Examining the relationship between music instruction and sustained auditory attention in five to ten-year-old children: A systematic review

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- Mrs Combrink acted as an independent party involved in providing consensus regarding inclusion of, and determining quality of, selected studies

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Abstract

Background: It has long been suspected that music instruction has benefits for children's neural and cognitive development, including auditory abilities. Although the effect of music on attention has been investigated it has predominantly focused on visual attention, selected auditory attention, or divided auditory attention. Consequently, the impact of music on sustained auditory attention is not well defined and therefore demands investigation and clarity. In order to contextualise the topic this study provides a comprehensive review of literature regarding auditory development and attention, in addition to the systematic review of ten eligible studies.

Objectives: The study aims to critically appraise peer-reviewed articles from the past decade pertaining to the correlation between music instruction and sustained auditory attention in typically developing five- to ten-year-old children.

Method: A systematic search of literature was conducted with five electronic databases, using primary and secondary search phrases. The PRISMA-P guidelines were followed to identify ten studies for inclusion in the review. These studies were assessed in terms of quality, using the HTA quality checklists, and in terms of bias, using the Cochrane Collaborations tool for risk of bias for quantitative studies and the CASP checklist for qualitative studies.

Results: Music instruction has a predominantly positive correlation with sustained auditory attention in children yet is limited by associated variables, such as complex sound environments and age of commencement of music instruction. Several causes are suggested for SAA enhancements, such as alterations in neural structure and function, transfer of musical skills to other domains, and the use of specific musical characteristics. Although the evidence favours the study's hypothesis (i.e. music instruction does lead to enhanced sustained auditory attention), limitations are present. Furthermore, the studies included in the systematic review did not always examine sustained auditory attention directly, rather focusing on highly interlinked functions (e.g. attentional control).

Conclusion: Recent research evidence suggests that music instruction contributes to enhanced sustained auditory attention in young children yet is limited by a number of variables. Therefore, should educators wish to improve children's sustained auditory attention in the classroom and during learning, they should be cognisant of these factors and make efforts to enforce them.

Keywords

Auditory attention; auditory skills; children; executive functioning; music instruction; music lessons; musical training; music tuition; sustained auditory attention

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List of acronyms and abbreviations

SAA: Sustained auditory attention

CASP: Critical appraisal skills program

dB: Decibel

EEG: Electroencephalograph

ERP: Event-related potential

fMRI: Functional magnetic resonance imaging

GRADE: Grading of recommendations assessment, development and evaluation

HTA: Health technology association

Hz: Hertz

MRI: Magnetic resonance imaging

PRISMA-P: Preferred reporting items for systematic review and meta-analysis protocols

SES: Socio-economic status

Chapter 1
Introduction

1.1 Introduction and background to the study

Research efforts have found that musical instruction can result in neural and cognitive enhancements (e.g. Carey, Rosen, & Krishnan et al., 2015; Habibi, Damasio, & Ilari et al., 2017; Pantev & Herholz, 2011; Strait & Kraus, 2014) – enhancements which are especially heightened for those who commence music instruction early in life (for purposes of this study, music education or music tuition refers to formal class music, music training to instrument lessons, and music instruction to both). Structural and functional alterations of neural regions and executive functioning abilities, such as attention, constitute such enhancements. Attention is a complex construct consisting of a variety of forms, including divided auditory attention, selective auditory attention, and sustained auditory attention. The present study will focus on only one form, namely, sustained auditory attention (hereon referred to as SAA) referring to "the self-directed maintenance of cognitive focus under non-arousing conditions" (Clayton, Yeung, & Kadosh, 2015, p. 1) and plays a significant role in mediating auditory behaviour and perception (Kaya & Elhilali, 2017). Although the correlation between music instruction and auditory abilities has been well-documented within the field of neuroscience, there appears to be little documentation regarding auditory attention – research into auditory attention focuses predominantly on selected and/or divided auditory attention but not SAA. To the best of the reviewer's knowledge, there is currently no review of recent evidence documenting correlations between music instruction and SAA. In efforts to fill this void, this study provides a comprehensive overview of literature regarding auditory attention and development of five to ten-year-old children to provide context and background to the study, in addition to highlighting areas which require further investigation. This is in supplementation to the systematic review of select studies which meet defined eligibility criteria.

The present study assumes a hypothesis that music instruction does promote SAA in five to ten-year-old children - a hypothesis which, if affirmed, will highlight the importance of incorporating music education into the school curriculum, as a means to enhance childhood development, and specifically auditory attention. SAA plays a role in academic environments as it is required for learning in terms of concentrating on and engaging with taught content (Gomes, Molholm, Christodoulou, Ritter, & Cowan, 2000). This systematic review hopes to collate evidence for improved SAA in children due to music instruction, and in-so-doing advocates for the importance of music instruction. Moreover, the present study aims to provide a tentative answer to the question that has led to opposing views among researchers – that is, whether music instruction does result in enhanced SAA in children and if so, what the potential causes are thereof.

1.2 Aims of the study

The aim of this systematic review is to explore recent literature in order to ascertain whether research evidence suggests a correlation between music instruction and enhanced sustained auditory attention in typically developing five to ten-year old children, further exploring the potential causes of such a correlation. Moreover, the study aims to highlight research gaps and thereby provide recommendations for future research.

1.3 Research questions

The main research question guiding this study is:
To what extent does music instruction lead to enhanced sustained auditory attention in typically developing five to ten-year-old children, as suggested by recent research evidence?

Secondary research questions related to the main research question are:

- What potential causes are suggested in recent research evidence for correlations between music instruction and enhanced sustained auditory attention?

1.4 Research methodology

The present study falls within the paradigm of interpretivism and adopts a qualitative approach. A systematic literature review of recent research evidence was conducted according to PRISMA-P guidelines (Shamseer et al., 2015). Data collection techniques and methods were determined by these guidelines, including a search strategy and list of eligibility criteria from which ten studies were identified for inclusion in the review. The studies constituted a mixture of qualitative and quantitative designs. Further, quality and risk of bias assessments for each study were included, as per PRISMA-P guidelines. Thematic text analysis and the use of thematic matrices enabled the effective analysis, synthesis and comparison of relevant data from each study. Additionally, an assessment of the reliability of the cumulative evidence was conducted via means of GRADE (Grading of Recommendations Assessment, Development and Evaluation) criteria (Guyatt et al., 2011). Chapter three provides a more detailed explanation of the methodology process.

1.5 List of definitions

Active music listening: A musical activity which involves performing bodily movements in response to music, either a live or recorded performance. Movements can include the use of props, such as scarves. (Sportsman, 2011).

Auditory divided attention: The ability to focus on multiple sources of sound simultaneously (Gomes et al., 2000).

Auditory masking: Masking occurs when the perception of a sound is affected by the presence of another sound. Masking can be in the frequency domain (i.e. simultaneous masking) or within the time domain (i.e. temporal masking). It can also be forward (when the masking sound precedes the masked sound) or backwards (when the masking sound occurs after the masked sound) (Gelfand, 2009).

Auditory selected attention: The ability to attend to target auditory information while ignoring other auditory stimuli (Gomes et al., 2000).

Bandwidth: A range of frequencies within a given band (range) that is used for transmitting a signal (Oxford University Press, 2019).

Broadband noise: Noise whose energy is distributed over a broad section of the audible range of frequencies (Gracey & Associates, 2019).

Call and response: An activity in which a leader sings, chants or plays short musical phrases and the ‘chorus’ repeat the phrases in unison or individually (Sportsman, 2011).

Executive functions: A set of cognitive skills that are necessary for the cognitive control of behaviour, such as attentional control, inhibition, and working memory (Semrud-Clikeman & Ellison, 2009), and to engage in purposeful, goal-directed behaviour (Gioia, Isquith, Retzlaff, & Espy, 2002).

Far transfer: Occurs when the resemblance between the training and transfer domains is not clear (Hyde et al., 2009).

Frequency discrimination: The ability to detect changes in the frequency of tonal stimuli, related to pitch and music perception (Litovsky, 2015).

Frequency resolution: The ability to respond to a single frequency in a acoustic stimulus in the presence of other frequencies (Spetner & Olsho, 1990).

Gamelan: Musical ensembles of various sizes of Balinese descent with an emphasis on rhythm and played on pitched percussion instruments with bronze keys, known as metallophones (Harnish, 2013).

Individual instrument lessons: Consisting of one student and a teacher proficient in the musical instrument of choice, focusing on technique and posture. The student receives feedback and suggestions from the teacher (Sportsman, 2011).

Near transfer: Occurs when there is a close resemblance between the training domain and the transfer domain (Hyde et al., 2009).
Passive music listening: A musical activity involving listening to pieces of music, either live or recorded, while remaining still (Sportsman, 2011).
Playing, singing or chanting a piece of music: A musical activity in which one plays, sings or chants a piece of music, either from a score or without. Singing includes lyrics, neutral syllables and solfege syllables. Performed in unison or in parts, in which case the music is divided into different parts (creating harmony) (Sportsman, 2011).
Rhythmic expectation: Refers to the ability to generate expectations based on perceived patterns of temporal dynamics or rhythm (Khalil, Minces, McLoughlin, & Chiba, 2013).
Solo performance: A performance featuring a soloist, either unaccompanied or accompanied, including both improvised and non-improvised music and occurring in a variety of settings (Sportsman, 2011).
Spectrotemporal processing: Neural responses determined by frequency versus time in terms of stimuli which excite or inhibit neural activity (Richard, Leppelsack, & Hausberger, 1995).
Sound segregation: The process by which a listener segregates the components of complex sound into different auditory components (Kayser, Petkov, Lippert, & Logothetis, 2005).
Transfer: The process by which cognitive development in one domain leads to the enhancement of skills in a variety of alternative areas (Hyde et al., 2009).
Warm-ups: Exercises to prepare the voice and body for music-making, including physical (e.g. stretching), vocal, breathing and instrumental exercises (Sportsman, 2011).
Working memory: The part of short-term memory concerned with temporarily holding information available for processing, contributing to reasoning, decision-making, and behaviour (Diamond, 2013; Miyake & Shah, 1999).

1.6 Delimitations of the study

As the study is a systematic literature review it will not provide data acquired from testing of participants but hopes to provide a sufficient theoretical foundation for future research. As it proved challenging to identify studies that investigated the research topic directly, studies that were highly interrelated to the primary research question were included so as to constitute a valid review. Due to a limited number of eligible studies, the review included no limit as to which studies were included or excluded based on their risk of bias and quality assessment ratings and accounted for the inclusion of review articles in the systematic review.

1.7 Chapter outline

While the present chapter has introduced the topic and provided background to the study, chapter two provides an overview of literature pertaining to the research questions to provide context and place the topic within a broader framework. Chapter three describes the research methodology used to extract and analyse data, while chapter four presents the procedures used and findings obtained. Chapter five presents a discussion of the findings in relation to appropriate literature, with chapter six concluding the study, providing a summary of the primary findings and its implications for future research.

Chapter 2
Literature review

2.1 Introduction

The first section of the chapter provides a concise overview of the anatomy of the ear and the hearing process, providing context to the study, as well as a discussion on theories of hearing as developed over time. Literature related to the auditory development of children is discussed to provide further context as to how music instruction may benefit SAA. In addition to providing context, a review of research findings regarding the influence of music on auditory abilities and attention is included, providing background to the study. Furthermore, as SAA involves attendance to verbal factors (i.e. speech), the similarities between speech and music processing are considered, as further substantiation for music's impact on children's cognitive development. The literature review concludes with an overview of the manner in which specific musical characteristics (e.g. pitch, loudness, and duration) are processed by the auditory system to provide further insight into how music might potentially impact SAA.

2.2 The auditory system: A brief overview

The following section serves to place the current study within a greater context, and to provide insight into how the ear 'works' as foundation to exploring how music might influence elements of auditory attention.

The auditory system comprises the ear and the auditory nervous system (Moller, 2014), the former acting as primary receptor converting sound vibrations into encoded neural impulses (Sterrenberg & Fouché, 2011), while the latter converts sounds into meaningful information. The ear comprises outer, middle, and inner ear, each with a particular function in the hearing process and accounting for the three-part structure which enables the ear to act as its own sound conducting mechanism (Alberti, 2001).

2.2.1 Anatomy of the ear

The outer ear

Hearing begins at the outer ear with the pinna – the visible portion of the ear - collecting sound waves and directing them to the auditory canal (Moller, 2014), angled so as to aid in sound localisation (Hood, 1977). Physical convolutions of the pinna account for time delays in arrival between direct sound and that reflected by its folds (Hood, 1977). The auditory canal transmits sound waves collected by the pinna to the tympanic membrane (i.e. eardrum) (Moller, 2014), marking the beginning of the middle ear. The length of the canal is approximately one wavelength of sound (14kHz) (Hammershoi & Moller, 1996) - sound transmission is thus dependent on the direction of the incoming soundwave. The canal further acts as a resonator (Lipscomb & Hodges, 1999), amplifying sound within the human hearing range (i.e. 20 Hz to 20 000 Hz).

