repetition - Timbre app session 2 – Digit Span – Block Design. Self-report questionnaires were given to parents/guardians during pick-up times and were returned when completed to their children's classrooms.

5.3. Results

All data were analyzed using SPSS version 20.00 and the R software environment (R Core Team, 2012).

A series of non-parametric comparisons (Mann-Whitney and Kolmogorov-Smirnoff) were performed between monolingual ($n = 39$) and bilingual children ($n = 7$) to identify any potential differences in linguistic or cognitive performance resulting from bilingualism. No statistically significant differences were found between monolingual and bilingual children in any of the tasks, thus one group including both monolingual and bilingual children was used for all subsequent analyses. Means and

standard deviations of participants' group performance on all linguistic and baseline cognitive tasks are presented in Table 5.2 below.

Table 5.2. Participants' performance in cognitive and linguistic tasks.

Tasks	Scoring	Min	Max	M	SD
BPVS	M = 100, SD = 15	88	140	112.43	10.43
CELF- LSI	M = 100, SD = 15	77	131	112.67	12.20
WPPSI-BD	Range = 1-19	7	19	12.04	3.09
Digit Span	M= 50, SD = 10	22	99	77.85	18.85

CELF- LSI = CELF - Language Structure Index, WPPSI-BD = WPPSI – Block Design, M = Mean, SD = Standard Deviation, Min = Minimum, Max = Maximum

Results from Study 4 are presented in 4 sections:

Section 5.3.1 presents the results gained from the exploration of the melodic priming effect in our sample.

Section 5.3.2 presents the results gained from correlations between performance in the musical structure task, the cognitive tasks, language grammar and the Music@Home questionnaire.

Section 5.3.3 is a further exploration of the relationship between the musical environment and language grammar, based on findings **from Section 5.3.2**.

Section 5.3.4 presents the results gained from multiple regression analysis where the language grammar was the dependent variable and an interaction between the Music@Home questionnaire and performance in the musical structure task was the independent variable.

5.3.1. Exploration of melodic priming.

Previous work on melodic priming in adults (Marmel & Tillmann, 2008; Omigie et al., 2012) has shown that speed of response is facilitated only for target notes/chords that are the same timbre as the preceding context (target notes all played on piano). However, as this is the first study examining melodic priming in very young children, data for both timbres is presented. Descriptive statistics for accuracy of responses and response times (RT's) sorted by target-type (high probability/low probability) and timbre (piano/trumpet) are presented in Table 5.3.

Given that developmental changes tend to occur rapidly during early childhood a preliminary analysis explored the possibility that age could exert an influence on either accuracy or speed of response. Possible gender differences were also examined using two separate 2x2x2 repeated measures ANOVAs with accuracy and RTs for correct responses as dependent variables. Timbre (piano/trumpet) and target-type (high/low probability) were entered as within-subject factors and age group (reception/year 1) and gender as between-subjects factors. This analysis yielded a significant main effect of age group on RTs [$F(1,42) = 21.66$, $p < .001$, $\eta^2 = .340$] reflecting the fact that older children were generally faster than younger ones (year 1: *Mean* RT = 797.09 msec; reception: *Mean* RT = 1106.69 msec). No significant main effect of gender on either dependent variable was observed (accuracy: $p = .898$, RTs: $p = .602$). No significant interactions of gender with any of the other factors were found when all target notes were considered (accuracy: all p 's $> .1$, RTs: all p 's $> .1$). Furthermore, no significant interactions of gender with any of the other factors were observed when only piano target notes were considered (accuracy: gender-target-type interaction $p = .380$, RTs: gender-target-type interaction $p = .544$). Finally, no significant interactions of age group with any of the other factors were found, either when all target notes were considered (accuracy: all p 's $> .1$, RTs: all p 's $> .1$) or when only piano target notes were considered (accuracy: age group-target-type interaction $p = .702$, RTs: age group-target-type interaction $p = .113$). Therefore, one group of boys and girls was used for all subsequent analyses as a means to increase statistical power.

Accuracy

A 2 x 2 repeated measures ANOVA was conducted on accuracy rates (the proportion of correct responses) with timbre (piano, trumpet) and target-type (high probability, low probability) as within-subject factors. No significant main effects or interactions were found (all p 's $> .1$) demonstrating that there was no influence of either timbre or target-type conditions on the accuracy with which children responded. This corroborates previous harmonic priming studies with pre-school (Marin, 2009) and school-aged children (Schellenberg et al., 2005) suggesting that no priming effect was present when response accuracy was considered.

However, since the focus of this study was melodic priming and previous work with adults has shown that response accuracy followed the expected pattern when the

target is the same timbre as the context (responses were more accurate for the high than for the low probability condition; Omigie et al., 2012), it was then possible that marginal effects of probability could be revealed if ANOVAs were run separately on piano and trumpet conditions. Therefore, two follow up repeated measures ANOVAs with target-type as within-subjects factor were run separately for target notes rendered in piano and for target notes rendered in trumpet.

The ANOVA for piano target notes revealed a significant effect of target-type [$F(1,45) = 7.23$, $p = .01$, $\eta^2 = .138$] with children responding more accurately to high- than to low-probability notes [high-probability (proportion out of 10): $Mean = 9.58$, $SD = .61$, low-probability (proportion out of 10): $Mean = 9.34$, $SD = .79$]. No effect of target-type was revealed in the analysis of trumpet target notes [$F(1,45) = .075$, $p = .785$, $\eta^2 = .002$].

Response times

Only response times (RTs) within 2 standard deviations of the mean response for each child were considered (Ratcliff, 1979; 1993). RTs for correct trials were entered into to a 2 x 2 repeated measures ANOVA with timbre (piano, trumpet) and target-type (high probability, low probability) as within-subject factors. The main effect of timbre was significant [$F(1,45) = 5.93$, $p < .05$, $\eta^2 = .117$] indicating that children generally responded faster to trumpet than to piano target-notes in both high- and low-probability conditions (see Table 5.3 for RT means and standard deviations). This may be because the trumpet timbre perceptually segregated from the preceding notes in piano timbre due to timbral effects on auditory stream segregation (Bregman, 1990). A marginally significant interaction between timbre and target-type [$F(1,45) = 3.73$, $p = .06$, $\eta^2 = .077$] was also revealed.

To further investigate the marginally significant interaction between timbre and target-type, two follow-up repeated measures ANOVA with target-type as within-subjects factor were carried out separately on piano and trumpet target notes. The ANOVA on piano target notes yielded a significant main effect of target-type [$F(1,45) = 4.82$, $p < .05$, $\eta^2 = .097$], demonstrating that, following the adult pattern, children responded faster to high- than low-probability piano targets (see Table 5.3 for RT means and standard deviations).

An ANOVA conducted on trials where target notes were rendered with trumpet, revealed no significant effect of target-type on RTs [$F(1,45) = .322$, $p = .573$, $\eta^2 = .007$]. This result extends findings with adults, indicating that the expected priming pattern was not present when target notes were rendered in a different timbre than the preceding context timbre (Omidie et al., 2012).

Table 5.3. Descriptive statistics for accuracy of responses and response times sorted by target-type (high probability/low probability) and timbre (piano/trumpet).

		High P Mean (SD)	Low P Mean (SD)
Accuracy (out of 10)	Piano	9.43 (.77)	9.19 (.95)
	Trumpet	9.26 (.95)	9.32 (.79)
RT(s)	Piano	0.95 (0.26)	0.99 (0.31)
	Trumpet	0.93 (0.27)	0.92 (0.27)

RT(s) = response times in seconds, P = probability, SD = standard deviation

5.3.2 Relationships between performance on the musical structure task, cognitive tasks, the Language Structure Index and the Music@Home questionnaire.

Based on previous work by Omidie et al., (2012) the difference in response times (RTs) and the difference in accuracy proportions between expected and unexpected endings in correct trials where piano was the target were taken as a measure of the degree of implicit expectations and knowledge of musical structure. To account for individual differences in average RTs and timbre discrimination ability, all score differences were normalized to *z*-scores. Normalized differences in RTs and accuracy rates were then correlated with performance on the language tasks, scores on the Music@Home Questionnaire and number of musical activities outside the home to identify possible associations.

With respect to differences in RTs, no significant correlations were found between strength of implicit expectations and any of the variables (see Table 5.4), suggesting that implicit knowledge of musical structure is formed independently of these specific cognitive and language abilities and these types of environmental experience. Another possibility is that the measure taken as evidence of the strength of implicit knowledge was not sensitive enough in discriminating between children. Therefore, as an alternative measure the difference in RTs between expected and

unexpected piano endings in correct trials was used, excluding trials where the final interval was large ($N = 5$). As reported by Huron (2006), listeners tend to rate small intervals as more expected than large ones, possibly reflecting the fact that small intervals occur more frequently in Western melodies. Therefore, this manipulation would presumably give a more controlled measure of implicit expectations ensuring that trials where the occurrence of large pitch jumps might have created distraction in children's speed of response were excluded.

As can be seen in Table 5.4 bivariate correlations using only trials with small pitch intervals as a measure of the strength of implicit expectations revealed no significant associations between implicit expectations and language grammar and between implicit expectations and cognitive abilities (non-verbal ability and verbal memory). This implies that implicit knowledge of musical structure and acquisition of structure in language either might not rely on shared cognitive resources at this age, or that they might develop at different speeds. Another possibility is that, as above, the difference in speed of response between high and low probability endings did not successfully reflect children's implicit knowledge of musical structure. Interestingly, a significant relationship between the Music@Home Questionnaire and language grammar was observed. This link is further explored in section 5.3.3.

With respect to differences in accuracy between high and low probability trials with piano endings, no significant correlations were found between this measure and any of the variables (see Table 5.4). Following the rationale of excluding the trials where the occurrence of large pitch jumps might have created distraction to the children, the difference in proportion of correct responses only for trials with small pitch intervals in the end was also calculated. A trend towards significance was observed between this more controlled measure and language grammar ($p = .099$) and between this measure and scores on the Music@Home Questionnaire ($p = .093$) (see Table 5.4).

Table 5.4. Bivariate correlations between controlled and uncontrolled measures of strength of implicit expectations, linguistic and cognitive tasks, and environmental variables.