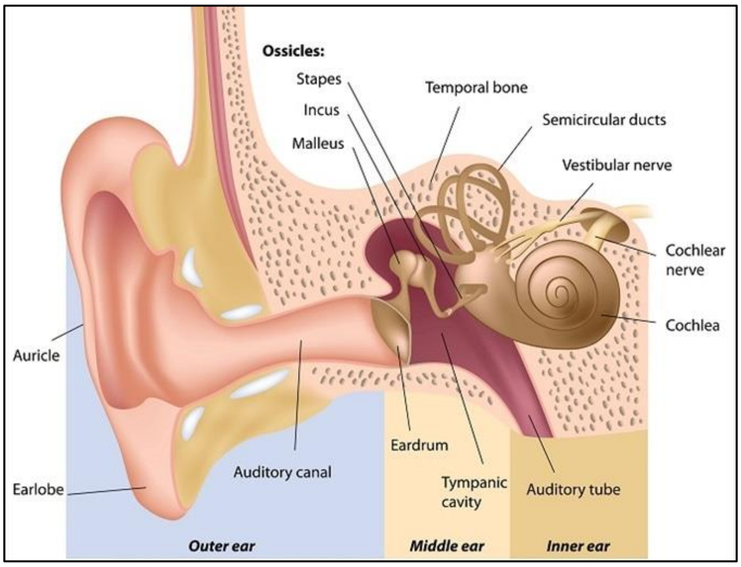

Figure 1: A diagram of the ear, indicating the outer, middle, and inner ears with their particular structures (Alila Medical Media)

The middle and inner ear

The middle ear houses the ossicles (small bones), consisting of the malleus (hammer), incus (anvil), and stapes (stirrup) (Sterrenberg & Fouché, 2011). The malleus is attached to the eardrum, while the stapes is connected to the oval window at the opposite end (Lipscomb & Hodges, 1999). Sound waves travel along the ossicles, causing them to vibrate, to reach the oval window – the opening into the inner ear (Netter, 2014). Upon arrival at the inner ear, sound vibrations pass to the most significant structure in the hearing process: the cochlea, containing hair cells and nerve fibres to transfer auditory information to the brain for processing (Alberti, 2001). It is longitudinally divided into three canals: the upper vestibular canal; the lower tympanic canal; and the inner canal (Sterrenberg & Fouché, 2011). The upper vestibular membrane and lower basilar membrane (Netter, 2014) act as the ‘roof’ and ‘floor’ of the inner ear, respectively. Embedded in the basilar membrane are rows of hair cells (Sterrenberg & Fouché, 2011) to transfer auditory signals to the brain for processing.

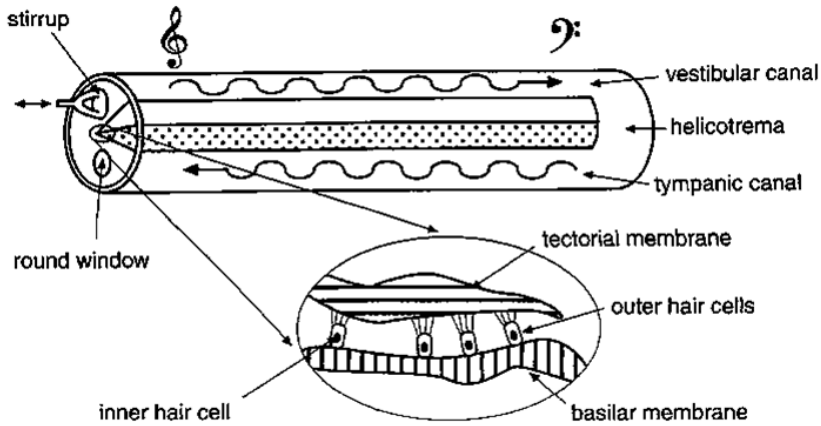

Figure 2: Diagram of the cochlea as if it were unrolled (Lipscomb & Hodges, 1999, p. 87)

membrane to vibrate (Lipscomb & Hodges, 1999), in turn causing the hair cells to respond to specific frequencies, with low frequencies occurring near the apex and high frequencies towards the base of the cochlea (Moller, 2014). Interestingly, "the musically most important range of frequencies […] covers [approximately] two-thirds of the extension of the basilar membrane" (Roederer, 1975, p. 21). As sound waves travel along the membrane they cease as they arrive at their particular point of resonance – the brain therefore suppresses high frequencies in favour of low frequencies, as the latter are required to travel further to their point of resonance. Hair cells convert vibrations into nervous impulses (Alberti, 2001), stimulating nerve endings at the base of the each cell (Moller, 2014) to transport auditory information to the auditory cortex for processing.

2.2.2 Making sense of sound

Central auditory processing occurs as nervous impulses are carried from the cochlea along a complex chain of nuclei (i.e. the ascending auditory nervous system) to the auditory cortex, where sounds are interpreted. However, unlike other sensory systems, upon arrival at the auditory cortex much of the stimulus has been pre-processed by the ear and some localised processing centres along the ascending auditory pathway (Lipscomb & Hodges, 1999). The auditory cortex consists of a primary region surrounded by several secondary regions (King & Schnupp, 2007) responsible for integration, interpretation, and understanding of stimuli (Lipscomb & Hodges, 1999) - otherwise known as 'higher order' processing (required for music processing). The role of the auditory cortex is thus to collate analysed data obtained along the auditory pathway to create coherent, meaningful sounds.

Nuclei comprising the ascending auditory pathway are organised in a tonotopical structure (Handel, 1993) – a structure of specific sound frequencies received by specific receptors and traveling along selected neural pathways (Lipscomb & Hodges, 1999). The tonotopical structure accounts for various neural clusters within the primary region of the cortex responding to different types of sound and acoustic information, sorting and encoding it to be sent to secondary regions for higher processing (Lipscomb & Hodges, 1999). Researchers (Weinberger, Ashe, & Edeline, 1994) have found that learning can cause sensory processing alterations, in that individual neurons are capable of being retuned to respond more favourably to different frequencies, thereby opposing the tonotopical structure. Such research into hearing was based on early theories of hearing, established from the 1800's onwards.

2.2.3 Theories of hearing

The place theory

Theories of hearing first emerged during the latter half of the 1800s, beginning with the Helmholtz resonance theory, which describes the phenomenon of air resonating in an air-filled cavity (e.g. blowing over the top of an empty bottle) (Helmholtz, 1885). Helmholtz posited the idea of an apparatus that can detect specific frequencies from a complex sound, developing a resonator to identify various frequencies or musical pitches. He later revised his theory as he became curious about the resemblance of the basilar membrane to the strings of a harp or piano. He posited that, just as each string of a harp or piano sounds a particular pitch (Lipscomb & Hodges, 1999), so too does the basilar membrane contain individual fibres to analyse individual pitches (Finger, 2001). This revised theory became known as the place theory, stating that perception of sound is dependent on the point at which each frequency creates vibrations along the basilar membrane (Lipscomb & Hodges, 1999). In this way, it was theorised, the inner ear acted as its own frequency analyser, an idea corroborated by Alberti (2001) more than a century later. Alberti suggested that due to the resonance of particular points of the basilar membrane to specific frequencies, the inner ear produces an automatic frequency (pitch) and intensity (loudness) analysis of sound – an analysis which in turn influences perception of sound. However, shortcomings of the place theory were identified by other researchers (Licklider, 1956; Schouten, 1940; Thurlow, 1943), pointing out that it does not account for the perception of complex tones. Yet despite these shortcomings, the underlying idea of particular points on the basilar membrane responding to particular frequencies prevailed, and is now an established aspect of the hearing process (Babbs, 2011; B. C. Moore & Sek, 2013; Schreiner, Froemke, & Atencio, 2011; Stevens, Davis, & Lurie, 1935; Stevens & Warshofsky, 1965).

The temporal theory and frequency theory

An alternative to the place theory, the temporal theory, suggests that sound perception depends on the utilisation of neural temporal patterns to respond to sound (Schouten, 1969). Temporal theory believes that the pitch of a pure tone is determined by the rate of neuron firing patterns. It thus contradicts the place theory which states that pitch is determined by the location of specific frequency vibrations along the basilar membrane (Kiang, Baer, Marr, & Demont, 1969).

The frequency theory, established by Heinrich Rinne in 1865, challenged the place theory. He proposed that the idea of complex sounds being divided into simple sounds, only to be reconstructed in the brain for processing, as implied by the place theory, would not result in efficient hearing (Finger, 2001). In 1886 William Rutherford also contradicted Helmholtz's hypotheses, suggesting that the auditory cortex, rather than the inner ear, performed a frequency analysis of sound (Finger, 2001). Both Rinne and Rutherford therefore suggested a higher-order level of auditory processing than simply the ear, as initially suggested by Helmholtz. Furthermore, their research was based predominantly on the perception of low frequencies of sound.

The place theory of pitch perception

Georg von Békésy, the "molder [sic] of the modern theory of basilar-membrane resonance [of the ear]" (Stevens & Warshofsky, 1965, p. 54) revised Helmholtz's place theory in 1947. Much like Helmholtz conceived his place theory based on the resemblance of the basilar membrane to the strings of a piano or harp, von Békésy compared the quality of the human ear to the telephone systems of the time. He built a synthetic model of the cochlea in order to study the workings of the inner ear (Stevens & Warshofsky, 1965), observing the movements of the basilar membrane when stimulated by sound. From his observations, von Békésy proposed that high frequencies create more vibration at the base of the cochlea, while low frequencies create more vibrations at the apex, an idea that has become part of contemporary explanations of hearing (see Alberti, 2001; Moller, 2014). Von Békésy further corroborated Helmholtz's theory that specific points along the basilar membrane respond to particular frequencies. Von Békésy's work became known as the place theory of pitch perception, paying homage to its extension of the place theory. Yet despite making great advancements in research into hearing, von Békésy, like his predecessors, predominantly measured low frequency responses (B. C. Moore, 2003), omitting the measurement of high frequencies.

The volley theory

The volley theory (Wever, 1949) suggested that neurons in the auditory system respond to sounds by repeatedly firing action potentials out of phase with one another, yet when combined achieve a greater frequency of sound for encoding and processing at a quicker rate than that of individual neurons. Multiple neurons could thus 'fire' in a 'volley' (Finger, 2001) which would later combine and equal the original frequency of the sound stimulus. The volley theory was proposed to combat a shortcoming of the frequency theory, namely, that it did not account for the perception of upper frequencies. Ironically however, the volley theory only accounted for a small section of the full range of human hearing (Finger, 2001).

The cocktail party effect and 'on and off' sounds

While theories of hearing provide explanations of the perception of sound, other theories account for the processing of sound. Colin Cherry proposed the 'cocktail party effect' (Cherry, 1953), in an attempt to explain the phenomena of isolating individual sound streams in the presence of multiple, competing streams. In order to investigate his 'cocktail party effect', Cherry (1953) conducted a series of experiments in which participants were exposed to two simultaneous, contrasting messages and were required to separate them. He found that automatic neural adjustments for intensity differences in sound, originating from multiple sources, accounted for the isolation of multiple sound streams. While Cherry's explanations may prove inaccurate, his ideas formed the basis of selective attention, which involves the selective attending to specific sounds in complex listening environments (Alberti, 2001). Similar to Chery's 'cocktail party effect' is the notion simply termed 'on and off sounds' (Davis & Silverman, 1978). This idea refers to the ability of neurons to respond only to the onset of sounds while others respond only to the termination of the same sounds. For example, being acutely aware of the sound of an air conditioner which disappears into the background after a short period of time. In the same manner, when the conditioner is switched off, one is at first aware of the absence of sound, yet that too becomes part of the background. Both 'on and off sounds' and the cocktail party effect indicate a level of higher-order auditory perception, as they both infer maintaining attention in more complex sound environments.

Advances in research into neurobiology, human anatomy, and hearing have contributed to the development and advancement of initial theories of hearing. Prior to the 1900s the majority of theories, although correct in their hypotheses, appeared to predominantly account for the perception of low frequencies only, despite the capacity of the human ear to also hear high frequencies. Original theories have thus since been expanded upon and incorporated into more contemporary hearing theories. Possibly more consequential than understanding how humans hear, it is significant to consider how hearing abilities develop through childhood, as immature auditory skills may influence sound perception, and perhaps even SAA.

2.3 Auditory development from infancy to age ten

Auditory abilities begin developing during the second trimester of gestation in which the cochlea reaches full maturation. Development of the auditory system continues into the perinatal period - a time of rapid maturation of auditory brainstem structures (J. K. Moore & Linthicum, 2007) necessary for development of the auditory cortex (Bishop, Hardiman, & Barry, 2011) – and is fully functional by 29 weeks gestation, enabling the foetus to receive and recognise music and language (Graven & Browne, 2008). Upon entering the postnatal period, various auditory abilities continue to develop.

2.3.1 Auditory development during infancy

Frequency resolution and discrimination

Due to gestational auditory developments, infants demonstrate several adult-like cochlear functions at birth (Abdala & Chatterjee, 2003). These functions continue to develop further, such that by six months old, infants demonstrate well-developed auditory perception (Louw & Louw, 2014) with auditory neurons having reached 50 to 60 percent of their adult size. In infancy, frequency and decibel levels impact auditory capacities greatly, due to the cochlea's tonotopical structure (Graven & Browne, 2008), and care should thus be taken in ensuring background sounds remain at certain frequency and decibel levels. Graven and Browne (2008) advise that as the period between birth and six months is critical to successful development of the auditory system, background sounds should remain below 60dB and be within a mid to high frequency range, as sounds outside these parameters disrupt healthy auditory development. Frequency resolution, one of the auditory abilities emerging during infancy, should therefore correspond with the suggestions of Graven and Browne, in that infant's sound resolution should be limited to high frequencies, as low frequencies might damage healthy auditory development. Spetner and Olsho (1990) tested frequency resolution in three- and six-month-old infants at 500, 1000, and 4000 Hz (i.e. high frequencies). They found that by three months of age, frequency resolution is mature at 500 and 1000 Hz, yet remains immature at 4000 Hz. However, by six months of age, adult-like frequency resolution was demonstrated at 4000 Hz. Spetner and Olsho (1990) therefore limited their tests to high frequencies, perhaps due to the potential damage to auditory development of low frequencies, as suggested by Graven and Browne (2008). It is thus inferred that although well-developed, infant auditory capabilities remain immature at this stage.

Abdala and Folsom (1995) corroborated the findings of Spetner and Olsho (1990) regarding infants' development of frequency resolution by measuring frequency resolution at brainstem level, and discovering mature frequency resolution at six months of age, yet immature frequency resolution at three months of age. Furthermore, their findings - and those of Spetner and Olsho (1990) - coincide with typical development of frequency discrimination, which starts developing at seven months (Bargones & Werner, 1994).The auditory ability of infants appear to be predominantly related to skills involving frequencies of sound – frequency resolution, discrimination, and tuning. Bargones and Werner (1994) investigated frequency discrimination by comparing adults' and infants' ability to detect expected and unexpected frequencies. While adults were more sensitive to frequencies they expected to hear than to unexpected frequencies, infants were equally sensitive to both expected and unexpected frequencies. Infants thus monitor a broad range of frequencies, as they have yet to develop the skills to isolate target stimuli (Bargones and Werner, 1994). Newman and Jusczyk (1996) substantiate this finding, by demonstrating that infants are able to segregate sounds only under select conditions, such as the identification of competing voices only under conditions of sound intensity differences.

Absolute thresholds

Just as infant auditory discrimination and resolution appear to be limited to high frequencies, so too do absolute thresholds. According to some research, absolute thresholds first mature at high frequencies, while low frequency thresholds remain immature until childhood (Lynne A Werner & Gray, 1998). Based on such research findings, it is suggested that absolute threshold development occurs in parallel with both frequency discrimination and resolution development. Likewise, another form of auditory threshold, namely, gap detection threshold (i.e. the ability to hear gaps in tones and noises), was also found to remain immature throughout infancy. Lynne A Werner, Marean, Halpin, Spetner, and Gillenwater (1992) measured gap detection thresholds in three-, six-, and twelve-month-olds and in adults for broadband noise and low-pass noises (i.e. blocking out high frequencies by only allowing low frequencies to be heard).Gap detection thresholds were poor among infants compared to adults, and showed no improvement between three and twelve months of age, substantiating other research findings of frequency discrimination and resolution (see Abdala & Folsom, 1995; Graven & Browne, 2008; Spetner & Olsho, 1990). Changes in the frequency of the sound stimulus resulted in changes in infant's gap detection threshold, thereby highlighting the significant role of frequency in infant auditory perception (Lynne A

Werner et al., 1992). Werner and her colleagues, performing subsequent, similar experiments, yet employing different testing methods, reported the same poor gap detection among other infant participants (Lynne A Werner, Mancl, & Constantino, 1994).

Auditory sensitivity

Yet another auditory capacity demonstrated by infants is that of auditory sensitivity (i.e. the degree to which one is sensitive to sound stimuli), and pertains to decibels, rather than frequency(Gelfand, 2009). Tharpe and Ashmead (2001) investigated the auditory sensitivity of infants by studying monthly behavioural responses to speech noise stimuli in participants aged between birth and twelve months. Each month's test increased in intensity by minus 2dB until participants visibly responded to sounds. An infant auditory threshold estimate was thus obtained, reaching an asymptote at six months old, indicating rapid behavioural auditory development between birth and six months of age. The rate of behavioural auditory development, as indicated by auditory sensitivity, thus seems to gradually decrease after six months of age while it is posited that the reverse is true of the rate of development of physiological auditory capabilities (such as frequency resolution).

Infants' auditory sensitivity to broadband noise was examined by L.A. Werner and Boike (2001), whose findings suggest that this ability remains immature in infancy, as although the auditory system filters out extraneous noise surrounding target tones, the infant has difficulty in extracting those tones from the background. This finding contradicts the postulation that infants are able to monitor a broad range of frequencies (Bargones & Werner, 1994), but as Bargones and Werner (1994) place no age limit on the ability to monitor many frequencies simultaneously, perhaps this skill develops in parallel with sensitivity to broadband noise.

Much auditory development occurs during infancy, specifically from birth to six months (Louw & Louw, 2014). Although physiological and behavioural aspects of audition develop at differing rates, one leads into and contributes to the other. Yet more developments are required in order for hearing to reach complete, adult development (Bargones & Werner, 1994; L.A. Werner & Boike, 2007; L.A. Werner, 2001). Audition thus continues to develop into early childhood, during which time infant capabilities are extended and new skills emerge.

2.3.2 Auditory development during early childhood

During early childhood auditory abilities become more advanced. Higher order functions begin to play a role in auditory processing, lending more precision to auditory skills. Yet despite the many advances occurring during this period, auditory abilities do not reach fully adult-like levels. The skills of frequency resolution and discrimination, already rather mature in infancy, continue to develop into the early childhood years.

Frequency resolution and discrimination

Hartley, Wright, Hogan, and Moore (2000) explored the development of frequency resolution in six to ten-year-old children and adults. Six-year-olds demonstrated adult-like frequency resolution, coinciding with healthy cognitive development. The increasing communication between the auditory cortices of both brain hemispheres specifically develops, contributing to this improved frequency resolution (Hartley et al., 2000). It is therefore understandable that music is believed to promote frequency resolution, as music activates neural activity across both hemispheres (Altenmüller, 2003; Tramo, 2001). In terms of frequency discrimination, childhood skills appear to remain much like that during infancy, in which discrimination of high frequencies is well-developed, while discrimination of low frequencies is limited (see Graven & Browne, 2008; Werner & Gray, 1998). Fischer and Hartnegg (2004) tested children, aged seven to seventeen years, on a series of tests measuring frequency discrimination abilities. Results indicated that low frequency discrimination remains immature until ten or eleven years of age, at which stage it reaches adult-like levels, while high frequency discrimination is well-developed at an earlier stage. It is postulated that the developmental trajectory of both frequency discrimination and resolution echoes that of their development in infancy, in that frequency resolution appears to develop frequency discrimination.

Although research indicates that frequency resolution is mature by childhood, frequency discrimination seems to remain immature. The measurement of ERPs in seven to twelve-year-old children in response to syllable or tone stimuli, paired with deviant tones (Bishop et al., 2011) validated the findings of Fischer and Hartnegg (2004). Bishop et al. (2011) suggested prolonged development of discrimination capabilities which continue to develop through childhood and into adolescence. It is interesting to consider these findings in light of theories of hearing, which appear to predominantly account for the perception of low frequencies (see Finger, 2001; Moore, 2012) with little consideration of high frequencies. It is therefore suggested that theories of hearing remain applicable to fully developed auditory systems of adults, not to the immature systems of children.

Sound segregation

The capacity for selective listening – or sound segregation – is indicated by research to continually improve as infants cross the threshold into childhood (e.g. Hollich, Newman, &

Jusczyk, 2005; Litovsky, 2015; L.A. Werner & Boike, 2001). Added to this ability for isolating particular sounds is the emergence of the highly interrelated auditory masking (Hartley et al., 2000). Sussman, Wong, Horváth, Winkler, and Wang (2007) compared auditory streaming in two groups of children (ages five to eight, and nine to eleven) and adults, to determine their ability to distinguish between one or two sound streams. Differences were not only observed between children and adults, but also between the two groups of children. The older children (aged nine to eleven) demonstrated more adult-like sound segregation, in that they could perceive two distinguishable sound streams differing little in frequency level. However, the younger children (aged five to eight) required larger frequency differences to distinguish the two streams. Sussman, Wong, et al. (2007) suggest that although being functional early in life, stream segregation takes time to develop, maturing as the child ages and interacts with increasingly complex soundscapes. They suggest that the capacity for selective hearing does therefore not differ much between infancy and early childhood, due to its gradual development. The difference between sound segregation abilities of the two groups of children, as identified by E. Sussman et al. (2007), suggests an emerging capacity for masking - the more precise the ability for sound segregation, the better the ability for masking.

Auditory masking

Buss, Hall, Grose, and Dev (1999) explored the forward, backward, and simultaneous masking performance of children (aged five to eleven) compared to adults. Each form of masking was found to improve with age. Later revising this study, Hall, Buss, and Grose (2005) investigated the difference between adults' and children's (aged five to ten) capacity to detect auditory signals in the presence of masking stimuli, concluding that children employ cues to separate sounds, yet are less able than adults to identify, and therefore utilise, all available cues. Hall, Buss, and Grose (2005) therefore identified some shortcomings of children's masking abilities - children's capacity for masking is limited to their skill in utilising available cues. Moreover, masking ability appears to mature at a quicker rate than sound segregation, despite being similar in function. Perhaps the rapid developmental rate of masking is a result of the infant's ability to distinguish the mother's voice among a crowd of competing sounds (Louw & Louw, 2014), a more inherent ability compared to selective listening skills which develop with experience (Morrongiello & Gotowiec, 1990).

In a similar study to that of Hall et al. (2005), Leibold and Neff (2007) examined the influence of sound source features on masking abilities in children. Their findings supported that of Hall et al. (2005), namely, that children struggle to segregate target sounds from the masker in complex sound environments. Nonetheless, Hall et al. suggest that by age seven or eight, children demonstrate adult-like capability to overcome distracting effects, yet only when provided with cues to distinguish target sounds from the masker. Difficulties in auditory masking present a disadvantage however, as the competing sounds and noises can be detrimental to children's hearing (Hall et al., 2005). Rapid development of masking skills is thus a potential means by which auditory development has counteracted this potential shortcoming. Conversely, selective listening develops over time with experience, as a more complex feature of auditory perception (Wightman & Kistler, 2005). Examining selective listening, Wightman and Kistler (2005) exposed children and adult participants to a target sentence in one ear, with a competing sentence in the other ear. Results corroborated that of other, similar studies (Hall et al., 2005; Leibold & Neff, 2007) in which children demonstrate more informational masking than adults, indicating difficulty in extracting target sounds from distracting soundscapes. Yet despite showing difficulties, children's auditory masking remains somewhat adult-like, as even adults exhibited difficulties in extracting target sounds in the presence of auditory distractors.

Although highly developed by childhood, auditory abilities, contributing to effective auditory attention, continue to develop into adolescence. As a higher-order function, auditory attention begins to develop during early childhood. Comprised of several different forms, it is impacted by several variables. As auditory attention is the focus of the present study, the following sections serve to provide context and an overview of literature in this field of interest.

2.4 Auditory attention

Attention is defined as an interaction between bottom-up and top-down processing, and between automatic and controlled processes (Cummins, 2017), and forms a significant part of cognition. Auditory attention contributes to successful learning by limiting input information to maximise stimulus information processing and storage (Soltanparast, Sameni, Jafari, & Salehi, 2014). Attentional processes involve a complicated network of factors influencing which stimuli are singled out for processing, based on physical characteristics and the receiver's motives, interests, and cognitive strategies (Gomes et al., 2000). Auditory attention involves essential functions for establishing foundations for higher-order processes, such as language skills and memory (D. C. Miller, 2013). Three forms of attention are identified: selective attention, divided attention, and sustained attention. Sustained auditory attention, the focus of the present study, refers to the ability to remain vigilant on a particular task for a prolonged period of time (Clayton et al., 2015). As SAA constitutes one form of attention, it is pertinent to consider aspects of auditory attention in general, which inherently includes sustained attention.

2.4.1 Attention theories and models

Various theories and models of attention have been proposed in efforts to explain and understand attentional processes, included here to provide further insight (and perhaps understanding) into the attention skills of children. Each attention theory contributes a unique insight into attentional capacity and processing, while most have contributed, in some manner, to contemporary attention theories.