	RTs	RTs (sm)	Acc	Acc (sm)	NVA	VM	LSI	M@H	Mus Act
RTs	-	.02	.11	.23	-.03	.14	.02	-.00	-.02
RTs (sm)	.82**	-	.07	.15	.02	-.09	.05	-.02	-.02
Acc	.11	.07	-	.66**	-.00	.03	.03	-.06	-.04
Acc (sm)	.23	.15	.66**	-	-.25	.20	.24 ¹	.26 ¹	-.03
NVA	-.03	.02	-.00	-.25	-	.30	.32*	-.21	.00
VM	.14	-.09	.03	.20	.30	-	.76***	.28	.39*
LSI	.02	.05	.03	.24	.32*	.76***	-	.35*	.36*
M@H	-.00	-.02	-.06	.26	-.21	.28	.35*	-	.49***
Mus Act	-.02	-.02	-.04	-.03	.00	.39**	.36*	.49***	-

¹marginally significant *p* values (*p* = .099 and .093 respectively)

p* < .05, *p* < .01, ****p* < .001, RTs = Mean difference between between response times in high and low probability trials with piano endings, Acc = Mean difference between between accuracy rates in high and low probability trials with piano endings, RTs (sm) = Mean difference between between response times in high and low probability trials with small intervals at the end, Acc (sm) = Mean difference between between accuracy rates in high and low probability trials with small intervals at the end, NVA = Non-Verbal Ability, VM = Verbal Memory, LSI = Language Structure Index, M@H = Music@Home- Preschool, Mus Act = Musical Activities outside the home.

To further investigate the trend towards significance between music structural processing and language grammar, a linear regression model was built where implicit knowledge of musical structure (as measured by the difference in accuracy rates between high and low probability piano endings with small pitch intervals, henceforth, musical structure) was entered as an independent variable and language grammar was

entered as a dependent variable. Age and gender were also entered into the model to explore whether they could explain any variance in language grammar. Backward manual elimination of variables was used (see section 2.3 for a detailed explanation of this regression method) and statistical analysis was conducted using R software.

Results showed that there was a marginally significant effect of musical structure on language grammar [$Beta = -26$, $t(42) = 1.77$, $p = .08$] while age and gender did not have an effect on the dependent variable after taking into account the variance explained by musical structure [Age: $Beta = -.01$, $t(42) = -.79$, $p = .43$, Gender: $Beta = .09$, $t(42) = .61$, $p = .54$]. The overall model was not significant [$F(3, 42) = 1.24$, $p = .30$, $R^2 = .08$]. Using the `drop1()` function variables were gradually eliminated (based on the AIC and p-values, first gender and then age were eliminated) until only musical structure remained in the final model [$Beta = .24$, $t(44) = 1.68$, $p = .09$]. However, the final model did not explain a significant amount of variance in language grammar, although a trend towards significance was observed [$F(1, 44) = 2.83$, $p = .09$, $R^2 = .06$].

Correlations were performed between the controlled measure of musical structure and all subscales of the Music@Home Questionnaire and subtests of the Language Structure Index to examine whether specific associations were driving the trends towards significance. As seen in Table 5.5 two subscales of the Music@Home Questionnaire were significantly associated with musical structure, namely Parent Initiation of Musical Behaviour and Breadth of Musical Exposure. Therefore, although the Music@Home Questionnaire did not significantly predict musical structure, dimensions of this construct did emerge as relevant to musical development. However, only the association between musical structure and Breadth of Musical Exposure remained significant after controlling for parents' musical sophistication and children's musical activities outside the home.

Table 5.5. Bivariate correlations between musical structure subscales of the Music@Home-Preschool and subtests of language grammar.

Music@Home-Preschool subscales	Difference in acc (sm)	After controlling for Gold-MSI and MusAct
Parental beliefs	.23	.15
Child's active engagement	.02	-.02
Parent initiation of mus beh	.31*	.26
Breadth of musical exposure	.32*	.35*
Language Grammar subtests	Difference in acc (sm)	
Sentence Structure	.23	.22
Word Structure	.19	.14
Recalling Sentences	.17	.17

* $p < .05$, ** $p < .01$, *** $p < .001$, *acc* = accuracy, *Gold-MSI* = Parent's musical sophistication, *MusAct* = child's musical activities outside the home.

5.3.3. Further exploring the relationship between informal musical experience in the home and language grammar

To further explore the significant association between the Music@Home Questionnaire and language grammar observed in the results presented in section 5.3.2, a multiple regression model was employed, with language grammar as the dependent variable and Music@Home, formal musical activities outside the home and parents' musical sophistication (as measured by the Gold-MSI) as independent variables. Reading to the child was entered into the model to examine whether it would affect the interpretation of the model. Backward manual elimination of variables was used. Bivariate correlations between language grammar, the musical environment variables and reading are presented in Table 5.6. As seen in Table 5.6 all variables are significantly associated with language grammar, while the highest correlation coefficient was between the Music@Home Questionnaire and language grammar.

Table 5.6. Correlations between language grammar, Music@Home, Gold-MSI and reading to child.

	M@H	Reading to child	Gold-MSI-Mus Sophistication	Musical Activities (outside the home)
Grammar	.43**	.32*	.33*	.36*

* $p < .05$, ** $p < .01$, *M@H* = Music@Home-Preschool

The first multiple regression model with all variables entered as predictors²⁰ was moderately significant [$F(4, 32) = 2.73, p < .05, R^2 = .25$] while no variable significantly predicted language grammar independently from the others. Using the drop1() function variables that did not improve the model were eliminated (based on the AIC and p-values, variables were eliminated in the following order: Musical Activities outside the home, parent's Musical Sophistication and Reading to child). In the final model only the Music@Home Questionnaire significantly predicted language grammar (Model 1; see Table 5.7). However, the previous model where Reading to the child was also present, explained a notably greater proportion of variance despite this variable not significantly predicting language grammar. To ensure that Reading does not add explanatory value to the model, an ANOVA was used to compare Model 1 where Music@Home was the only predictor to Model 1a where both Music@Home and Reading scores were entered as predictors. As seen in Table 5.7, the two models did not differ significantly indicating that Reading does not explain a significant amount of variance in language grammar over and above Music@Home.

Table 5.7. Summary and comparison between Models 1 and 1a.

	<i>Beta</i>	<i>t</i>	<i>p</i>	<i>R</i> ²	<i>AIC</i>	<i>F</i>	<i>p</i>	Model Comparison
Model 1				.12	210.63	5.84	<.05	
M@H	.35	2.41	<.05					
								Model 1 vs Model 1a
Model 1a				.23	187.84	5.65	<.05	$F(1,37) = 2.51, ns$
M@H	.37	2.50	<.05					
Reading	.23	1.58	<i>ns</i>					

M@H = Music@Home Preschool

As a final step, associations between language grammar and different subscales of the Music@Home Questionnaire were examined to identify which specific aspects of informal musical experience in the home might contribute the most to language development. Correlation analyses between language grammar and the separate subscales of the Music@Home Questionnaire, namely, Parental Beliefs, Child

²⁰ Please note that parental education (i.e., primary caregiver educational level) was not entered into the regression model as its association with the outcome of interest i.e., grammar skill was not significant ($r = .18, p = .23$).

Engagement with music, Parental Singing-Music Making and Breadth of Musical Exposure were performed. As can be seen from Table 5.8, significant correlations were found between grammar and Parental Singing/Music-Making and between grammar and Breadth of Musical Exposure. A trend towards significance is also observed between language grammar and the child’s engagement with music ($p = .09$). However, when controlling for Reading to child, parent’s musical sophistication and child’s musical activities outside the home, the only association that remained significant was between children’s grammar skills and Breadth of Musical Exposure.

Table 5.8. Bivariate and partial correlations between language grammar and the Music@Home Q subscales.

	Parental Beliefs	Child Engagement with music	Parent Initiation of Singing/Music-making	Breadth of Musical Exposure
Grammar	.15	.26	.39*	.50**
After controlling for Reading to Child, Gold-MSI and Mus Act				
Grammar	.08	.20	.18	.40*

* $p < .05$, ** $p < .01$, Mus Act = Child’s musical activities outside the home

5.3.4. Interaction between the Music@Home Questionnaire and musical structural processing in predicting language grammar.

Based on the findings from Study 2 where the interaction between informal musical experience at home and musical ability significantly predicted linguistic development, it was deemed necessary to investigate whether this would also be the case with music and language structure. It was hypothesized that an association between music and linguistic structural skills could vary as a function of home experience with music. Two linear models were used with language grammar as the dependent variable: first, a model where the interaction between the difference in RTs (high - low probability endings in trials with small intervals) and scores in the Music@Home Questionnaire was entered as the independent variable (Model 1) and second, a model where the interaction between the difference in accuracy rates (high - low probability endings in trials with small intervals) and scores in the Music@Home Questionnaire was the independent variable (Model 2). None of the models were significant [Model 1: $F(1, 40) = 2.38$, $p = .13$, $R^2 = .05$; Model 2: $F(1, 40) = .04$, $p = .82$, $R^2 = .001$] suggesting that

although informal musical experience in the home is associated with the development of language grammar, it does not play a role in the relationship between the processing of musical and linguistic structure.

5.4. Discussion

The aim of Study 4 was to explore young children's processing of Western musical structure and its relationship to language grammar, as well as to investigate whether informal musical experience in the home was associated with the development of the above abilities.

In order to examine 4- to 6-year-old children's processing of music structure, a novel musical task was used to probe melodic priming. Participants were presented with short melodies embedded in an iPad application with colorful graphics, and were required to make speeded judgments about the timbre of the ending notes. Ending notes were of high or low probability, as estimated by a computational model taking into account the preceding melodic context (IDyOM; Pearce, 2005). Faster response times and higher accuracy rates for high probability notes rendered in the same timbre as the context were taken as evidence of a melodic priming effect (i.e., evidence that the children have already formed melodic expectations reflecting their knowledge about which notes are more likely to follow others in a Western melody). The difference (in msec) between response times to high and low probability notes was taken as a measure of the strength of this effect. Standardized measures of language grammar were also administered to young participants. Finally, parents completed the newly developed Music@Home questionnaire, assessing informal musical experience.

With respect to the first research question regarding children's processing of musical structure, results showed that children responded with greater accuracy in high relative to low probability piano endings. Furthermore, children showed faster response times when identifying high probability relative to low probability piano notes. These results are broadly in agreement with previous research on melodic priming effects in adults (Marmel et al., 2008; 2011; Tillman, 2005; Tillmann, Bigand, Escoffier, & Lalitte, 2006; Omigie et al., 2012) demonstrating that highly expected target notes and chords facilitate individuals' speed and accuracy of response. Notably, an experiment exploring melodic expectations in individuals with congenital amusia and typical controls that made use of the same computational model (i.e., IDyOM; Pearce, 2005) to

select high and low probability targets reported priming effects for both response times and accuracy (Omigie et al., 2012)²¹.