Attention theories

During the 19th century psychology emerged as a distinct discipline involving efforts to measure and quantify common mental processes. Esteemed psychologists thus began investigating the cognitive function of attention (O'Donnell & Cohen, 1993). As a pioneer of experimental psychology, Wilhelm Wundt conceived consciousness as a large, 'apprehended' field of sensory and mentally derived content. Attention focused on a small area of this apprehended field (Wundt, 1902) and the degree to which perception of stimuli was enhanced by attention was determined by its 'clarity' in consciousness. Wundt (1902) further believed that several elements within this apprehended field could be focused on simultaneously yet was limited to a maximum of seven elements. Wundt's (1902) theory was later extended by his own student, Edward Titchener, who proposed a two-factor process of attention, suggesting the combined processes of increased clearness of attended-to sensations of ideas, and inhibition of impressions of memory images (Titchener, 1908). Titchener's (1908) propositions were therefore similar to the original proposition of Wundt (1902), in terms of clearness of consciousness in attention processes. Yet Titchener (1908) believed that inhibition also played a significant role in attentional processes; a role that would, a century later, be suggested as playing a significant role in sustaining attention.

Wundt (1902) and Titchener's (1908) attention theories emphasised the role of consciousness, therefore implying an automaticity of attention processes and providing little room for the role of effort. Meanwhile, William James, one the most influential 19th Century psychologists (O'Donnell & Cohen, 1993) defined attention as an active, rather than passive, process. W. James (1890) further suggested a motivational component of attention, stating that the attention focused on an object is a function of the interest expressed for it. In other words, W. James viewed effort as a driving force of focused attention. Like Titchener (1908), W. James identified two attention processes, terming them passive and active. The former was considered as effortless and reflexive, while the latter was considered voluntary and effortful. W. James further added a new component to his theory, namely, the idea of inattention, which he believed occurred as a result of redundant, or repetitive, stimuli. He therefore suggested the use of practice as a means to counteract inattention, believing the more practiced a process, the more habituated it becomes (and thus requires less effort) (W. James, 1890).

Walter B. Pillsbury adopted the concept of attention as ‘clearness’ as first suggested by Wundt (1902). However, Pillsbury (1908) stressed biological foundations of attention processes and its involvement in other aspects of cognition, such as working memory (Pillsbury, 1908). Resembling Wundt’s theory even further, Pillsbury also proposed a number of objects that can be attended to simultaneously – five to eight – in contrast to Wundt’s postulation of three to seven. Like Titchener (1908) and W. James (1890), Pillsbury also cited a two-factor process of attention, yet he cited physiological rather than psychological processes. Pillsbury’s process included the added component of reinforcement (or facilitation), referring to the increase in activity of one nerve cell due to the activity of another; and inhibition, referring to the opposition of two cells working simultaneously. Pillsbury posited a highly influential role of inhibition in attention, corroborating Titchener’s ideas. Moreover, the reinforcement process could account for Pillsbury’s suggestions of the role of memory in attention as reinforcement could denote increased activity of memory, resulting in increased attention. Pillsbury’s two physiological processes can be likened to W. James’ two forms of attention (i.e. active and passive). The employment of working memory is predominantly an involuntary process, thereby correlating with passive attention; while inhibition requires effort and is voluntary, thereby correlating with active attention.

Another theory, the filter theory (Broadbent, 1958) suggests that information considered irrelevant is discarded while relevant information is stored in short term memory for further processing (Milliken & Tipper, 1998). Broadbent (1958) implies a limited capacity of information processing, such that a selective filter is required to discard irrelevant information and allow relevant information to pass through the filter into short-term memory. A degree of controlled attention, accounting for selectivity in encoding incoming information is thus implied, indicating a degree of effort (see W. James, 1890). The filter theory accounts for early descriptions of auditory selective attention, which, according to Broadbent’s suggestions, contribute to sustained attention processes. The filter theory is especially pertinent in terms of musical stimuli, as complex musical works bombard the listener with multiple streams of auditory information which, although creating a holistic musical piece, can overwhelm the auditory system with information (O'Donnell & Cohen, 1993). The filter theory was, however, found to have shortcomings, as it was discovered that not only can individuals selectively attend to specific sounds, but they can also shift attention to previously unselected stimuli (Broadbent, 1958). This idea of shifting was later incorporated into Mirsky and colleagues' (1991) attention model, as an essential function of attention.

Models of attention

Attention models focus on defining features of attention which contribute to attention processes. One of the first models of attention (Treisman, 1969) suggested a filter-attenuation model, positing that by focusing on a sound source with alternative stimuli present, difficulty in concentrating on the focal stimulus would result. These findings contrasted that of the filter theory (Broadbent, 1958), and even somewhat accounted for its shortcomings, by postulating that stimuli not attended to are merely reduced, rather than being filtered out completely. In this context, the attention system employs the mechanism of reduction of irrelevant stimuli to reduce interference in the processing of relevant information. Treisman (1969) therefore presented another possible explanation of selective attention, by describing another means by which effort is employed to actively attend to selected stimuli. Luria (1973) proposed another model, postulating three simultaneously active systems which combine involuntary and voluntary attention processes. These three systems are separated into: a) attentional control (selective and sustained attention); b) cognitive flexibility (working memory, shifting, and conceptual transfer); and c) goal setting (initiating, planning, problem solving, and strategic behaviour). Luria's ideas are therefore akin to attention theories which propose two attention processes – Luria simply adds a third process. Some aspects of these three systems, such as working memory and strategic behaviour (i.e. inhibition) validate the cognitive psychologists' initial explanations of attention, with inhibition implicated in Titchener's (1908) theory, and memory in Pillsbury's (1908) theory.

Posner and Petersen (1990) suggested an attentional structure consisting of three prominent attention functions: a) orienting to sensory events; b) selecting stimuli for conscious processing; and c) alerting (arousal was later added as a fourth component). These three processes demonstrate different characteristics, and therefore place different demands on the information processing system. Posner and Petersen also describe two processes of attention, making clear distinctions between automatic (i.e. passive) and controlled (i.e. active) attention, thereby corroborating prior ideas (e.g. W. James, 1890; Pillsbury, 1908; Titchener, 1908). Another model (Mirsky et al., 1991; Mirsky & Duncan, 2001) was developed based on a series of neuropsychological tests measuring attentional features in both children and adults. Based on these features, a taxonomy of attention functions was suggested, including: focus/execute; sustain and stabilise; shift; and encode. Mirsky's (2001) focus/execute and sustain and stabilise functions correlate with Posner and Petersen's selecting and alerting, respectively. Each function is supported by different brain regions, specialised for its specific purpose, and incorporated into the auditory system (Mirsky et al., 1991).

More than a decade later Knudsen (2007) proposed a new framework of attention, proposing a combination of four distinct processes, namely, working memory, competitive selection, top-down sensitivity control, and automatic filtering for salient stimuli. Knudsen believed that attention is responsible for selecting the information that gains access to working memory and for the emergence of the proceeding recurrent loop utilised to process that information. Similarities between Knudsen's and Luria's (1973) work is found in the inclusion of working memory and goal-directed behaviour as fundamental components of attention processes. Knudsen further proposed a separation of voluntary and involuntary control of attention, suggesting the former involves the first three processes (i.e. working memory, top-down sensitivity control, and competitive selection) operating in a recurrent loop, while the latter constitutes the fourth process of salience filters. The process of filtering for salient stimuli is an automatic process of responding to stimuli that are of instinctive or learned biological importance (Luria, 1973). As an automatic process, salient filters are therefore excluded from voluntary (active) attention processes. Due to his elements of attentional control Knudsen's framework has implications for how attention is maintained during specific tasks, specifically those requiring sustained attention.

2.4.2 Influential factors in auditory attention

SAA involves the maintenance of attention over extended periods of time (Clayton et al., 2015), a task that may prove challenging in complex sound environments in which certain variables impact attention abilities, causing possible disruptions to SAA. It is therefore significant to consider such influential factors, several of which are identified in the review studies. Some factors may be externally manipulated and controlled to a degree, while others are less manageable.

Biological auditory skills

Auditory abilities develop over time, determined by a biologically predetermined developmental trajectory (Litovsky, 2015; J. K. Moore & Linthicum, 2007; L. Werner, Fay, & Popper, 2011). As such, these auditory skills might exert a significant impact on attention capacities, as they are inherently biological and can therefore not be easily manipulated. Ridderinkhof and Van der Stelt (2000) emphasised that while young children possess selective attention capacities, the efficiency and speed of these skills remains rudimentary, and are even further reduced in complex sound environments. As selective attention capacities remain immature in early childhood (Sussman, Wong, et al., 2007), it is suggested that listening environments remain rather simple,demanding little stream segregation, to ensure as much maintence of auditory attention as possible. Van der Molen (2000) implied similar conclusions, showing that some mechanisms of attention show differing developmental rates. Van der Molen further suggested a close link between maturation of the frontal lobe and inhibitory control. As postulated by cognitive psychologists who developed pioneering theories of attention, inhibitory control plays an influential role in active attention processes (Luria, 1973; Pillsbury, 1908; Titchener, 1908). It is thus fitting that van der Molen suggests that inhibitory control exerts a significant effect on auditory attention capacities, further positing that inhibitory control matures with age. This implicates age as a variable exerting an effect on auditory attention, as is evidenced by typical development of auditory abilities with age (Bishop et al., 2011; Fischer & Hartnegg, 2004; Leibold & Neff, 2007).

The influence of age on executive functions was investigated by V. A. Anderson, Anderson, Northam, Jacobs, and Catroppa (2001) with a sample of 138 Australian children, aged eleven to seventeen years old (as the present study is concerned with auditory attention, only results regarding attention abilities – forming part of executive functions – are discussed). Based on their findings, attentional capacity and processing speed appear to develop rapidly from infancy through early childhood, implying the rapid maturation of auditory attention capabilities in early childhood (Anderson et al., 2001). Implications for SAA then, based on findings from Anderson et al.'s study, are favourable – SAA is rather mature by early childhood, although showing some immature aspects. However, this study was conducted with Australian participants – were the same tests to be performed with children of other nationalities, results may present differently. That is not to say that development of attentional capacities is not standard among different nationalities – rather that the influence of cultural and social orientations may exert a degree of influence over stimulation of neural factors, which might influence rate of development (Han & Northoff, 2008; Hedden, Ketay, Aron, Markus, & Gabrieli, 2008; Wong, Perrachione, & Margulis, 2009).

The suggested influential variable of age on attention capacities is further corroborated by a study that examined the influence of story interruptions, age, and vocabulary knowledge on sustained attention in three to four year old children (Gianvecchio & French, 2002). Findings emphasise the improvement of SAA with age, implying, as did previous studies (see Buss et al., 1999; Fischer & Hartnegg, 2004; Sussman, Wong, et al., 2007), an influence of developmental trajectories on auditory attention skills. It is possible that by isolating those auditory attention skills which are almost adult-like in early childhood, and combining them with knowledge of the impact particular variables have on attention, musical activities can be shaped to target mature auditory capacities while limiting use of the immature aspects. Inattentiveness further contributes to reduced SAA among children, by leading children to perform more poorly than adults on the same task, as children remain 'off-task' and fail to obtain significant information about target sounds (Leibold & Neff, 2007). Inattentiveness may also account for the reduced auditory sensitivity of young children (Tharpe & Ashmead, 2001; L. A. Werner & Boike, 2001). Children are therefore seen as less attentive than adults, as they experience difficulty detecting and discriminating between multiple sound streams (Fischer & Hartnegg, 2004; Hill, Hogben, & Bishop, 2005; Ridderinkhof & Van der Stelt, 2000; Van der Molen, 2000). It is therefore important for educators to take into consideration the inattentiveness of young children, who require tasks and stimuli that embody few sound streams, in order that sound can be effectively detected, discriminated, and processed. However, despite efforts to reduce the presence of distracting factors, children's attention capacities remain developmentally immature (Bishop et al., 2011; Fischer & Hartnegg, 2004; Leibold & Neff, 2007) While it is therefore possible to attempt to create sound environments promoting SAA, such efforts are limited.

Elements of auditory attention

In addition to biological and external factors, aspects of auditory attention may themselves wield a degree of influence on attention skills, such as auditory attentional control (Wu, Weissman, Roberts, & Woldorff, 2007). This element of auditory attentional control was found to operate, in part, by biasing processing in the sensory cortex to target stimuli (Wu et al., 2007), implying a degree of selective attending to sounds deemed relevant to the context. The idea of attentional control involving an element of selective attention is not a new idea, being originally proposed by Luria (1973). However, Luria suggested that attentional control includes both selected and sustained attention, the latter of which was not much considered by Wu et al. (2007). It is probable however, that despite not considering SAA, the findings from Wu et al.'s (2007) study have implications for sustained attention – if selected and sustained attention operate within the same system of attentional control (as Luria first suggested) then perhaps the processes involved in biasing the sensory cortex to target stimuli also affects ability for remaining vigilant over time. Wu et al. also found that the auditory cortex can even be activated in silence, in which there is simply an inner expectation of sound. Yet this activation only occurs in musical contexts, in the silence of intervals between musical tracks/movements, or in the quiet of musical interludes. It is therefore implied that attentional control networks operate supramodally, meaning abstract functioning is implemented to activate the auditory system in spaces of musical silence (Wu et al., 2007). Should the auditory cortex be activated during a musical piece, selective attention processes could potentially focus on particular sound streams, yet during intervals of silence, sustained attention processes would retain activation of, and ultimately, engagement with the music. Although based in neuroscientific methods (i.e.fMRI testing), Wu et al.'s findings present with certain limitations, as no participant demographics are provided. It is therefore uncertain as to which age group these results apply. It is conceivable that testing was conducted with adolescents or adults, as attentional control does not appear to be a significant developmental factor of audition in childhood (Boothroyd, 1997; Gomes et al., 2000; Litovsky, 2015; J. K. Moore & Linthicum, 2007).