These findings are further contextualized when considering previous research in harmonic priming in pre-school (Marin, 2009) and school-aged children (Schellenberg et al., 2005) that has revealed priming effects in response times, but not accuracy rates. This is partly in contrast to our results, which revealed a priming effect in both response times and accuracy rates. It is important to note however, that both of these studies used chord progressions specifically composed for the experiments, whereas the present study investigated priming effects in melodic sequences selected from an existing database of folk tunes, thus providing a better simulation of everyday musical exposure.

With regards to young children's processing of melodic structure, findings so far have been inconsistent. For example, 4- and 5-year-old children did not exhibit awareness of implied harmonic structure in melodies when required to make evaluative judgments about endings in typical Western melodic sequences (Corrigall & Trainor, 2013). Conversely, Schellenberg et al., (2002) suggested that 5-year-old children's sung continuations of short melodies showed that their melodic expectations conformed to the principle of pitch proximity (i.e., successive notes tend to be close in pitch) one of the two principles that, according to Schellenberg (1997) influences the formation of melodic expectations. However, all 5-year-old children in this experiment ($N = 15$) were selected on the basis of their high musical aptitude and sophistication compared to peers, undermining the generalizability of these results to a broader population. In contrast, the sample in the present study consisted of 46 children with various levels of engagement in formal musical activities outside the home. Furthermore, their level of formal musical experience was not associated with the strength of their melodic expectations.

Taken together, the results above confirm that young children between the ages of 4 and 6 years can already process Western melodies in an adult-like manner, and that the melodic priming task used in the present study was more sensitive in probing implicit musical knowledge relative to previous tasks used in the literature. Furthermore, these findings indicate that the IDyOM model represents a promising approach for modelling melodic expectations in young children as well as in adults.

²¹ Accuracy: Omigie et al., 2012: $F(1,22) = 5.37, p = .03$, Present study: $F(1,45) = 7.23, p = .01$; Response Times: Omigie et al., 2012: $F(1,22) = 6.13, p = .02$, Present study: $F(1,45) = 4.82, p = .03$.

To explore associations between music structural processing and the development of grammar, the mean difference in response times and the mean difference in accuracy proportions between expected and unexpected endings in correct piano endings were taken as a measure of the degree of the melodic priming effect, reflecting implicit knowledge of musical structure. Results showed no associations between these measures and grammar scores. Based on the fact that small intervals are prevalent in Western music (Huron, 2006) and that child listeners are more likely to develop expectations for notes that are closer to each other early in development (Schellenberg et al., 2002) a more controlled measure was therefore created by excluding trials where large pitch jumps occurred at the end of the melodies. Mean differences between high and low probability piano endings only for trials with small pitch jumps were thereby calculated for both response times and accuracy rates. With this manipulation, processing of musical structure as reflected in accuracy rates but not response time differences, showed a marginally significant association with language grammar. This result provides some indication that music structural processing may develop in parallel to structural processing in language but further research is needed to understand the nature of the potential relationship between these two skills across development.

Another aim of this study was to investigate the role of home musical experience in the development of musical and language structure abilities and the relationship between them. To this end, we first examined individual links between the Music@Home Questionnaire and the musical and linguistic measures. Results showed a trend towards significance in the relationship between musical structure and the Music@Home questionnaire (as reflected in accuracy rates²²). To further examine this trend, the links between the musical measure and individual subscales of the Music@Home Questionnaire were explored. This analysis revealed moderate but significant relationships between musical structure and two subscales, namely Parent Initiation of Musical Behavior, and Breadth of Musical Exposure. These subscales reflect two aspects of the role of caregivers in shaping their children's musical environment, first, their active participation and initiation of musical interactions with their children and second, the richness of musical input they provide. Therefore, the role of the caregiver as an active agent in the shaping of the child's musical environment is

²² Mean difference between high and low probability piano endings only for trials with small pitch jumps.

highlighted. Specifically, the strongest association was between breadth of musical exposure and musical structure, as this remained significant after controlling for musical sophistication of the parents and the child's musical activities outside the home. This is in agreement with the hypothesised link between acquisition of musical structure and everyday musical experience, a link that corroborates the notion that implicit musical learning emerges from informal exposure to a given musical culture and that melodic expectations can reflect this type of learning in children (Bigand & Poulin-Charronnat, 2006; Tillmann, 2005). These findings also complement previous studies, which have shown that participation in musical activities can increase sensitivity to culturally specific features of music in infants younger than 12 months (Gerry et al., 2012; Gerry, Faux, & Trainor, 2010). It is important to note however, that infants in these studies were assigned to formally structured music classes (Kindermusik classes) as opposed to the informal family environment measured in the present study.

Critically, the Music@Home Questionnaire was significantly associated with the development of language grammar, further substantiating and extending findings with younger children from Study 2 of this thesis, but also findings about musically trained preschoolers showing advantages in the processing of language grammar (Marin, 2009). In Study 2, informal musical experience was significantly correlated with standardized scores on the same measure of language grammar used in Study 4. This suggests that the complex input that music provides may facilitate children in extracting and internalizing linguistic structures from their environment (see also Thiessen & Saffran, 2009). Furthermore, in section 3.4 it was proposed that the pro-social role of collaborative music-making (Custodero, 2006; de Vries, 2005; Kirschner & Tomasello, 2010) may facilitate language learning by creating an environment fortified with positive social interaction between children and their caregivers (see also Kuhl et al., 2003). The fact that the same association pertains to older age groups indicates that informal musical experience may play a central role in language acquisition across development possibly through a combination of motivational and perceptual factors (see section 3.4 for a more detailed discussion on this issue).

It is worth noting that in the present study, as opposed to Study 2, the issue of specificity of the informal musical experience effect was addressed by controlling for musical sophistication of the parents, children's formal musical activities outside the home and parent's reading to the child, an important factor reflecting general engagement of parents with their children, which has previously been shown to play a

crucial role in language development (Farrant & Zubrick, 2013; Sénéchal et al., 2008). Results showed that home musical experience remained the sole predictor of language grammar after accounting for all other variables. This strengthens the argument for a unique predictive relationship between musical experience in the home and language development.

The dimensions of the home musical experience that appeared to be more strongly associated with language were, similar to that observed in the case of musical structure development, parent initiation of musical behaviour and breadth of musical exposure, while the association between grammar skills and breadth of musical exposure was the strongest, as it remained significant after musical sophistication of the parents, the child's musical activities outside the home and the degree of reading to the child were accounted for. Clearly, the breadth of musical stimulation and input that parents provide is an important dimension of the home experience with music, that may influence development in both the musical and the linguistic domains.

Finally, motivated by findings from Study 2 which showed that the interaction between informal musical experience in the home and musical ability significantly predicted linguistic development, the potential interaction between the Music@Home Questionnaire and music structural processing and language grammar was explored. The results however did not support this hypothesis, suggesting that the relationship between language and music structural processing does not vary as a function of the home experience with music. Another possibility is that the nature of the relationship between these three variables was masked by the fact that the musical and linguistic tasks were not equivalent with respect to the processing resources that they engaged (see section 6.4 for a detailed discussion on this matter). Clearly, this limitation restricts the generalizability of these results regarding the role of informal musical experience in the home in the development of language and music structural processing and more research is needed to elucidate the nature of the relationships between these variables.

In summary, the results of the present study confirm the hypothesis that young children between the ages of 4 and 6 years can process Western melodic structures similarly to adults, and that the melodic priming task making use of the IDyOM model was more sensitive in probing implicit musical knowledge relative to previous tasks used in the developmental literature. Only a marginally significant association was observed between the processing of musical structure and grammar. In addition, the Music@Home Questionnaire and more specifically, parents' active participation in shaping the child's

musical environment was associated with both musical and linguistic development. The predictive strength of informal musical experience on language development was notable and remained even after important factors such as reading to the child and parents' musical sophistication were accounted for. These findings significantly contribute to our knowledge about environmental influences that can be beneficial for development and add new intuitions regarding musical experience in the early years.

CHAPTER 6: IMPACT, LIMITATIONS AND FUTURE DEVELOPMENTS

Abstract

Chapter 6 provides summaries of the research studies and their findings. It then discusses the theoretical impact of the main findings as well as their implications for early childhood education, policy and practice. Limitations of the present thesis are also outlined and possible developments for future research are discussed. Finally, an overall summary of the present project's aims, conclusions and contributions is provided.

6.1. Introduction

The notion that music and language share important similarities is consistent across the fields of musicology, psychology and cognitive neuroscience. Based on this idea, research on the analogies between the cognitive and neural bases of musical and linguistic abilities has been burgeoning in recent years, with studies regularly uncovering links between musical and linguistic abilities across human development (e.g., Anvari et al., 2002; Gordon et al., 2014; Slevc et al., 2009). Importantly, improvements in linguistic skills have been associated with formal musical experience in both adults (see Kraus, & Chandrasekaran, 2010 for a review) and children (e.g., Barac et al., 2011; François et al., 2013).

The overall aim of the present thesis was to elucidate part of the developmental trajectory of the relationship between music and language starting from the early preschool years, an age group that has so far been neglected. To this end, the studies of this thesis address questions related to the early associations between linguistic and musical skills and the influence of the informal home musical experience on early language and musical development. Furthermore, the present studies provide researchers with novel experimental tools for the assessment of young children's musical skills and informal musical experience in the home.

The following sections summarize the current studies and their findings and discuss their theoretical and practical implications. The limitations of the present research are also outlined and directions for future research are proposed.

6.2. Summary of findings

6.2.1. Study 1: Links between the early development of musical and linguistic abilities.

Study 1 approached the music-language link in young preschoolers from a broad perspective, investigating associations between a range of musical skills and two key domains of language development, namely phonological awareness and grammar. Both these areas were considered due to their critical role in the development of more fine-grained aspects of language production and understanding (Hoff & Shatz, 2007) as well as their central role in school readiness and later academic attainment (Cunningham & Carroll, 2015; Deacon & Kirby, 2004; Melby-Lervag et al., 2012).

With the aim of exploring the links between early musical skills and language development, 3- and 4-year-old children were tested on a range of musical skills such as pitch, tempo, rhythm and melody perception, and song and synchronization ability, using novel age appropriate tasks and measures designed specifically for this study. The design of these tools constitutes the first step for the development and validation of an up-to-date musical assessment battery for young preschoolers as none was available previously. Standardized tests for the assessment of phonological awareness and language grammar were used, while non-verbal ability and verbal memory as assessed with standardized tests were accounted for. To explore the role of musical experience in the family in musical and linguistic development, parents completed a questionnaire assessing frequency and type of informal musical interactions and exposure in the home while their musical sophistication was controlled for.

Results from correlational analyses revealed that both melodic and rhythmic skills were significantly associated with tasks measuring phonological awareness and grammar. More specifically, significant relationships emerged between timing abilities such as tempo and rhythm perception, synchronization and phonological awareness scores. Rhythm perception was also significantly correlated with one of the language grammar tasks (*Recalling Sentences*) while a significant relationship between melody perception and one of the phonological awareness tasks (*Sentence/Syllable Segmentation*) was found. Marginal associations were finally observed between melody perception and phonological awareness composite scores and between song production and language grammar composite scores. These findings suggest that music and language learning may rely on common mechanisms from early in development.

Critically, results for regression analyses showed that musical abilities differentially predicted linguistic development in young preschoolers. Specifically, synchronization and rhythm perception emerged as the most significant predictors of phonological awareness even when cognitive skills such as verbal memory and non-verbal ability were accounted for. Moreover, melody perception was found to be the most significant predictor of language grammar ability over and above the influence of non-verbal ability and verbal memory, highlighting a novel link between musical and linguistic skills. These findings are important because they suggest that separate auditory skills might work to strengthen different language domains during the early preschool years.

6.2.2. Study 2: The impact of informal musical experience in the family on musical and linguistic development.

The aim of Study 2 was to investigate associations between informal musical experience in the family and early musical and linguistic development. Another related aim was to examine the role of informal musical experience in the associations between specific musical and linguistic skills as these were identified in Study 1.

Correlational analyses revealed a novel association between this type of environmental input and the development of language grammar. This finding underlines the importance of singing and music making in language learning. Interestingly, no consistent associations were found between musical experience in the family and children's musical skills, emphasizing that musical interactions rather than focusing on practising musical skills, may serve as a means for emotional bonding (see Cirelli et al., 2014; Trainor & Hannon, 2013 for evidence that musical interactions may facilitate emotional bonding between caregivers and their children) which in turn may assist learning in other domains such as language.

Another important finding was that musical experience in the family mediated the predictive associations between musical and linguistic skills that were observed in Study 1 (i.e., the link between rhythmic abilities and phonological awareness and the link between melody perception and grammar). More specifically, children from more musically enriched environments showed a stronger connection between musical and linguistic skills suggesting that the pairing of words and music usually present during

early musical interactions may enhance interconnectivity between relevant cognitive domains.

6.2.3. Study 3: Music@Home Questionnaire: A novel instrument for the measurement of informal musical experience in the home in the early years.

Given the novel findings on the influence of informal musical experience on language development, Study 3 was dedicated to the creation and validation of a parent report instrument to assess informal musical experience in the family for children under the age of 5 years. As musical engagement at home changes as a function of the child's age, two versions of the Music@Home Questionnaire were developed, i.e., Preschool and Infant, the latter to develop compatible research at an earlier age in the future.

An initial pool of items was first generated. The number of original items was subsequently reduced through the use of exploratory factor analysis, which was also used to identify the factor structure of the questionnaires. At a later stage, data from a different sample of participants were used to consolidate the factor structure and evaluate the reliability and validity of the new instrument. Finally, correlational analysis was used to test associations between the Music@Home factors and two subscales of the Gold-MSI assessing parents' musical training and active engagement with music.

Results showed that both the Infant and Preschool versions of the Music@Home Questionnaire had a hierarchical factor structure: a general factor was identified that consisted of all the items in the questionnaire and corresponded to informal musical experience in the family, while sub-factors representing different dimensions of this construct existed in parallel (Chen, West, & Sousa, 2006; Beaujean, 2014). Similarities and differences emerged between the Infant and the Preschool versions' factor structure and items, revealing interesting variations in the ways that parents engage musically with their children at different developmental stages. More specifically, the Music@Home-Preschool comprised of four factors, namely, Parental Beliefs, Child Engagement, Breadth of Musical Exposure and Parent Initiation of Musical Behaviour. The Music@Home-Infant version comprised of Parental Beliefs, Child Engagement, Parent Initiation of Singing, and Parent Initiation of Music-making.

The Music@Home-Infant and Preschool versions showed highly significant correlations with a subscale of the Children's Musical Behavior Inventory or CMBI (Valerio et al., 2012) measuring parental involvement with music (i.e., *Parent Music Activities*), establishing convergent validity of the new instrument. Weak to moderate

associations between the Music@Home Preschool and Infant versions and two subscales from a validated instrument (i.e. Stim-Q) assessing the cognitive enrichment of young children's environment (*Reading and Parental Involvement to Developmental Advance* or PIDA) established divergent validity. Finally, differential associations between two subscales of the Gold-MSI (*Active engagement with music* and *Musical training*) and the two versions of the Music@Home Questionnaire i.e., Infant and Preschool, reflected noteworthy differences in the mode of parent-child interactions between the two age groups.

6.2.4. Study 4: Links between music and language structure and the impact of informal musical experience in the home on these skills.

Study 4 explored whether young children's (4 to 6 years - old) processing of Western musical structure is associated with the processing of structure (i.e., grammar) in language. Using the newly developed Music@Home Questionnaire, the potential relationship between home experience with music and the development of these language skills was also examined.

An original musical task was used to explore young children's processing of musical structure. In this task, children were presented with short melodies and were required to make speeded judgments about the timbre of the ending notes, which were either of high or low probability as calculated by a computational model taking into account the preceding melodic context (IDyOM; Pearce, 2005). Faster response times and higher accuracy rates for high probability endings (rendered in the same timbre as the context) were taken as evidence of a melodic priming effect; in other words evidence that the children have knowledge about which notes are more likely to follow others in a Western melody. The difference between response times and accuracy rates to high and low probability endings was taken as a measure of the strength of melodic expectations with stronger melodic expectations reflecting more consolidated processing of musical structure (Omigie et al., 2012). Standardized measures were used for the evaluation of language grammar while parents completed the Music@Home-Preschool assessing informal musical experience in the home.

Results showed that participants responded faster and with greater accuracy to high probability relative to low probability endings (i.e., they exhibited a melodic priming effect), supporting the hypothesis that children between the ages of 4 and 6 years can already process Western melodic structures similarly to adults (Marmel et al.,

2008; 2011; Tillman, 2005; Tillmann et al., 2006; Omigie et al., 2012). Importantly, the newly developed task provided a suitable method for probing this knowledge.

No associations were observed between measures of music and language structural processing in the overall data set. However, when a more controlled measure of the strength of melodic expectations was used by excluding trials where large pitch jumps occurred at the end of the melodies, a marginally significant association was found between the composite language grammar scores and music structural processing as reflected in accuracy rates (but not response times). However, it was not possible to identify any unique significant relationships between this controlled measure of music structural processing and individual tests of language grammar.

With respect to the impact of informal musical experience in the home, results showed a marginally significant association between musical structure (as reflected in accuracy rates) and the Music@Home Questionnaire. Further illuminating this trend, moderate but significant relationships between musical structure and two subscales of the Music@Home Questionnaire were revealed, namely *Parent Initiation of Musical Behaviour* and *Breadth of Musical Exposure*, while the link between breadth of musical exposure and musical structure remained significant even after controlling for musical sophistication of the parents and the child's musical activities outside the home.

Critically, the Music@Home Questionnaire predicted the development of language grammar even after accounting for confounding variables such as musical sophistication of the parents, children's formal musical activities outside the home and crucially, parent's degree of reading to their child, an activity that has previously been shown to play an important role in language development (Farrant & Zubrick, 2013; Sénéchal et al., 2008). These findings suggest that the role of parents in shaping their child's musical environment may be a critical influence in the development of complex language skills. It is important to note that these findings are consistent with Study 2 where, despite using different assessment tools, it was concluded that home experience with music might have a crucial influence on children's development of complex language skills such as grammar. Similar to what was observed in the case of musical structure development, the subscales of the Music@Home Questionnaire that appeared to be more strongly associated with language development were: *Parent Initiation of Musical Behaviour* and *Breadth of Musical Exposure*, while the association between breadth of musical exposure and language skills remained significant even after measures

of musical sophistication of the parents, the child's musical activities outside the home and reading to the child were accounted for.

Finally, the results did not support the hypothesis that an interaction between the Music@Home Questionnaire and music structural processing predicts the development of language grammar. In other words, the relationship between language and music structural processing did not appear to vary as a function of the informal musical experience in the home. However as discussed in section 6.4, limitations with respect to the musical and linguistic measures used may have masked the nature of the relationship between the three variables.

6.3. Impact of the thesis

The impact of the present findings in terms of research, educational and policy contexts is discussed in this section. Ways forward for future studies are also considered.

First, the finding from Study 1, that musical abilities are associated with language development in young pre-schoolers, supports previous research in the literature suggesting that language and music rely on shared mechanisms for sound category learning (e.g., François & Schön, 2014; McMullen & Saffran, 2004; Patel, 2008; 2013). Importantly, Study 1 identifies music-language links in a younger age group than previously studied and shows that these associations are not accounted for by individual differences in non-verbal ability or verbal memory.

By extending the reported association between phonological awareness and rhythmic abilities to an earlier age (3- and 4-year-old children) and by revealing a novel link between melody perception and grammar skills in this age group, Study 1 contributes towards a comprehensive account of the music-language relationship from a developmental perspective and adds to the relevant literature (Anvari et al., 2002; Forgeard et al., 2008; Gordon et al., 2014; Verney, 2013; Woodruff-Carr et al., 2014). Indeed, the developmental trend of the relationships between musical and linguistic skills appears to change over time with specific auditory skills becoming more relevant to language at different times in development. For instance, the well-documented association between rhythmic abilities and phonological awareness in 4-year-old children (Anvari et al., 2002; Verney, 2013; Woodruff-Carr et al., 2014) does not appear to be as relevant at the age of 6 (Forgeard et al., 2008; Gordon et al., 2014). Similarly,

the link between grammar skills and rhythmic discrimination reported in 6-year-old children (Gordon et al., 2014) was not apparent in the young preschoolers tested in the present sample.