In support of Wu et al.'s (2007) suggestions of activations of the auditory cortex in silence, Zatorre (2007) presented a similar hypothesis, positing involvement of the auditory cortex in the processing of stimuli unrelated to sound, and in the absence of sound. Zatorre however, rather than examining the activation of the auditory cortex in absence of sound, examined how factors unrelated to sound – memory, attention, and mental imagery – play a role in eliciting neural responses in the auditory cortex. Indeed, Zatorre's suggestions herald early (and a few more recent) theories of attention which implicate similar factors, such as working memory (Knudsen, 2007; Mirsky et al., 1991; Pillsbury, 1908) and impressions of memory images (Titchener, 1908). Although such factors are not directly involved in auditory function, it is likely they do contribute to, and likewise influence, auditory skills. Such influences are said to account for complex behaviours and various cognitive processes (Zatorre, 2007). Furthermore, neural sensory areas were found to focus on the recalled, current, or future features of a stimulus. Zatorre therefore postulated that properties of individual stimuli will exert an influence on the degree of auditory attention attributed to particular tasks, in addition to factors within the external environment which exert further effects. While variables such as memory, attention, and mental imagery may account for complex behaviours, it is likely that they also influence cognitive processes, which in turn might impact auditory attention capacities. It is interesting that once again, the role of memory has emerged in investigations into attention. It can thus be concluded, based on early theories and models of attention, to more recent investigations of attention, that memory is intertwined with auditory attention.

External influential factors: Musical tasks and rewards

The ability to remain focused on a particular task for extended periods of time is suggested, by descriptions of developmental auditory abilities, to be limited, even in adults, and is further said to be influenced by the type of task one is focusing on (Betts, Mckay, Maruff, & Anderson, 2006; Jackson & Balota, 2012). It has been found that decrements in sustained attention are likely to occur if the task is cognitively simple and repetitive, and uninteresting to the individual (Langner & Eickhoff, 2013). Cognitively simple tasks stimulate few brain regions, while sustained attention tasks should elicit activations in a distributed network of brain areas (Langner & Eickhoff, 2013). It is postulated that sustaining attention is a multi-component, non-unitary function, involving a combination of a) recurrent processes sub-serving arousal maintenance and b) transient processes sub-serving reorienting of attention (Langner & Eickhoff, 2013). The successful activation of both processes will potentially lead to improved task vigilance. Although Langner and Eickhoff (2013) present new ideas in terms of sustained attention processes, they recall elements of earlier research (Knudsen, 2007; Luria, 1973; Mirsky et al., 1991; Posner & Petersen, 1990) which posit a combination of two or three processes as contributing to attention. Moreover, Langner and Eickhoff's idea that repetitive and uninteresting stimuli lead to reduced vigilance validates W. James' (1890) much earlier arguments that inattention occurs as a result of redundant or repetitive stimuli. Langner and Eickhoff's findings hold significant implications for utilising musical training as a means to promote SAA, as it is easy for musical tasks to become boring and repetitive, as is the nature of musical practice and training (Patel, 2011). For example, consider the learning of a new piece of music, in which one does not simply start playing the entire piece from start to finish. Effective practice requires the division of the piece into smaller sections, each of which are practiced individually many times over, until each section has been successfully learnt (Gruson, 1988; Howard, 1982).

Perhaps the solution to maintaining interest in musical stimuli lies in the provision of external rewards, as a means to motivate students to remain vigilant to the task at hand. Yet such a notion is refuted by Esterman, Reagan, Liu, Turner, and DeGutis (2014) who examined aspects of sustained attention – accuracy and variability – and their decrements over time in the presence of rewards. Rewards took the form of monetary incentives or the promise of early completion of the task. Findings indicated no difference in sustained attention over time as a result of the motivation of a reward. Indeed, performance continued to decrease over time. It is thus implied that accuracy and variability, as part of the larger sustained attention, are not malleable by enhanced effort. Despite a decrement in performance, effort was enhanced in attempts to acquire the reward, yet even improved effort could not counteract the depletion of cognitive resources required to remain vigilant. Esterman et al.'s findings of enhanced effort not maintaining attention over time contradict that of attention theories which suggest that effort is a crucial, contributing factor to attention (Broadbent, 1958; W. James, 1890). Yet these theories consider attention holistically, rather than focusing on sustained attention specifically, which may account for the contradictory findings. Nonetheless, as sustained attention is a form of attention, it should remain susceptible to increased effort.

Further research into SAA and the role of effort in maintaining vigilance will need to be conducted in order to resolve this contradiction.
Attention is susceptible to a multitude of influential factors, including age, maturation of neural regions, and elements of auditory attention itself. While most of these variables cannot be controlled for, they provide insight on which the establishment of environments conducive to SAA can be developed. An important factor influencing auditory attention abilities is the underlying shared neurological bases of music and language processing. Indeed, these domains demonstrate some overlapping processing systems – a fact that will influence the degree of impact music has on SAA.

2.5 Shared cortical networks for language and music

Research has provided evidence of shared neural bases between music and language – that is, similar neural regions are activated by stimuli from both domains (Steinbeis & Koelsch, 2007; Yu et al., 2017). This has implications for auditory attention, as the primary goal of SAA is to ensure effective attendance for communication – the predominant function of both music and language (Kraus et al., 2014) It is therefore inferred that music instruction, via enhancing SAA, will also lead to better engagement and processing of language. Furthermore, by reviewing studies linking music instruction to improvements in speech perception and phonological awareness, further substantiation for the impact of music on children's overall cognitive abilities is provided.

Singing and syntactic/linguistic processing

One of the most effective means of investigating overlapping neural regions of speech and music processing is to consider neural activity when singing. Singing constitutes both music (i.e. melody) and language (i.e. lyrics) and therefore involves simultaneous processing of language and music (Schön et al., 2010). Investigators have found activation in Broca's area, a region of the frontal lobe involved in speech production, as a result of singing (S. Brown, Martinez, Hodges, Fox, & Parsons, 2004), therefore suggesting this area is not only stimulated by language but also by music. It further implicates the activation of areas in both brain hemispheres, with left-hemispheric and right-hemispheric language and music processing, respectively (Callan et al., 2006). This use of both hemispheres correlates with suggestions of healthy auditory development, in which infants are already processing musical stimuli across both hemispheres (Hartley et al., 2000). S. Brown et al. (2004) further indicated that melodic repetition and harmonisation produce similar, and greater, patterns of activation than monotonic singing.

Callan et al. (2006) examined a similar hypothesis to that of S. Brown et al. (2004), asking participants to passively listen to spoken or sung lyrics and to covertly sing or speak visually presented song lyrics. Their hypothesis, as with S. Brown et al. proved accurate – several brain networks are involved in the perception and covert production of singing and speech, with Broca's area also being implicated. Similar studies continued to be conducted, such as that of Schön et al. (2010), whose experiments of exposing participants to spoken or sung words while performing a same-different task, led to results which suggest that neural activity in the language and music regions argue against domain specificity, rather implying a common network involved in both speech and music processing. Yet Kunert, Willems, Casasanto, Patel, and Hagoort (2015) who, although presenting similar findings implicating Broca's area when singing, propose that a language effect of music is only visible under conditions of increased demands on shared neural resources. They posit that music and language remain separate domains while drawing on the same high-level syntactic integration resources in Broca's area, rather than the suggested overlapping neural regions postulated by previous studies (e.g. Schön et al., 2010). It appears there is dissension among researchers regarding the shared neural networks of music and language processing, specifically in terms of singing, as opposing views regarding whether networks overlap or simply draw from the same resource pool are found. Further research into this area is therefore required to clarify such disagreements. However, across the studies, the involvement of Broca's area in the processing of both language and musical syntax prevails.

Other studies examining the shared neural resources of music and language employ a different approach to presenting participants with expectancy violations, but rather introduce syntactic integration difficulty. For example, one study employed an experiment which combined sung materials with linguistic and musical complexities (Fedorenko, Patel, Casasanto, Winawer, & Gibson, 2009). Results revealed an interaction between musical and linguistic processing, implying a degree of shared resources. Fedorenko et al. (2009) altered the typical experiment used to measure such cognitive behaviour, by introducing an out-of-key note in the sung materials, paired with a specific word. Sentence comprehension was found to decline when a word was paired with an out-of-key note. It is therefore inferred that musical harmony does indeed influence the successful comprehension of language, as initially suggested by S. Brown et al. (2004) who emphasised the use of musical harmony to produce greater neural activation.

A study manipulating linguistic structural integration difficulty via syntactic expectancies, and comparing the influence of harmonic manipulations on linguistic processing (Slevc, Rosenberg, & Patel, 2009), validates the propositions of Fedorenko et al. (2009).

Participants performed self-paced reading of sentences, in which structurally unexpected words caused temporary syntactic processing difficulties. Each segment of the sentence was paired with a musical chord, together forming a coherent chord progression. Structurally unexpected words were periodically paired with structurally unexpected (i.e. dissonant) chords (in this manner Slevc et al.'s (2009) study paralleled Fedorenko et al.'s study). Similarities between the two studies continue, with Slevc et al.'s (2009) findings replicating that of Fedorenko et al.: participants experienced difficulty in processing unexpected words when paired with unexpected chords, thereby reducing sentence comprehension. These results suggest that music and language draw on a common pool of neural resources for integrating incoming elements, whether musical or linguistic, into syntactic structures (Slevc et al., 2009). Slevc et al.'s conclusions are therefore akin to those of Kunert et al. (2015). Although Slevc et al. do not discuss the involvement of Broca's area in this shared processing, it is likely that this neural region is the 'pool of resources' to which they refer, based on the findings of other, similar studies. The findings of Fedorenko et al. and Slevc et al. are validated by comparable studies (Carrus, Pearce, & Bhattacharya, 2013; Zioga, Luft, & Bhattacharya, 2016) which pair violated sentences with melodies. Similar findings were obtained, providing substantial evidence for the claim that music and language share neural resources.

Fitzroy and Sanders (2013) identified a further aspect to the shared resources of music and language, by comparing musicians' and non-musicians' neural activity within both the language and music domains. Although musicians and non-musicians showed equal overlapping resources, musicians demonstrated more specialised cortical organisation of syntactic processing in both domains. Fitzroy and Sanders therefore imply that musical training enhances the overlapping processing of speech and music stimuli. This study has important implications for the present review, in that although music aids in the perception of speech among the general population, formal musical training may further enhance this perception, by improving the processing of linguistic and musical stimuli. However, as with other studies investigating comparable hypotheses, Fitzroy and Sanders utilised adult participants, with discrepancies in the age ranges of groups of musicians and non-musicians. Similar results may therefore not be replicable with children, due to the immaturity of their neural structures and processing abilities. It would seem pertinent for future research to investigate such claims in children and potentially discover an approximate age at which music and language processing begin to overlap. Also focusing on the contributions of musical training to improved linguistic processing, Yu et al. (2017) explored the relations between components of music (e.g. rhythmic analysis) and language (e.g. semantic processing). While music tuition resulted in better semantic processing, it did not create better phonological processing. Yu et al. therefore conclude that while music tuition does contribute to improved linguistic processing, these improvements appear to be limited to particular components of language. Their conclusions thus validate those of Fitzroy and Sanders, who found mostly equal linguistic processing skills among musicians and non-musicians.

Linguistic abilities and phonological awareness

Reading skills, as highly linked to linguistic capacities, are also impacted by music. As linguistic processing shares neural resources with music processing, reading skills are indirectly affected by musical stimuli (Anvari, Trainor, Woodside, & Levy, 2002). For example, Strait, Hornickel, and Kraus (2011) assessed 42 normal-hearing children (with a broad range of reading skills) on a variety of cognitive function (e.g. working memory, reading ability, SAA) responses to acoustic regularities in sound. Although finding evidence for shared neural processing centres of music and linguistics, results further highlighted the significance of rhythmic regularities in language and music to successfully process and understand content. It is therefore posited that musical rhythmic tasks are of great benefit to reading abilities (Strait et al., 2011). However, as the population size of the study was small, across a large age group, it is difficult to ascertain if these reading improvements are reflective of larger sample sizes across multiple contexts.