Critically, the identification of specific commonalities between distinct language and music skills at an early age, that may be based on common underlying mechanisms, informs influential accounts according to which speech and music rely on shared but also distinct cognitive systems (Patel, 1998; 2003; Peretz, 2006). It also brings together theories of musical and linguistic development that support a step-by-step acquisition of skills in both modalities (Cohrdes et al., 2016; Dowling, 1999; Welch, 1985) by suggesting that the distinct abilities that rely on common learning mechanisms may develop in parallel and in an orderly manner. The operation of these mechanisms may also partly determine the developmental trajectory of the music-language connections. Specifically, it is proposed that sensitivity to metrical structure in 3- and 4-year-old children may contribute both to phonological awareness and to rhythm perception and production skills. In addition, young preschoolers might be processing melodies as well as grammatical structures by extracting statistical regularities from their environment. Whilst sensitivity to statistical regularities in the auditory input may be crucial for phonological awareness and rhythm perception, it appears to be more relevant for these particular skills at an earlier developmental stage (Hannon & Trehub 2005; Kuhl et al., 1992; Mugitani et al., 2009, Werker & Tees, 2005).

The above findings provide transferrable insights for early years educational provision by suggesting ways forward in the use of music education as a tool for strengthening language development and preventing potential language-learning difficulties. Specific musical training programs could be designed to address language difficulties at an age where the brain is still highly plastic; for instance, based on the present findings, a musical training program focusing on melody could be used to strengthen grammar skills in children who appear to exhibit early difficulties in this domain. Indeed, previous examples of music classes focusing on timing (based on the reported association between rhythm and phonological awareness) have been successful in promoting phonological skills in typical (Verney, 2013) and dyslexic children (Overy, 2003; 2008).

This investigation is also a first step to the creation and validation of an up-to-date novel musical abilities assessment battery for preschool children. So far, the Gordon's Audie's test (Gordon, 1989) which includes two subtests, melody and rhythm

discrimination, is the only published musical skill measurement suitable for 3- and 4-year-old children. Clearly, a new, updated battery of tasks that makes use of recent advancements in music psychology research and measures a broader range of aptitudes, giving complementary information about a child's musical ability, will be a useful tool for music and developmental research, allowing future researchers to address important questions generated by the present investigation.

The association between musical experience in the family and the development of grammar reported in the second study is the first evidence that informal musical input can have an effect on the development of complex language skills such as grammar in 3- and 4-year-old children. By underlining that children's language development can benefit from this type of informal experience from a very young age, this finding directly informs early childcare practice both in the family and in educational contexts. Furthermore, the fact that informal musical experience in the home can have moderating effects on the early links between musical and linguistic skills opens new areas of inquiry about the mechanisms through which musical experience may promote language development.

The development and validation of the Music@Home Preschool and Infant questionnaires (Study 3) generates impact for the wider community as it provides researchers in the fields of psychology and education with a valid and reliable instrument for the assessment of informal musical experience in the home. This type of environmental input has not been extensively investigated, although this research has begun to show its potential benefit for developmental outcomes. The Music@Home questionnaires can be used to answer a wide array of research questions. Examples include exploring associations between this type of environmental experience and characteristics of the family such as attachment relationships, parent's mental health, previous experience with music and socio-economic status. Additionally, studies translating and adapting the Music@Home questionnaire to other linguistic and cultural environments are already in progress (Spanish: Nùñez, Campos & Martínez-Castilla, in prep., Italian: Franco & Boem, in prep., Flemish: Van Puyvelde, in prep.). Such studies are of great interest, as they provide us with a means to explore cultural variations of musical experience during the early years.

Investigating the potential contribution of informal musical input to

developmental outcomes such as linguistic, cognitive, social and musical skills significantly adds to the field of child development and has important implications for early childcare practice and early childhood education. Critically, the fact that the Music@Home Infant and Preschool questionnaires comprise of sets of factors allows for the investigation of how different aspects of informal musical experience can differentially contribute to development.

From a theoretical perspective, by using a large sample to identify different dimensions of informal family-based musical experience, the third study contributes to a comprehensive description of how parents interact musically with their children under the age of 5 years, adding to previous research that has investigated this subject in older age groups (Brand, 1986; Custodero & Johnson-Green; 2003; deVries, 2009; Illari, 2005; Mehr, 2014; Shoemark & Arnup, 2014; Valerio et al., 2012; Youm, 2013; Young, 2008). Importantly, it brings together dimensions of family musical experience (i.e., parental beliefs about music and development, child engagement with music and parent-child musical interactions) that had previously been recognized and explored only in isolation (e.g., Custodero & Johnson-Green; 2003; Illari, 2005; Mehr, 2014; Valerio et al., 2012). However, new intuitions are also offered. Specifically, one novel dimension not previously addressed is the breadth of musical exposure in the home. This emerged as a separate factor in the Music@Home-Preschool and it includes music that is sung or listened to. Indeed, exposing children to a wide range of musical styles may reflect a unique type of musical sophistication that motivates parents to include their children in a rich musical environment. An interesting question for future research would be to investigate how this dimension may relate to other characteristics of the family such as family size, socio-economic status or personality traits of the parents.

Furthermore, the third study highlights parallels and differences between musical experience in the infant and preschool years, offering new insights about how this type of environmental input may vary as children develop. Perhaps the most interesting observation is that singing and music making comprised a single factor in the Preschool version, but emerged as two separate factors in the Infant version. Primarily this distinction reflects the fact that until the age of 2 years, infants do not engage in active music-making as much as older children. However, it also underlines that parental singing holds a central position in infancy and is potentially important for later development. Indeed, relevant research has emphasized the role of singing in regulating arousal (Shenfield et al., 2003), building emotional interaction (Nakata & Trehub, 2004;

Van Puyvelde et al., 2014), promoting social development (Van Puyvelde & Franco, 2015) and even facilitating phonetic learning through the strengthening of speech patterns (Lebedeva & Kuhl, 2010; Schön et al., 2008; Thiessen & Saffran, 2009). The potentially critical role of parental singing for developmental outcomes is yet to be investigated by systematic longitudinal studies that should address how song exposure during infancy may affect later social, emotional or linguistic development (but see Franco et al., 2015; 2016 for preliminary findings). An instrument with good psychometric properties such as the Music@Home-Infant that includes a separate subscale for singing can be a valuable measurement tool for such future endeavours. It should be noted however, that an in-depth investigation of the potential effects of parental singing on development should make use of this subscale as a screening tool while also including more detailed, preferably qualitative measures such as interviews or observations based on real time recordings.

In Study 4, the fact that young participants exhibited a melodic priming effect provides evidence that 4- to 6- year old children can process structural aspects of Western melodies in an adult-like manner (Marmel et al., 2008; 2011; Tillman, 2005; Tillmann, Bigand, Escoffier, & Lalitte, 2006; Omigie et al., 2012). Although some previous studies with children (preschool: Marin, 2009; school-aged: Schellenberg et al., 2005) have also revealed priming effects in response times, these effects were observed in a context of chord progressions rather than melodies. This is important because melodies comprise an important part of Western, but also non-Western musical traditions, hence the present results may generalise cross-culturally. Furthermore, contrary to previous studies that used chord sequences composed especially for the experiments, the current task used melodies drawn from an existing database of folk tunes, contributing to the ecological validity of the findings.

Crucially, the current musical task and the model used to compute probability of occurrence of the priming notes (IDyOM; Pearce, 2005) were successful in probing implicit knowledge of Western melodic structure in young children. This is important, given that previous findings on young children's processing of melodies have been inconclusive (Corrigall & Trainor, 2013; Schellenberg, 2002), possibly due to limited sensitivity or appropriateness of the tasks used. Specifically, in Corrigall and Trainor's (2013) study, 4- and 5-year-old participants failed to show awareness of an underlying harmonic structure in typical Western melodies when asked to make explicit evaluations

about the melodies' endings (i.e., children did not show a preference for endings that were "in-harmony" according to Western rules of musical structure). In contrast, Schellenberg et al. (2002) demonstrated that when 5-year-old children were required to sing the continuation of short melodies, the tones they produced were proximate in pitch to the preceding ones, a predominant property of Western musical sequences that according to Schellenberg (1997) influences listener's melodic expectations. However, Schellenberg et al.'s task required a high level of musical aptitude and findings were based on a small sample (N = 15) of 5-year-old children especially selected to be musically sophisticated. In contrast, the sample in Study 4 consisted of children with various levels of formal musical experience (N = 46) allowing for generalizability of the results.

Results of the fourth study regarding the informal musical experience in the home, showed that two subscales of the newly developed Music@Home Questionnaire, namely *Parent Initiation of Musical Behaviour* and *Breadth of Musical Exposure* were significantly associated with performance in the music structural processing measure, although the association between the full Music@Home and musical structure was only marginally significant. Specifically the link between breadth of musical exposure and musical structure remained significant even after musical sophistication of the parents and the child's musical activities outside the home were accounted for. Demonstrating for the first time that richness of musical input in the home may be associated with the development of music structural processing has theoretical implications, as it strengthens the notion that implicit learning of musical structure emerges from informal everyday exposure to music of a given culture (Bigand & Poulin-Charronnat, 2006; Tillmann, 2005). It also furthers previous studies with infants, which showed that participation in formal music classes enhances culture-specific musical knowledge (Gerry et al., 2012; Gerry, Faux, & Trainor, 2010). From a practical perspective, music education specialists could benefit from the above finding, as it underlines ways with which caregivers can promote musical development in the early years.

The fact that the Music@Home Questionnaire predicted the development of language grammar over and above the influence of confounding factors such as musical sophistication of the parents, children's formal musical experience and parental reading has important theoretical implications. Combined with the results from Study 2, which showed that informal musical experience in the home was associated with the same standardized measure of language grammar in younger children (3- and 4-year-olds),

these findings provide support for a key role of informal musical experience in the home in the acquisition of complex language skills across early development. Although a number of studies have so far indicated that formal musical experience is related to positive linguistic outcomes in children under the age of 6 years (Barac et al., 2009; Degé & Schwarzer, 2011; Verney, 2013) the role of informal musical input has so far been under-represented in the literature. Crucially, in addition to revealing a new type of environmental influence that can be beneficial for language acquisition, these findings open a new area of inquiry into the mechanisms that underlie the relationship between home experience with music and its impact on language development.

Finally, the combined findings of Studies 2 and 4 generate impact for early childcare practice in both family and educational contexts. Encouraging parents and early childhood educators to enrich the child's environment with musical stimuli may not only promote language acquisition in typically developing children, but also act as a potentially protective factor against poorer outcomes in language development in disadvantaged groups.

6.4. Limitations and future developments

A number of outstanding issues related to the three studies of this thesis, as well as directions for future research are discussed in this section.

First, although the musical tasks in the first study were carefully designed to meet the latest advances in early musical development and to address the challenges of testing young preschoolers, a thorough examination of the reliability and validity of the musical abilities battery was beyond the scope of the present project. This may especially in one case, have compromised the reliability of the results. Specifically, the relationship between pitch perception and language development was non-significant, a finding that contradicts previous research suggesting links between pitch processing and language skills (Forgeard et al., 2008; Lamb & Gregory, 1993). However, the pitch perception task might have tapped into attentional and memory resources to a greater extent than anticipated, possibly because the use of sine waves rather than instrument sounds was tiring and uninteresting for young participants in Study 1. This assumption is supported by the fact that pitch perception, contrary to the other musical tasks, exhibited low correlations with all other musical tasks while showing a highly significant association with digit span, a test that explicitly taps verbal memory. Clearly,

more research is needed before one can draw conclusions about the relationship between pitch perception and language skills in young preschoolers.

Future studies could extend the present research by investigating the psychometric properties of the musical abilities tasks in a larger sample of 3- and 4-year-old children. A complete battery of musical tasks for this age group could generate impact for the wider community since i) it can aid music education experts and parents to identify the child's specific musical strengths at a very young age and ii) given that specific associations between musical and linguistic abilities are established, this battery could be used as a language-free tool for identifying children at risk for learning difficulties in multicultural environments.

Another limitation of Study 1 relates to the differential associations that were observed between musical and linguistic skills in young preschoolers namely, an association between rhythmic abilities and phonological awareness and an association between melody perception and grammar skills. Although the first association is directly predicted by the hypothesis that rhythmical and phonological processing in early development partly depend on the entrainment of neuronal networks to the patterns formed by strong and weak beats in both language and music (Goswami, 2011), the association between melody perception and language grammar is less clear. Statistical learning, which is thought to underlie the internalization of both melodic (François & Schön, 2014) and grammatical patterns (Gómez & Lakusta, 2004; Saffran, 2003; Saffran & Wilson, 2003) may be a key mechanism linking melody perception to grammar acquisition during the third and fourth year of age. This is highly plausible, given that evidence has shown that children are in the process of internalizing melodic and harmonic structures during this specific stage of development (Corrigall & Trainor, 2009; 2013) and that the acquisition of grammar is a long and complex process that continues into the late preschool years (Brooks & Kempe, 2012; Brown, 1973). However, the present study was not designed to investigate mechanisms underlying the links between musical and linguistic skills and the above hypothesis remains an interesting possibility for future research to examine with the development of age-appropriate methods.

Findings from Study 2 showed a significant association between musical experience in the family and the development of language grammar, offering support for the idea that higher levels of musical engagement in the home can serve as

scaffolding for the acquisition of complex verbal skills. Nevertheless, the issue of how specific the influence of informal musical experience in the home is on linguistic development requires further consideration. Given that parental education did not correlate with home experience with music or with the linguistic development variables (phonological awareness and language grammar) it is highly unlikely that the observed link could be attributed to the parents' level of education. Still, it is possible that parents who engage musically with their children are generally more open to other shared activities such as book reading, a variable consistently found to be associated with improvements in linguistic skills (Farrant & Zubrick, 2013; Sénéchal, Pagan, Lever, & Ouellette, 2008). Other variables, such as general enrichment in the home, attachment styles or parental sensitivity could also come into play when considering influences on development. The current study did not control for such variables but this limitation should be addressed in future work.

Another area of enquiry for future studies pertains to the specific mechanisms through which informal musical experience may promote language development. For instance, investigating whether learning enhancements occur due to the emotionally stimulating nature of musical engagement or due to perceptually facilitating aspects of exaggerated speech in song is an intriguing question for future research. Furthermore, it would be interesting for neuroscientific studies to address the issue of how informal musical experience may moderate relationships between language and music skills. For instance, examining whether children with higher levels of musical engagement in the home show enhanced interconnectivity in relevant areas of the brain already identified as the neural basis for these inter-related skills could be an important area of investigation.

Indeed, the fact that children from families with higher levels of musical engagement showed a stronger pairing between musical and linguistic skills opens new areas of investigation into how musical experience can affect development. One interesting possibility is that informal musical experience provides a context of positive interpersonal interaction for the linking of speech and music, thus enhancing interconnectivity between relevant brain areas. However, it is worth noting that our analysis does not give us a conclusive answer about whether the above interaction could also work the other way round, i.e., the relationship between informal musical experience and linguistic skills could vary as a function of the children's musical ability. Indeed, the possibility that children with a stronger inclination towards music might be

more engaged and benefit from frequent musical interactions is equally reasonable. In support of this notion, research has shown that participants with higher levels of engagement in music community classes showed stronger benefits in speech encoding and reading scores (Kraus et al., 2014). Distinguishing between the two possibilities is an interesting issue that could be addressed in future studies.

Finally, further research using correlational designs to address links between music and language would benefit from larger samples as a means to increase statistical power. Indeed in the first study of the present project, some correlation coefficients that approached significance (e.g., those between melody perception and phonological awareness and between song production and grammar skills) might have reached significance if a bigger sample had been tested. Moreover, a larger sample would allow for additional analyses (e.g., factor analyses or structural equation modelling), offering the possibility to model complex relationships between musical and linguistic skills as well as examine the impact of other variables such as general cognitive abilities and environmental factors. However, it is important for future studies to take into consideration that due to young preschoolers' short attention span or the fact that they are usually not familiar with structured testing environments, a significant amount of time and effort is required for their assessment.

In Study 3, Music@Home questionnaires were administered to large samples of participants first for the development and exploration of their factor structure (Stage 1) and subsequently for the evaluation of their psychometric properties (Stage 2). However, the vast majority of participants were highly educated (undergraduate degree or above) and belonged to high-income classes. In addition, the distribution of participants in Stage 2 was skewed towards managerial and professional occupations. Clearly, our sample failed to adequately represent families with low socio-economic status (SES) and education. Therefore, future studies should include the administration of the questionnaires to lower socio-economic strata of the population to explore whether the good psychometric properties established in the present project would still be exhibited. A related question is whether the nature and frequency of musical interaction in low SES families would be different from that offered in more advantaged families like those in the sample tested here.

Another limitation of the third study pertains to the sample gathered for the development and evaluation of the Music@Home-Infant. Specifically, families with

infants between the ages of 10 months and 2 years were over-represented in both stages 1 and 2, while the number of participating families with young infants was considerably smaller. As a result, a few items that emerged from the analysis as important elements of the questionnaire factors do not directly apply to younger (< 8 months) infants as they describe activities that need a certain level of motor and cognitive development (e.g., “*My child rarely makes music*”, “*I have noticed my child moving in time with the beat of the music*”). Currently this issue is addressed by adding an explanation in the introductory paragraph of the Music@Home-Infant, encouraging parents of young infants to interpret these items openly and apply them to their individual circumstances (e.g., a young baby could be “making music” by intensely and interactively vocalizing when caregivers sing to her). In future studies using the questionnaire with infants under the age of 8 months, this issue could be resolved by removing items from the analysis that do not correspond to the developmental stage of the participants. Considering the rapid and significant progress of developmental milestones during the first year of life, future extensions of this study should re-evaluate the psychometric properties of the Music@Home-Infant using a sample stratified by age (e.g., 3-6 months, 7-10 months etc.) thus providing sets of questions tailored to each developmental stage and to the needs of separate research questions.

Based on previous studies with children suggesting an overlap between the processing of language and music structure at the neural level (Jentschke et al., 2008 with 4- and 5-year-old children; Jentschke & Koelsch, 2009 with 10- and 11-year-old children), Study 4 was designed to investigate whether this relationship holds true in young children when using behavioural measures and ecologically valid musical stimuli. Although initial results showed no associations between music and language structural processing, a marginally significant relationship was revealed when a more controlled measure of implicit knowledge of musical structure was used (i.e. mean differences between high and low probability piano endings only for trials with small pitch jumps). Although this result provides some indication of an overlap between the development of music and language structural processing, this evidence is not conclusive. It is also important to note that correlations between the controlled measure of musical structure and individual tests of language grammar did not reveal any significant associations.

The inconclusive nature of these results may have stemmed from limitations in

the experimental methods. More specifically, a melodic priming task was used to probe melodic expectations and a standardized behavioural test was used to assess language grammar. In the musical task, children were required to make speeded responses about the timbre of target notes. In other words, this was an implicit task utilizing the auditory modality. The language task, on the other hand was an explicit test that required multimodal processing i.e., it required children to match visual stimuli to sentences of increasing syntactic complexity, complete sentences by producing morphologically correct utterances and repeat sentences of increasing length, thereby engaging a number of additional skills such as visual perception, speech production and verbal memory. Therefore, the language task employed a disproportionate amount of processing resources compared to the musical task. Furthermore, the language task included a greater number of trials overall, whereas a limited number of trials had to be taken into account when calculating the musical structure measure (only correct piano trials were taken into account). Therefore the two tasks, although more ecologically valid compared to those used in previous studies (e.g., electrophysiological methods and musical stimuli specifically composed for the experiments; Jentschke et al., 2008; Jentschke & Koelsch, 2009), may not have been matched in terms of sensitivity in assessing children's skills. Given this limitation, it is notable that a trend towards significance was observed in the association between the two abilities, suggesting that this could be strengthened with better-matched tasks.

Perhaps an interesting expansion of Study 4 would be to administer a variation of the current music task that included a greater number of trials with small pitch jumps at the end of the melodies as a means to increase the sensitivity of the measure. Another possibility would be to use a language task that is equivalent to the music task with respect to the number of trials and format. For example, children could listen to short phrases that would include syntactically *expected* or *unexpected* target words (*unexpected* words create syntactic ambiguity and can be thought as equivalent to unexpected notes in music; Slevc et al., 2009) and asked to make speeded judgments about the voice tone of the target word (e.g., female or male voice tone).

However, standardized language measures were used in the current study because they have been shown to correlate strongly with children's real-time language performance as reflected in measures of spontaneous speech (Bornstein & Haynes, 1998; Condouris, Meyer, & Tager-Flusberg, 2003; Ukrainetz & Blomquist, 2002). Therefore, compared to non-standardized experimental tasks they may provide a more

objective assessment of language development with predictive power for future outcomes. Perhaps future studies could benefit from a combination of standardized language tests as well as well-matched experimental language and music tasks.