Moreno et al. (2008) conducted a longitudinal study to examine the effect of six months of music tuition on cognitive functions of eight-year-old children, such as reading and linguistic pitch processing. Findings suggested that music tuition significantly influences the development of neural processes, and results in transfer of musical skills to linguistic abilities. However, this study was conducted with Portuguese children – the population sample was thus limited to a particular nationality and age group, limiting results. Were the same study to be conducted with a different population sample, results may present differently. Supporting Moreno et al.'s findings that music tuition results in improvements in linguistic skills, Kraus et al. (2014) investigated the effect of two years of music training on children's (aged six-and-a-half to nine years old) speech abilities. Results suggested that two years of music training led to improved reading and language skills. Interestingly, controls who participated in only one year of musical training did not demonstrate changes in neural processing function – supporting Patel's (2011) emphasis on the prolonged repetition typical to musical training and practice as contributing to alterations in linguistic processing. Kraus et al. (2014) postulate that, based on their findings, active and repeated engagement with sound – as is typical of musical practice - alters neural functions for both speech and music processing, leading to improvements in linguistic abilities and associated skills (e.g. reading).

Regarding phonological awareness (the awareness of the sound structure of words) Lamb and Gregory (1993) measured possible correlations between musical aptitude and phonological awareness. Their findings indicated that children exposed to music instruction demonstrate improved ability to decode units of speech (e.g. syllables and phonemes) than those who never engaged in music instruction. Other research has since supported some of these pioneering claims of Lamb and Gregory, with Bolduc and Montésinos-Gelet (2005) suggesting that music instruction contributes to phonological memory, in turn leading to better linguistic skills. Additionally, (Gromko, 2005) found that music instruction leads to advanced development of phonemic awareness among five and six year olds, thereby supporting the claims of Lamb and Gregory, and Bolduc and Montésinos-Gelet. Many other studies continue to corroborate these findings (Anvari et al., 2002; Degé & Schwarzer, 2011; Flaugnacco et al., 2015; Patel & Iversen, 2007; Slater et al., 2014) all coming to similar conclusions: music instruction improves phonemic awareness and linguistic abilities in young children. Such research provides substantiation for the topic of the present study, as it indicates a high degree of influence of music on children's neural structure and cognitive abilities in general. Although drawing similar conclusions, findings should be compared with caution, as each study employed a different age range within their population sample, which although falling within a broadly defined range of 'young children', may influence cognitive abilities demonstrated, based on age-defined developmental trajectories.

Music and language as distinct cortical networks

Although recent research evidence has predominantly focused on examining the overlapping resources involved in music and language, distinct patterns of activation for music and language persist. Rogalsky, Rong, Saberi, and Hickok (2011) corroborate the postulations of Kunert et al. (2015) and Slevc et al. (2009), who each highlight the single entities of music and language, which merely draw on the same pool of resources, rather than sharing neural bases. Rogalsky et al. further posit a large degree of non-overlap between the two domains, based on a basic hierarchical processing of music and speech, which each recruit distinct cortical networks. In contrast to previous studies, Rogalsky et al. do not implicate Broca's area as a shared neural resource. In fact, they found no activation in Broca's area when conducting their tests of presenting participants with scrambled sentences and novel melodies. It is interesting that although the testing methods remain similar to that of other studies, Rogalsky et al. found different results. Perhaps these other studies which implicate Broca's area as a source of shared neural resources, employed tasks requiring the use of higher-order cognitive processes, such as working memory and cognitive control, which operate in both domains, while Rogalsky et al.'s study did not. It is likely that SAA constitutes another of these higher-order cognitive processes, as an executive function, and as a result of being interlinked with working memory.

It is clear from a review of literature that the neural correlation between music and language is complex and multifaceted. Music and language consist of shared components (such as pitch, loudness, and duration) the processing of which influences potential overlap between the two domains (Callan et al., 2006; Fedorenko et al., 2009; Kunert et al., 2015). Additionally, processing abilities of adults and children differ due to the degree of maturity of neural structures (Bishop et al., 2011; Fischer & Hartnegg, 2004; Sussman, Wong, et al., 2007) and should thus be taken into account when considering degree of neural overlap. Nonetheless, it is likely that the presence of such an overlap contributes to the processing of music, which in turn may influence maintenance of auditory attention. It is thus appropriate to consider how the components of pitch, loudness and duration are processed across both domains.

2.6 Auditory processing of music and speech characteristics

Speech and music share some characteristics, such as pitch (frequency), loudness (intensity), and duration (temporality). As language and music are processed by overlapping regions of the brain these characteristics also share, by extension, shared neural resources (Fedorenko et al., 2009; Kunert et al., 2015; Zioga et al., 2016). Insight into how the brain perceives pitch, loudness, and duration in both domains may provide further understanding of how music instruction might lead to improvements in SAA.

2.6.1 Pitch (frequency) perception

Pitch refers to the auditory attributes of sound, ordered from low to high, (X. Wang & Walker, 2012), with high frequency tones perceived as higher in pitch than those with low frequencies (Lipscomb & Hodges, 1999). Pitch is defined as “the perceptual correlate of the periodicity, or repetition rate, of an acoustic waveform” (Oxenham, 2012, p. 1). Pitch is considered as “one of the most important information-bearing components shared by both [music and language] domains” (Plack & Oxenham, 2005, p. 49). Pitch is therefore investigated as a potential contributing factor to SAA, as the influence of music on the pitch domain of speech provides further substantiation for the impact of music on cognitive skills in general, including auditory skills.

Lower and upper pitch limits

The manner in which the auditory cortex perceives, and processes pitch has been examined by many researchers, in efforts to shed light on auditory perception. One study examined the lower limit of melodic pitch for harmonically complex tones, referring to "the repetition rate below which listeners [can] no longer recognise that one of the notes in a four-note, chromatic melody [has] changed by a semitone" (Pressnitzer, Patterson, & Krumbholz, 2001, p. 2074). According to earlier research (Backus, 1977) the human ear is capable of perceiving pitches between 20 and 20 000 Hz. However, in contradiction to Backus' (1977) findings, Pressnitzer et al. (2001) posited a lower limit of 30Hz, indicating a decreased lower limit of melodic processing as compared to Backus. It is plausible that the dissention between the two findings of the lower pitch limit is based on the type of tone that was utilised to measure pitch perception. Pressnitzer et al. focused on harmonically complex tones, while it is highly likely that Backus based his findings on the perception of simple tones, therefore accounting for the 10Hz difference. Pressnitzer et al. further suggested that only tones between 30 and 4000 Hz are capable of eliciting pitches that carry melodic information, essential for music perception. Coincidentally, the value of 30Hz also corresponds approximately to the lowest note of the piano (Backus, 1977).

As Pressnitzer et al. challenged traditional conceptions of lower limits of pitch, so too did A. J. Oxenham, Micheyl, Keebler, Loper, and Santurette (2011) challenge traditional conceptions of upper pitch limits. Earlier research implies that the human ear can recognise pure-tone frequencies of up to four or five kHz – a limit which coincides with the highest notes produced by some high-pitched musical instruments (e.g. piccolo) (B. C. Moore, 2003). Oxenham et al. tested upper limits of pitch and melody perception using a combination of pure and harmonically complex tones. They found that pitch perception can be elicited by harmonically complex tones containing individual harmonics above six kHz – a value well above the traditional upper pitch limit. It is plausible that this newly conceived upper limit was identified by means of the inclusion of harmonically complex tones, in addition to pure tones. It is particularly interesting to note that when testing lower pitch limits, Pressnitzer et al. also employed harmonically complex tones in place of pure tones – a decision that led to results which contradict that of widely-accepted, traditional pitch limits. Taken together, these findings suggest that harmonically complex tones extend the limit of pitch perception, in both directions, perhaps due to the series of overtones present in these complex tones (B. C. Moore, 2003) providing the ear with more stimuli on which to focus.

Pitch discrimination and detection

Related to limits of pitch perception are pitch detection and discrimination skills. As noted, pitch identification and discrimination capacities remain immature in childhood (Bishop et al., 2011; Hill et al., 2005). Similar differences are also found between those exposed to music instruction and those with no exposure (Bidelman, Gandour, & Krishnan, 2011; Musacchia, Sams, Skoe, & Kraus, 2007; Wong, Skoe, Russo, Dees, & Kraus, 2007). This implies a degree of contribution by music instruction to pitch perception abilities, thereby indirectly contributing to auditory skills, of which SAA forms part. C.-Y. Lee and Hung (2008) examined this difference of pitch discrimination among musicians and non-musicians, in which English-speaking participants were asked to identify specific Mandarin tones across a series of tasks. Mandarin was chosen as it is a lexical tone language, meaning the distinctive pitch used with a given syllable contributes to its meaning. Musicians outperformed non-musicians across all detection and discrimination tasks, yet still showed some decrement in speed and accuracy in correct identification of tones in some tasks. It was concluded that the type of acoustic input played a significant role in musicians' correct detection of Mandarin tones, and that the musician's main advantage lay in their more well-developed listening skills – listening skills which may incorporate an element of SAA. C.-Y. Lee and Hung's findings suggest that the provision of specific variables is required for musical training to produce an effect on auditory abilities. It should also be noted that while this study is highly replicable, the mean age of participants was 22 years old. Were the same tasks to be administered to children, who demonstrate immaturity in their auditory detection and discrimination skills (Bishop et al., 2011; Fischer & Hartnegg, 2004; Hill et al., 2005) and have likely had less exposure and experience in musical training, different results may be obtained.

Magne, Schön, and Besson (2006) examined whether musical training facilitates pitch processing in both music and language among eight-year-old children. By analysing ERPs and behavioural data obtained through manipulations of pitch, such that final notes or words of musical phrases or sentences, respectively, were either congruous, or weakly or strongly incongruous. Results indicated that musician children, with several years of musical training, were better able to detect small pitch variations at the end of short musical phrases than non-musician children. Magne et al. therefore postulated that if musical training is able to improve efficiency of pitch discrimination in music, it too should improve pitch detection in speech. By extension then, based on the shared neural resources of music and language (Yu et al., 2017), and the influence of musical training on the cognitive aspect of speech, it is possible that musical training indirectly influences auditory abilities (e.g. SAA).

Neural pitch processing

Anatomically speaking, pitch is processed across several neural regions, with primary processing occurring in the central auditory cortex (Patterson, Uppenkamp, Johnsrude, & Griffiths, 2002). Yet pitch processing shows hemispheric lateralisation, although predominant activity occurs in the right hemisphere, specifically for musical stimuli (Patterson et al., 2002; Zatorre, Belin, & Penhune, 2002). Patterson et al. (2002) employed fMRI tests to identify various stages of melodic (pitch) processing in the auditory cortex. Findings supported their hypothesis of a hierarchy of pitch processing, in which central activity moves away from the primary auditory cortex in parallel with melodic progression. Higher-order processes, such as pitch tracking, are said to occur in more distributed regions beyond the primary auditory cortex, and predominantly in the right hemisphere (Zatorre et al., 2002). Such findings do not contradict the postulations of music stimulating activity across both hemispheres, but rather refine this concept by implying an asymmetrical hemispheric activation (Patterson et al., 2002). Patterson et al. further indicate that more complex tones require distributed, higher-order processing while simpler tones are processed directly in the auditory cortex. This supports the inferences of Oxenham et al. (2011) and Pressnitzer et al. (2001), who differentiate between perception of harmonically complex tones and pure tones. It is therefore concluded that more complex tones require higher-order processing to be fully processed, yet simpler, pure tones contain fewer auditory cues and so can be processed more easily.

The predominance of the right hemisphere in pitch perception is corroborated by Penagos, Melcher, and Oxenham (2004) who posit the involvement of both hemispheres in processing pitch, with the right hemisphere holding more importance than the left. Penagos et al. also corroborate the idea of distributed pitch processing, presenting evidence for the involvement of the nonprimary auditory cortex in processing pitch. Such postulations are similar to Zatorre's (2007) belief that the auditory cortex is involved in processing stimuli unrelated to sound. Neurological evidence suggests that the right auditory cortex has finer pitch resolution than the left (Hyde, Peretz, & Zatorre, 2008) indicating a degree of hemispheric specialisation in pitch perception, further validating findings of both Penagos et al. and Patterson et al. It is significant to consider however, that Hyde et al.'s (2008) findings were identified among adults, and once again, may present differently among children whose auditory system remains immature (Bishop et al., 2011; Fischer & Hartnegg, 2004; Hill et al., 2005; Sussman, Horváth, Winkler, & Orr, 2007). Yet as their results corroborate that of earlier studies it is likely these results are true of both adults and children. Moreover, healthy auditory development of the child demands the utilisation of both hemispheres in processing auditory stimuli (J. K. Moore, 2002; X.-D. Wang, Wang, & Chen, 2013) – what developmental research may simply have failed to mention is that auditory processing is hemispherically asymmetrical. Moreover, the notion of pitch processing occurring predominantly in the right hemisphere can be interpreted in context of S. Brown et al.'s (2004) postulations, of linguistic processing occurring mainly in the left hemisphere and music processing occurring mainly in the right hemisphere. Despite being a component of both language and music, pitch is more significant to musical stimuli than to speech, in terms of perhaps carrying more useful information. It is therefore logical that pitch processing takes place primarily in the hemisphere associated with music perception.

Just as C.-Y. Lee and Hung (2008) found differences in pitch discrimination among musicians and non-musicians, Musacchia et al. (2007) identified similar biological differences between the two groups. They found that musicians show earlier and larger brainstem responses to both speech and musical stimuli and a more synchronous response to auditory stimuli. They further demonstrate an enhanced representation of the neural area responsible for pitch perception, and it is speculated that this enhancement is a result of extensive musical practice over time (supporting findings of Pantev, Engelien, Candia, & Elbert, 2001; Patel, 2011; Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995; Weinberger, 2004). Enhanced brainstem responses to speech are further identified as a result of musical training, associated with increased neural plasticity (Musacchia, Strait, & Kraus, 2008). It is suggested that improved plasticity is induced by the co-ordinated organisation of neural representations of pitch cues, of which musicians' representations are more robust, and are apparent both when listening, or when simultaneously listening to and viewing a speaker (Musacchia et al., 2008). Musicians therefore show enhanced pitch perception of both speech and musical stimuli (Musacchia et al., 2008). However, as is the case with the findings of C.-Y. Lee and Hung, musicians' enhanced brain plasticity seems to be stringent on a number of variables, indicating that neural plasticity for pitch processing is potentially experience-dependent (Bidelman et al., 2011). This improved plasticity is correlated with degree of musical experience and the relevance of stimuli to the listener (Bidelman et al., 2011). Yet despite the need for such variables, Bidelman et al. suggest that long-term pitch experience does improve the brain's ability to encode pitch regardless of the domain (i.e. language or music). Bidelman et al. (2011) further conclude that musical training leads to improved pitch perception of both music and language, providing further substantiation for the high degree of influence of music instruction on cognitive development of children.

2.6.2 Loudness (intensity) perception

Loudness refers to "the magnitude of an auditory sensation" (Fletcher & Munson, 1933) ordered from 'very soft' to 'very loud', and is the perceptual correlate of sound intensity

(Florentine, 2011) – the more intense a sound, the louder it is perceived to be. Loudness is influenced by a number of variables including the duration, bandwidth, and modulations of sound stimuli (Jesteadt & Leibold, 2011). It may be further impacted by contextual effects (Arieh & Marks, 2011) and procedures employed to measure loudness judgements (Marks & Florentine, 2011). Loudness also refers to the physical characteristic amplitude (or intensity),and is most often referred to in context of volume (Lipscomb & Hodges, 1999). Yet loudness is a concept separate from volume, with the former relating to increasing intensity and the latter to the perception of the amount of space a sound appears to occupy (Lipscomb & Hodges, 1999). Loudness is measured in terms of sound pressure level, known as decibels (dB). Normal conversation occurs at 60dB (moderate sound level) with very loud sounds (~110-120dB) being painful to the ear, with the softest sounds capable of being heard by the human ear (~10-20dB) on the opposite end of the continuum (Lipscomb & Hodges, 1999). In a musical context, the human ear can detect sounds ranging from 40dB (a quiet pianissimo) to approximately 90dB (a full orchestral fortissimo) (Lipscomb & Hodges, 1999). Loudness is coded and transmitted by the firing rate of hair cells of the basilar membrane. As the intensity of a sound increases so too does the firing rate – but only to a certain point (Lipscomb & Hodges, 1999). If the intensity continues to increase such that maximum firing rate is reached, the range of resonance expands outward along the membrane (Lipscomb & Hodges, 1999). The perception of loudness is therefore a result of the total number of neural impulses fired by the hair cells.

Loudness and auditory capacities

Sound intensity, like other aspects of sound (e.g. pitch), involves a complex network of information processing (Belin et al., 1998). Biologically, the firing rate of hair cells determines loudness perception, yet perception is more complicated than activity of neural impulses, especially in the presence of influential variables (Belin et al., 1998). Perception of loudness of 45 normal hearing participants was examined to determine whether neural activity of the auditory cortex is related more to the physical parameter of sound intensity or to the perceptual measure of loudness ratings (Röhl & Uppenkamp, 2012). Results indicated a linear increase along the auditory pathway across a range of 30dB, indicating that the stage at which perceived loudness is transformed into neural activation is processed in the auditory cortex. Moreover, activity of the auditory cortex appears to be a linear reflection of subjective loudness judgements, rather than a reflection of physical sound pressure level – it thus indicates a transformation of sensation (loudness rating) into perception (stimulus intensity). Röhl and Uppenkamp's (2012) study highlights the complicated nature of sound intensity, and how perceived loudness and physical loudness (as defined by decibel level) may differ. Loudness perception is therefore similar, to a degree, to pitch perception, in which perceived pitch may not accurately reflect the frequency of a sound.

Intensity of sound was found to impact auditory abilities of infants and children, influencing auditory sensitivity and reaction times to sound (see Graven & Browne, 2008; Tharpe & Ashmead, 2001). Although by childhood intensity perception is rather mature, loudness perception may differ to the actual intensity of a sound, thereby potentially influencing how sound is processed and attended to. It is possible that such a factor could influence SAA responses, based on perceived loudness, specifically in a musical context in which decibel range is limited. Sound intensity further plays a significant role in communicating the emotion of vocal stimuli. X. Chen, Yang, Gan, and Yang (2012) asked participants to rate anger levels of neutral and angry prosodies prior to, and following, sound intensity modifications, measuring responses by means of EEG recordings. Findings revealed that by merely modifying sound intensity levels, participants rated prosodies as more or less angry, based on an increase or decrease in intensity level, respectively. In addition to having a unique role in vocal emotion, intensity then too appears to affect music perception, specifically perception of music with lyrics, as it suggests that the intensity of the music may impact how the lyrics are emotionally perceived (X. Chen et al., 2012). Moreover, if intensity cues of emotion are combined with pitch cues of tones, the perception and processing of auditory stimuli becomes much more complex than originally conceived and will in turn impact auditory-related capacities (Juslin & Laukka, 2003), such as auditory attention.

Affect and arousal

Similar to the ability of sound intensity to convey vocal emotion is the plausible influence of negative affect on sound intensity. In the case of the former, intensity is exerting an influence on affect, while in the case of the latter, affect is exerting an influence on perceived intensity. Nevertheless the underlying idea remains: an individual's emotion may influence how they perceive sound intensity (Asutay & Västfjäll, 2012). Negative affect in particular influences loudness perception, as suggested by Asutay and Västfjäll (2012), who used a conditioning paradigm to pair some auditory stimuli with aversive expereinces, and some without. When paired with an aversive experience, auditory stimuli were perceived as not only louder, but also more negative and fear-inducing. Individual affect remains an uncontrollable factor – while it can be manipulated to an extent, it is impossible to control an individual's emotions. Siegel and Stefanucci (2011) found similar results in their study, in which participants were induced into a negative or neutral mood prior to listening to a series of short, neutral tones and rating perceived loudness of the tones. Participants in a negative mood rated the tones as louder than those in a neutral mood.

Loudness has also been found to have an impact on arousal, a significant feature of attention processes according to some attention models (Langner & Eickhoff, 2013; Posner & Petersen, 1990). Dean, Bailes, and Schubert (2011) examined the influence of perceived intensity on arousal levels, by presenting listeners with manipulations of intensity profiles of various pieces of music. Results indicated a powerful effect of intensity on arousal, across a range of musical contexts, as intensity influenced arousal levels. As arousal is a contributing factor to SAA, this finding is especially pertinent to the present review, as perceived loudness of music may have a direct impact on the ability to remain vigilant.

The intensity of music and sounds is often linked to duration of sound, with a common misconception of more intense sounds lasting longer - intense sounds are merely perceived as having a longer duration (Goldstone, Lhamon, & Sechzer, 1978; Xuan, Zhang, He, & Chen, 2007). Thus, just as pitch and loudness play a role in the perception of auditory stimuli, so too does duration of sound.

2.6.3 Duration (temporal) perception

Duration refers to the psychological variable that is associated with time (Lipscomb & Hodges, 1999). Every stimulus has a duration, the accurate perception of which is vital to successfully negotiating the environment (Matthews, Stewart, & Wearden, 2011). Temporal perception results from a series of ‘psychological moments’ each with its own time span (R. C. James, 1950). In a musical context, duration consists of sounds organised in time (Lipscomb & Hodges, 1999) – time is thus a vital component of music, defining both beat and metre. In fact, duration is so significant to music that it is possible to identify melodies simply by hearing the rhythm (R. C. James, 1950).

Duration and attention

Attentional mechanisms play an influential role in the perception of duration (S. W. Brown & Merchant, 2007; Buhusi & Meck, 2009; Eagleman & Pariyadath, 2009; Grondin & Rammsayer, 2003; Hemmes, Brown, & Kladopoulos, 2004). It is thus fitting that duration and attention are linked, as temporal perception may impact the duration of sustained attention responses (Eagleman & Pariyadath, 2009). The period preceding presentation of a ready signal (i.e. a temporal reference for response preparation) and target stimuli is known as a foreperiod, modulating attention mechanisms necessary for temporal information processing (Grondin & Rammsayer, 2003). In a series of experiments, Grondin and Rammsayer (2003) randomly varied the duration of the foreperiods preceding testing, finding correlations between length of foreperiod and perception of duration. The longer the foreperiod, the longer duration was perceived to be. These findings suggest that temporality does indeed play a significant role in modulating attention processes and is therefore perhaps the most prominent of the three components (i.e. pitch, loudness, duration) contributing to SAA. Correlations between duration and attention is further highlighted by the postulation that concurrent task conditions lead to a decrease in perceived duration, due to attentional resource allocation (Hemmes et al., 2004). This hypothesis becomes clearer when compared to the findings of Grondin and Rammsayer who indicate that attention mechanisms are modulated by specific processes (i.e. foreperiods), enabling better duration perception. Meanwhile, as stipulated by Hemmes et al. (2004), concurrent tasks place increased demands on attention resources, thereby producing difficulties in accurately perceiving duration – a task which itself requires a degree of maintained attention. Hemmes et al.'s findings might introduce further implications for tasks involving SAA as, under such resource-sharing conditions, sounds may be perceived as longer than they actually are and interfere with vigilance processes.

Brown and Merchant (2007), who present evidence of a shared set of attentional resources for both sequence and time perception, validate the findings of Hemmes et al. (2004). Brown and Merchant posit that sequence and time perception are interlinked cognitive processes, relying on a common set of attentional resources. However, the sharing of attentional resources detracts from one of the two tasks, due to the limited pool of attentional resources available (S. W. Brown & Merchant, 2007). Therefore, in instances of dual-task conditions, it is postulated that duration perception diminishes.

The utilisation of shared attentional resources for maintaining attention in dual-task conditions is supported by neurological studies. One study affirmed that neural networks involved in time perception comprise regions concerned with both time accumulation and maintenance of attentional resources (Buhusi & Meck, 2009). Data suggests that estimated durations are shorter when attending to a second task. Buhusi and Meck (2009) implicate working memory in their hypothesis, including memory as an element of attention, which also utilises cognitive resources. It is interesting that Buhusi and Meck incorporate memory into their notions, as many earlier theories and studies have identified memory as an essential contributing factor of attention (Broadbent, 1958; Knudsen, 2007; Luria, 1973; Pillsbury, 1908; Zatorre, 2007). It is therefore highly plausible that memory is indeed also negatively affected by resource sharing demands and, as it is intertwined with attention, may also exert an influence on SAA.

Attention, as a non-temporal feature, may impact perceived duration. Eagleman and Pariyadath (2009) conceived a novel framework to account for the correlation between attention and duration. They suggest that the perception of duration is dependent on the efficiency of neural coding (i.e. the amount of energy expended in representing a stimulus), with more intense stimuli appearing to last longer as they evoke a larger neural response. They continue to posit that repeated stimuli are perceived as shorter in duration than a novel stimulus of equal duration, due to neural coding effects. This notion of repetition presents a disagreement to the beliefs of W. James (1890) and Langner and Eickhoff (2013), who state that repetition may lead to inattention (which could in turn disrupt duration perception processes). Yet S. Brown et al. (2004) suggested that melodic (i.e. pitch) repetition results in greater neural activation. It is therefore highly likely that the repetition to which Eagleman and Pariyadath refer is a form of pitch repetition, which activates neural coding. Nevertheless, it is interesting to note that different forms of repetition, in contrasting contexts (yet related to auditory attention) produce such varying results. Eagleman and Pariyadath infer that a larger neural response is the basis for increased attention and duration, believing improved perception of duration to be a driving force of attention. Their hypothesis contradicts that of others who posit attention as influencing duration (e.g. S. W. Brown & Merchant, 2007; Buhusi & Meck, 2009; Honing, Bouwer, & Háden, 2014), rather than vice versa. Yet what remains in corroboration with other investigations is the important role of attentional resources, which Eagleman and Pariyadath maintain. The basis for their explanation lies in the idea that stimulus duration reflects the magnitude of the neural response to the stimulus.