Finally, as a general comment that applies to both Studies 1, 2 and 4, although the reported associations provide important information regarding the music-language relationship from a developmental perspective, the correlational design of the present studies does not allow us to draw conclusions about a causal link between the two domains. Although important dimensions such as children's non-verbal ability or general enrichment in the home were controlled for, a variety of confounding factors such as demographic variables, personality traits, parenting styles or other parent-child activities can also contribute to language development (see also Corrigall et al., 2013; Schellenberg, 2004 for discussions relevant to formal music lessons). Randomized controlled trials (RCTs) that randomly assign children to musical or other types of training (control group) have provided an excellent means for showing causal effects of music on language and cognition, as groups in these studies can be matched on several cognitive and demographic variables (e.g., Barac et al., 2011; François et al., 2013). With respect to informal musical experience, using an RCT design to compare the impact of a musical enrichment in the home intervention to another type of enrichment (control) intervention is an interesting possibility. However, an important challenge refers to the degree of control one can have over everyday parent-child interactions to ensure that any observed effect can be assigned to one or the other intervention.

6.5. Concluding remarks

The present thesis sought to shed light on the developmental trajectory of the relationship between music and language, starting from the early preschool years. Motivated by research that has revealed parallels between the cognitive and neural bases of musical and linguistic skills on the one hand and enhancements in auditory and language-related skills associated with formal musical experience on the other, the present thesis followed two main strands of inquiry. First, associations between a wide range of musical and linguistic competencies in 3- to 6-year-old children, an age group so far under-represented in the literature, were examined. Second, the influence of a

hitherto unexplored dimension, namely informal musical experience in the home, on early language and musical development was investigated.

The combined findings of the present thesis significantly contribute towards a comprehensive account of the developmental course of the music-language relationship, not only by extending previously reported links in a younger age group, but also by uncovering novel associations between music and language skills. Critically, they inform theoretical accounts of the music-language relationship by proposing specific mechanisms that may underlie the previously reported associations. Furthermore, the present thesis provides the first evidence that informal musical input such as the one experienced in the home environment may predict the development of complex linguistic skills in young children across different age groups. This conclusion offers important support to the notion that enrichment of experience in one domain can influence development in the other, even when this enrichment is experienced in an informal everyday context. It also uncovers a new type of environmental input that can be beneficial for language acquisition, and opens a new area of investigation about the mechanisms through which informal musical experience may promote development. From a practical perspective, the combined findings of the present thesis turn attention towards musical enrichment as a potential protective factor against language difficulties and contribute considerable insights for early childcare practice in both family and educational contexts.

Finally, important methodological contributions of the current thesis include [a] a number of newly developed experimental tasks for the assessment of musical abilities in young children and [b] the Music@Home Questionnaire, a novel parent-report instrument with good psychometric properties for the assessment of informal musical experience in the home. These contributions provide researchers with useful tools to further develop music perception research in young pre-schoolers and to explore musical engagement in the home and its contribution to developmental outcomes.

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APPENDIX A

Enhanced Disclosure and Barring Services certificate (page 1)

STRICTLY PRIVATE AND CONFIDENTIAL

AIKATERINI POLYTIMOU
4 PENPOLL ROAD
LONDON
E8 1EX

79244801



Enhanced Certificate
Page 1 of 2

 Disclosure & Barring Service

Applicant Personal Details	Certificate Number 001432403763
Surname: POLYTIMOU	Date of Issue: 22 JANUARY 2014
Forename(s): AIKATERINI NINA	Employment Details
Other Names: NONE DECLARED	Position applied for: PSYCHOLOGY STUDENT PHD CHILD AND ADULT WORKFORCE
Date of Birth: 07 MAY 1982	Name of Employer: MIDDLESEX UNIVERSITY
Place of Birth: ATHENS GREECE	Countersignatory Details
Gender: FEMALE	Registered Person/Body: MIDDLESEX UNIVERSITY
	Countersignatory: KAREN RIDOUT

Police Records of Convictions, Cautions, Reprimands and Warnings

NONE RECORDED

Information from the list held under Section 142 of the Education Act 2002

NONE RECORDED

DBS Children's Barred List information

NONE RECORDED

APPENDIX A

Enhanced Disclosure and Barring Services certificate (page 2)

79244802

Page 2 of 2

Certificate Number 001432403763

Use of certificate information

The information contained in this certificate is confidential and all recipients must keep it secure and protect it from loss or unauthorised access. This Certificate must only be used in accordance with the Disclosure and Barring Service's (DBS) Code of Practice and any other guidance issued by the DBS. Particular attention must be given to the guidance in the fair use of the information in respect of those whose Certificate reveals a conviction or similar information. The DBS will monitor the compliance of Registered Bodies with this Code of Practice and other guidance.

This Certificate is issued in accordance with Part V of the Police Act 1997, which creates a number of offences. These offences include forgery or alteration of Certificates, obtaining Certificates under false pretences, and using a Certificate issued to another person as if it was one's own.

This Certificate is not evidence of identity of the bearer, nor does it establish a person's entitlement to work in the UK.

Certificate content

The personal details contained in this Certificate are those supplied by or on behalf of the person to whom the Certificate relates at the time the application was made and that appear to match any conviction or other details linked to that identity.

The information contained in this Certificate is derived from police records, and from records held of those who are unsuitable to work with children and/or adults, where indicated. The police records are those held on the Police National Computer (PNC) that contains details of Convictions, Cautions, Reprimands and Warnings in England and Wales, and most of the relevant convictions in Scotland and Northern Ireland may also be included. The DBS reserves the right to add new data sources. For the most up to date list of data sources which are searched by the DBS please visit the DBS website.

The Other Relevant Information is disclosed at the discretion of the Chief Police Officers or those of an equivalent level in other policing agencies, who have been approached by the DBS, with due regard to the position sought by the person to whom the Certificate relates.

Certificate accuracy

The DBS is not responsible for the accuracy of police records.

If the person to whom this Certificate relates is aware of any inaccuracy in the information contained in the Certificate, he or she should contact the Countersignatory immediately, in order to prevent an inappropriate decision being made on their suitability. This Countersignatory will advise how to dispute that information, and if requested arrange for it to be referred to the DBS on their behalf. The information should be disputed within 3 months of the date of issue of the Certificate.

The DBS will seek to resolve the matter with the source of the record and the person to whom the Certificate relates. In some circumstances it may only be possible to resolve a dispute using fingerprints, for which consent of the person to whom the Certificate relates will be required.

If the DBS upholds the dispute a new Certificate will be issued free-of-charge. Details of the DBS's disputes and complaints procedure can be found on the DBS's website.

Contact us

Post:	Disclosure and Barring Service PO Box 165 Liverpool L69 3JD	Telephone:	Customer Services: 0870 90 90 811 Welsh line: 0870 90 90 223 Minicom: 0870 90 90 344
Web:	www.homeoffice.gov.uk/dbs		
Email:	customerservices@dbs.gsi.gov.uk		

If you find this certificate and are not able to return it to the person to whom it relates, please return it to the DBS at the address above or hand it in at the nearest police station.

End of Details

disclosure disclosure disclosure disclosure disclosure

APPENDIX A

Letter of acceptance template (used in Studies 1, 2 and 4)

Letter of Acceptance by _____Nursery

I, _____Head Teacher of _____, agree for Aikaterini - Nina Politimou to conduct the study _____in _____at mutually convenient times between _____ and _____.

I have been provided with information about the research and have had the opportunity to ask questions and discuss any queries about the study with the researcher/s. I understand that:

- 1) For the children participating in the study, there are no risks other than those involved in taking part in any ordinary activity at school;
- 2) The study has received ethical approval by Middlesex University Psychology Department Ethics Committee;
- 3) Parents/guardians will be fully informed about the study characteristics prior to starting recruiting children and they will be provided with contact details for the researchers, should they have any queries. Furthermore, the researcher/s will be available to parents at pick-up time to answer queries before starting to collect data with children;
- 4) An opt-out consent procedure will be used with the parents/guardians to recruit children, i.e., all children attending the school aged as required by the study will be recruited unless the parents/guardians actively withdraw a child from the study by signing a declaration that they do not wish their child to participate;
- 5) If a child does not wish to participate or wants to withdraw in the middle of testing, they will be free to do so without having to give a reason;
- 6) The researcher will need date of birth and gender for each participant;
- 7) All data gathered from the children will be anonymised and securely stored (confidentiality).

Yours truly,

date: _____

APPENDIX A

Opt-out consent form template (used in Studies 1, 2 and 4)



Middlesex University School of Science and Technology
Psychology Department
Written Informed Opt-Out Consent

Study title: _____

(date)

Researcher: Aikaterini-Nina Polytimou, email: a.politimou@mdx.ac.uk

Supervisor: Dr. Fabia Franco, email: f.franco@mdx.ac.uk

I have understood the details of the research as explained to me by the researcher, and confirm that **I DO NOT** consent for my child to act as a participant.

Print name

Sign Name

Child name and gender

Date: _____

To the participant: Data may be inspected by the Chair of the Psychology Ethics panel and the Chair of the School of Science and Technology Ethics committee of Middlesex University, if required by institutional audits about the correctness of procedures. Although this would happen in strict confidentiality, please tick here if you do not wish your data to be included in audits: _____

APPENDIX A

Study 1 and 2 Information sheet



Psychology Department
Middlesex University
Hendon
London NW4 4BT

PhD researcher: Aikaterini-Nina Polytimou (Supervisor: Dr. Fabia Franco)

Music processing, language abilities and working memory in preschool children

Your child is being invited to take part in a research study. To help you decide whether you would like your child to take part, this information sheet explains why the research is being done and what it will involve. Please take your time to read the following information carefully, and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information.

What is the purpose of this research?

The purpose of this research study is to explore the relationship between music, language abilities and memory in young children. Drawing links between these aptitudes has important implications for children's education, as it helps us discover ways in which musical training may benefit their language and memory development. In the same way, unraveling the developmental path of music perception and production is important for designing age suitable music education programs.

Who is conducting and funding this research?

This research is being conducted as part of a PhD project by Miss Aikaterini-Nina Polytimou, it is funded by a Middlesex University scholarship, and supervised by Dr. Fabia Franco.

Does my child have to take part?

Participation is entirely voluntary. If you choose not to participate, it will not affect you or your child in any way. If you DO NOT give your consent for your child to participate, you will be asked to sign the attached opt-out form. Even if you give consent, you will still be free to withdraw your child at any time and without giving a reason if you change your mind.

What will my child be asked to do if we agree to take part?

Your child will be asked to perform a few musical tasks presented as games. For example, children will be listening to short melodies, rhythms or pitches (three at a time) and will be asked to identify the one that sounds different from the others. They will then be asked to do a brief language and a brief memory assessment. All of these tasks are suitable for preschool children living in the UK. They are also engaging and fun for children to complete. You will also be asked to complete a brief questionnaire containing general information

about your musical background and the child's exposure to music within the family. This can take place in your child's nursery during pick-up times or at home.

Where will the research sessions take place?

The session will take place at your child's nursery and will be conducted by Miss Polytimou, once she has become familiar with the children. A member of staff from the nursery will also be close-by. Every effort will be made to ensure that the research sessions are as enjoyable and relaxed as possible for the children. The time needed to collect your child's responses in the music task, language task and memory test will be distributed across separate sessions (possibly on different days).

Will all my child's details and assessment results be kept confidential?

Yes. All the information about participants in this study will be kept confidential and data will be stored safely and remain anonymous. Data for individual children will not be released to parents, however the results of the study for the whole sample of children as a group will be supplied upon request. Even if the results of the study are published in academic journals or scientific conference proceedings, no identifying information will be mentioned.

What are the risks?

All proposals for research using human participants are reviewed by an Ethics Committee before they can proceed. This research has been reviewed by the Middlesex University Psychology Department's Ethics Committee and it has been deemed to present no risks to children's or parents' physical, psychological or emotional well-being.

Contact:

If you require any further information or have any questions or comments about this study, please do not hesitate to contact Mrs Aikaterini-Nina Polytimou or Dr Fabia Franco:

Miss Aikaterini-Nina Polytimou, Department of Psychology, Middlesex University, London NW4 4BT

Tel: +44 07570685137, E-mail: A.Polytimou@mdx.ac.uk

Dr Fabia Franco, Department of Psychology, Middlesex University, London NW4 4BT

Tel: +44 (0)20 8411 5471, E-mail: F.Franco@mdx.ac.uk

*Thank you for reading this sheet and
considering whether or not you would like your child to take part in this study.*

*You do not need to do anything if you are happy for your child to participate.
Should you **NOT** agree to your child taking part in this study,
please complete the attached form
and return it to your child's nursery within one week from receipt of this document
This information sheet is for you to keep*

APPENDIX A

Study 1 and 2 Debriefing

Psychology Department
Middlesex University
Hendon
London NW4 4BT



PhD researcher: Miss Aikaterini-Nina Polytimou, Phone: +4407570685137, E-mail:

A.Politimou@mdx.ac.uk

Supervisor: Dr. Fabia Franco, Phone: +44 (0)20 8411 5471, E-mail: F.Franco@mdx.ac.uk

Music processing, language abilities and working memory in preschool children

This study is an exploration of young children's musical abilities and their relationship to their language and cognitive development. Musical abilities and knowledge is implicitly acquired through everyday experience, and one doesn't need to be musically trained to possess it. To what extent 3- and 4-year-old children's musical abilities are linked to their language and cognitive development is still largely unknown. Previous research in older children and adults has shown that musical skills can be closely related to cognitive aptitudes such as language and memory and that musical training can induce positive changes in brain and cognitive development. We therefore want to see whether this might be true for younger children.

We are using age-appropriate and fun tasks to evaluate musical, linguistic and memory abilities, and statistical methods to see if these are connected. This is of particular importance since it directly informs educational practice. If musical skills are indeed related to language and memory skills at this young age, musical training can be used to improve them at the time when the brain is still highly plastic. Also, in cases of children with language deficits, musical training may even become part of treatment. In addition, having knowledge of the developmental path of understanding musical structure and acquiring musical abilities can help us design age-appropriate musical education programmes thus maximizing benefits for preschool children.

To measure young children's musical abilities we ask them to make similarity judgments about melodies/pitches or rhythms that they listen to. More specifically, they listen to short music progressions and they are asked to decide whether they are same or different verbally or by pointing to pictures (this will be agreed with each child prior to testing and will depend on their preference). This will tell us whether already at this young age, they are able to perceive salient but also subtle differences between musical elements. They are also asked to imitate individual pitches and short rhythmic sequences, thus evaluating their music production performance. All musical tasks are presented to children in the form of musical games where they interact with toys/pictures. We then ask children to complete age-appropriate language and memory tasks that have been widely used in the UK and are known to be quite engaging and fun for young children. The general information about your musical background and the child's exposure to music will be used to provide a better description of our sample and to see if, for example, musical experiences at home may be related with children's abilities.

Please contact the researcher or supervisor if you have any further questions regarding this study, or Dr Miranda Horvath, Chair of the Psychology Ethics Committee if you have any complaints (M.Horvath@mdx.ac.uk).

Many thanks to you and your child for your co-operation!

APPENDIX A

Study 4 Information sheet

Psychology Department
Middlesex University
Hendon
London NW4 4BT



PhD researcher: Aikaterini-Nina Polytimou (Supervisor: Dr. Fabia Franco)

External collaborators: Lauren Stewart (Goldsmiths University), Marcus Pearce (Queen Mary University).

Processing of music and language structure: the role of the home musical environment

Your child is being invited to take part in a research study. To help you decide whether you would like your child to take part, this information sheet explains why the research is being done and what it will involve. Please take your time to read the following information carefully, and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information.

What is the purpose of this research?

The purpose of this research study is to explore the relationship between musical and linguistic abilities in young children. Drawing links between these aptitudes has important implications for children's education, as it helps us discover ways in which musical training may benefit their language development.

Who is conducting and funding this research?

This research is being conducted as part of a PhD project by Miss Aikaterini-Nina Polytimou, it is funded by a Middlesex University scholarship, and supervised by Dr. Fabia Franco.

Does my child have to take part?

Participation is entirely voluntary. If you choose not to participate, it will not affect you or your child in any way. If you DO NOT give your consent for your child to participate, you will be asked to sign the attached opt-out form. Even if you give consent, you will still be free to withdraw your child at any time and without giving a reason if you change your mind.

What will my child be asked to do if we agree to take part?

Your child will be asked to perform a musical task presented as a game with a touch screen and colourful graphics. More specifically, children will be listening to short melodies and they will be asked to determine whether the last note was a piano or a trumpet sound. They will then be asked to do a brief language and a brief cognitive assessment. All of these tasks are suitable for preschool children living in the UK. They are also engaging and fun for children to complete. You will also be asked to complete a brief questionnaire containing general information about engagement with music and other activities in the family. This can take place in your child's nursery during pick-up times or at home.

Where will the research sessions take place?

The sessions will take place at your child's nursery and will be conducted by Miss Polytimou, once she has become familiar with the children. A member of staff from the nursery will

always be close-by. Every effort will be made to ensure that the research sessions are as enjoyable and as relaxed as possible for the children. The time needed to collect your child's responses in the music, language and cognitive tasks will be distributed across separate sessions (possibly on different days).

Will all my child's details and assessment results be kept confidential?

Yes. All the information about participants in this study will be kept confidential and data will be stored safely and remain anonymous. Data for individual children will not be released to parents, however the results of the study for the whole sample of children as a group will be supplied upon request. Even if the results of the study are published in academic journals or scientific conference proceedings, no identifying information will be mentioned.

What are the risks?

All proposals for research using human participants are reviewed by an Ethics Committee before they can proceed. This research has been reviewed by the Middlesex University Psychology Department's Ethics Committee and it has been deemed to present no risks to children's or parents' physical, psychological or emotional well-being.

Contact:

If you require any further information or have any questions or comments about this study, please do not hesitate to contact Mrs Aikaterini-Nina Polytimou or Dr Fabia Franco:

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Complaints

Should you have any complaints or queries about the conduct of the researchers, please contact Dr Nicola Brunswick or Dr Lisa Marzano, Co-Chairs of the Psychology Ethics Committee, Department of Psychology, Middlesex University (address in heading) - Tel: 020 841 14532, E-mails: N.Brunswick@mdx.ac.uk, L.Marzano@mdx.ac.uk

Thank you for reading this sheet and considering whether or not you would like your child to take part in this study.

You do not need to do anything if you are happy for your child to participate.

Should you NOT agree to your child taking part in this study, please complete the attached form and return it to your child's nursery within one week.

This information sheet is for you to keep

APPENDIX A

Study 4 Debriefing

Psychology Department
Middlesex University
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PhD researcher: Aikaterini-Nina Politimou, 15/07/16

Processing of music and language structure: the role of the home musical environment

This study is an exploration of young children's understanding of Western music structure (of course there are other music traditions in other parts of the world). This is implicit knowledge that is acquired through everyday experience, and one doesn't need to be musically trained to possess it. To what extent 3- to 6-year-old children have knowledge about Western music structure (implicit understanding of which notes are more likely to follow others in a musical piece) is still largely unknown. This study aims at answering this interesting question using an age-appropriate and fun task. It will also aim at linking this element of musical knowledge with the development of language structure and morphology, given that previous research has shown that these two skills can be related in older children and adults.

In our musical task, which is presented as a game with colourful graphics, children listen to short melodies (one at a time) and are asked to say whether the last note was a piano or a trumpet sound by pointing to pictures on a touch screen. According to previous research, if children do possess implicit knowledge of Western harmony, their responses should be faster and more accurate when the last note is in-harmony vs out-of-harmony. We then ask children to complete age-appropriate language and cognitive tasks that have been widely used in the UK and are known to be quite engaging and fun for young children to complete. Finally, we ask parents to complete a short questionnaire giving information about engagement with musical and other activities in the household. This is of particular importance since it helps us explore whether certain types of experience might benefit musical and linguistic development.

Examining the associations between musical skill and experience and linguistic skills is essential as it can directly inform educational policy and practice. If specific musical skills and musical experience are indeed related to language at this young age, musical training can be used to support development. Also, in cases of children with language deficits, musical training may even become part of treatment.

Please contact the researcher or supervisor if you have any further questions regarding this study (contact details given at the bottom of this page), or, in case of complaints, Dr Nicola Brunswick or Dr Lisa Marzano, Co-Chairs of the Psychology Ethics Committee, Department of Psychology, Middlesex University (address in heading) - Tel: 020 841 14532, E-mails: N.Brunswick@mdx.ac.uk, L.Marzano@mdx.ac.uk.

Many thanks to you and your child for your co-operation!

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APPENDIX B

<https://drive.google.com/open?id=0B32pVWrUdLr8YzFJeJJCQVRqMIE>