Stimulus magnitude

The role of magnitude of a stimulus in duration perception was explored by a study (Xuan et al., 2007) which asked participants to compare two durations defined by the gaps in a sequence of digits. Findings revealed that the perception of the interval (the ‘gaps’) depends on the difference between the stimuli (the sequence of digits), and that novel stimuli are perceived as possessing a longer duration. Xuan et al. (2007) went on to postulate that by increasing the non-temporal magnitude of a stimulus, its perceived duration is also increased. In other words, the more intense a stimulus, the longer its apparent duration. It is therefore concluded that sound intensity and duration are inextricably linked, with each influencing perception of the other. With the idea of intensity and duration constantly influencing the other, and both exerting a unique effect on attentional processes, their influence is vast and difficult to predict. Nonetheless, what should be taken into account, and can be manipulated to a degree, is background stimuli. It has been noted that the effect of stimulus magnitude on perceived duration depends on the presence of background stimuli (Matthews et al., 2011). Therefore, it stands to reason that by limiting background auditory stimuli, a degree of control over the magnitude, and by extension apparent duration, of auditory stimuli could be maintained.

Musically, duration is arranged temporally as beat and rhythm, providing insight into music as events occur over time (Honing et al., 2014). The perception of beat is a bi-directional process (Honing et al., 2014) in that musical rhythm can induce a regular beat but a regular beat can also influence perception of rhythm. Beat perception is thus an interaction between top-down and bottom-up cognitive processes and plays an important role in the interpretation of music, as listeners use inferred beat to interpret music within a given, temporally regular context (Honing et al., 2014). The significance of rhythm supports suggestions by Strait et al. (2011) who posit that rhythmic regularity underlies both music and language processing. Not only is rhythm regarded an essential element of temporality in music, it is said to also play a key role in promoting SAA (Clayton et al., 2015; Helfrich et al., 2018). Perhaps this key role is attributed to its defining nature of temporality in music – rhythm forms part of duration, which in turn is intertwined with attentional resources. Although more research into the temporal nature of musical rhythm is required to determine the precise manner in which it might influence SAA, it would appear there is a link between rhythm as a temporal aspect and its role in developing SAA.

Pitch, loudness, and duration are characteristics found in both speech and music - a presence which contributes to shared processing centres in the brain (Fedorenko et al., 2009; Kunert et al., 2015; Yu et al., 2017). These three constructs also play specific roles in music, and are therefore prevalent in musical processing, and likely exert a degree of influence on auditory attention. Auditory processing is partly responsible for making sense of music, as musical stimuli are received, encoded, and processed by auditory regions of the brain (Pantev et al., 1998). Music instruction thus possibly exerts a degree of influence over auditory skills, including the various forms of auditory attention.

2.7 The impact of music instruction on auditory attention and abilities

Music instruction contributes to brain plasticity and shapes neural structure and function, specifically in the auditory cortex, whose primary function is auditory processing (Schlaug, 2015; White, Hutka, Williams, & Moreno, 2013). Music instruction thus also impacts auditory processing and auditory skills by means of both neurological and cognitive effects (Habibi, Cahn, Damasio, & Damasio, 2016; Habibi et al., 2017; Hannon & Trainor, 2007; Kraus & Banai, 2007; Schlaug, Norton, Overy, & Winner, 2005). Such influences may indirectly contribute to better auditory attention and are therefore pertinent to the present study.

2.7.1 Music instruction influences auditory abilities

Music is beneficial to the processing of auditory stimuli, in both a cognitive and neurobiological sense (Habibi et al., 2016; Schlaug et al., 2005). Although the focus of the present review is not general auditory abilities, the manner in which music influences processing of sound by means of auditory skills, may exert a degree of influence on SAA (D. C. Miller, 2013). Some of the most common auditory processing enhancements which result from musical training include: heightened auditory perception; more differentiated cortical evoked potentials: and enhanced neural encoding of specific acoustic features (Strait & Kraus, 2014). These three examples constitute features of audition, and therefore also play a role in managing SAA.

Neurological effects: Age of commencement of music instruction

Research evidence indicates musically-induced brain plasticity in children and adults (Habibi et al., 2017; Hallam, 2010; Schlaug, 2015; Schlaug et al., 2005). Schlaug et al. (1995) conducted one of the first studies directly testing the effects of age of commencement of music training on neural structure. Findings indicated an increased corpus collosum size in those who started musical training prior to age seven, in comparison to those who commenced training after that age. Results therefore implied greater hemispheric communication in musicians, as a result of the larger corpus collosum, which may in turn produce functional changes in the perception of auditory information. The plastic effects observed by Schlaug et al. (1995) coincide with the developmental trajectory of the auditory cortex in the first decade of life, in which hemispheric communication increases significantly (Hartley et al., 2000). Music, therefore, is not responsible for improved hemispheric communication, as this forms part of healthy neural development, but seems to merely accelerate it.

According to Pantev et al. (1998) - who measured cortical representation in skilled musicians and found 25 percent more cortical enlargement in musicians compared to non-musicians - neural changes are more pronounced in those who started musical training at an early age, thereby affirming the findings of Schlaug et al. (1995). Indeed, the influence of age of commencement of music instruction on SAA is identified as a prevalent factor among the studies included in the review (Hallberg, Martin, & McClure, 2017; Strait & Kraus, 2011). Based on proposed correlations between years of musical training and enlarged cortices, Pantev et al. (1998) suggest an experience-dependent plasticity of the auditory cortex, as structural changes are dependent on the degree of sensory input processed as musical skills develop over time. Plasticity of cortical enlargement is therefore similar to plasticity of pitch processing centres, in that the latter is also believed to be experience-dependent (C.-Y. Lee

& Hung, 2008) and correlates with the degree of musical training (Bidelman et al., 2011). It is speculated that the similarities between plasticity of the auditory cortex and pitch processing are more than coincidence. As a characteristic of sound, pitch is processed by the auditory cortex, plasticity of which is highly likely to exert similar plastic influences on pitch processing centres (Moreno et al., 2008). It is thus possible to assume that the enlarged cortices resulting from music instruction contribute to the improved function of pitch processing, and vice versa.

Neurological effects: Enlarged neural structures

Pantev and colleagues (2001) extended their earlier work (i.e. Pantev et al., 1998) examining the impact of musical training on the functional organisation of the auditory and somatosensory cortices. Their study is thus similar to that of the earlier study (Pantev et al., 1998) yet added the additional element of somatosensory effects (denoting sensations occurring anywhere in the body). Findings revealed enlarged cortical representations in the auditory and somatosensory domains as a result of many years of musical training (Pantev et al., 2001) supporting their earlier findings (Pantev et al., 1998). Moreover, they suggested that music training (and specifically practice) stimulates somatosensory plasticity, particularly in areas responsible for fine-motor movement. As with the implications of others (Schlaug et al., 1995), Pantev et al. (2001) suggest that those who begin musical training early in life demonstrate larger cortical representations – and better fine-motor skills – than those who begin later. However, unlike earlier studies, Pantev et al. do not provide an optimal age at which to commence musical training to achieve such plasticity but did show that even those commencing musical training later in life had larger cortical representations than non-musicians. Taken together, these results indicate an influential effect of age on neural enhancements as a result of music training, yet also provide clear evidence that despite the age at which an individual might commence musical training, neural advancements persist (Pantev et al., 2001; Pantev et al., 1998).

Not only does musical training impact the corpus collosum and cortical representations, but also grey matter volume (responsible for muscle control and sensory perception, including hearing) (Gaser & Schlaug, 2003). It is highly plausible that music tuition increases neuronal grey matter involved in audition as Gaser and Schlaug (2003) reported a positive correlation between musical proficiency and grey matter density in motor, auditory, and visuospatial regions when comparing musicians and non-musicians. Their findings corroborate that of earlier studies (e.g. Pantev and colleagues, 1998, 2001; Schlaug et al., 1995) who provide evidence for structural brain changes as a result of musical training. Moreover, Gaser and Schlaug found evidence suggesting that structural differences are more pronounced in those who commence training at earlier ages. However, Gaser and Schlaug introduced a new variable: they believed that the amount and intensity of musical practice contributes to the degree of neural changes produced. It is therefore proposed that although class music may contribute to neural plasticity, instrumental training and practice result in the greatest improvements in SAA. Intense, and large amounts of, musical practice require the maintenance of attention for extended time periods (Putkinen, Tervaniemi, Saarikivi, Ojala, & Huotilainen, 2014) which, as inferred by Gaser and Schlaug contributes to brain plasticity. In this manner, it appears the improvement of SAA by means of music instruction occurs in a continual cycle: SAA contributes to changes in brain structure and function, which in turn contributes to better SAA, which further induces plasticity, and so forth.

In addition to practice intensity, auditory stimuli that are deemed as behaviourally relevant constitute an additional variable which affects plasticity (Weinberger, 2004). Weinberger (2004) further reported that sensory cortices, specifically the primary auditory cortex, retain specific memory traces about the behavioural significance of relevant sounds, leading to brain plasticity formed by associative memory. It is interesting that audition is proposed as the sensory system benefitting most from associative memory influences, considering the highly interrelated nature of working memory and auditory attention (Buhusi & Meck, 2009; Knudsen, 2007; Pillsbury, 1908; Zatorre, 2007).

Findings from earlier studies regarding the increased corpus callosum (Schlaug et al., 1995) as a result of music training were validated by a longitudinal study in which five to seven year old children were exposed to fifteen months of instrumental lessons (Schlaug et al., 2005). In addition to demonstrating similar structural changes, children involved in music training (in comparison to controls who received no music training) demonstrated better auditory discrimination skills. Although changes were found after only fifteen months, these neural alterations were small, and were hypothesised by the authors to be larger were musical training to continue for a longer period of time (Schlaug et al., 2005). Moreover, testing was limited to instrumental training, rather than general class music, and findings are therefore limited to those learning to play an instrument. Schlaug et al.'s (2005) findings are akin to that of Gaser and Schlaug (2003) who imply that the greatest neural plastic effects occur due to intensive practice on a musical instrument. As the majority of studies continue referring to musical training as inducing neural plasticity, it begs the question as to what effects (if any) will result from general class music instruction, and highlights a significant area for future research.

More recently, a longitudinal study was conducted over a period of two years, in which the effects of music training on the developmental trajectory of children's (beginning at age six) brain structure was investigated (Habibi et al., 2017). Following two years of learning to play a string instrument, children demonstrated increased cortical thickness and better hemispheric communication. Habibi et al.'s (2017) findings support that of earlier research which reported similar results, with their findings suggesting musically-induced neural plasticity in both structure and function. It is thus conceivable that despite the prevailing effect of several variables, such as age of commencement of music training, music does contribute to improved brain development (Habibi et al., 2017; Hannon & Trainor, 2007; Patel, 2014; Schlaug et al., 2005; Skoe & Kraus, 2012; Strait & Kraus, 2014).

Neurological effects: Spectrotemporal processing and auditory evoked response
Rapid spectrotemporal processing (identification of stimuli which excite or inhibit neurons) has been associated with plasticity attributed to musical training in an fMRI study comparing abilities of musicians and non-musicians (Gaab et al., 2005). Gaab et al. (2005) postulated that music altered the functional anatomy underlying spectrotemporal processing, resulting in improved behavioural performance and a more efficient functional neural network, primarily in the language centres. It is plausible that the improvement of language processing also promotes better auditory attention, due to the shared neural networks of language and music (Fedorenko et al., 2009; Kunert et al., 2015; Schön et al., 2010; Yu et al., 2017). Gaab et al. further correlated the age of commencement of playing a musical instrument with a greater degree of improvement in rapid spectrotemporal processing. Their findings are therefore in agreement with that of Schlug et al. (1995), Pantev and colleagues (1998, 2001), and Gaser and Schlaug (2003) who all indicate greater neural enhancements when commencing musical training at an early age.

Other neurobiological behaviours, such as auditory evoked responses, are further believed to improve through involvement in musical training, as suggested by Fujioka, Ross, Kakigi, Pantev, and Trainor (2006) who, in a longitudinal study, recorded auditory evoked responses to a violin tone and a noise-burst stimulus in four to six-year-old children. Half of their participants participated in Suzuki violin lessons for one year, while the other half had no musical training. The violin students demonstrated larger cortical responses to violin sounds after receiving music lessons for one year, while the musically untrained students did not demonstrate this effect. Fujioka et al. suggested that these changes in neural processing occur as a result of the training of neural networks associated with sound categorisation and involuntary attention, which in turn contribute to better executive functioning across multiple domains. Again, it is plausible that language is one of these multiple domains to which they refer, due to the shared neural centres of language and music (Fedorenko et al., 2009; Kunert et al., 2015; Schön et al., 2010; Yu et al., 2017). Moreover, Fujioka et al. (like Gaab et al., 2005) focused on the effects of playing musical instruments, without considering general music tuition. This therefore raises the same question as earlier: will similar plastic effects be observed in cases of formal music education rather than training on a particular instrument? Another aspect to consider, in this focus on the playing of an instrument, is the element of intensive practice. It is possible that without this element, as in the case of general music classes, neural plasticity will be less pronounced.

Cognitive effects

The neurological changes induced by music training appear to lead to cognitive improvements, such as improved executive functioning and motor skills (Gaser & Schlaug, 2003; Habibi et al., 2017; Hallam, 2010; Hannon & Trainor, 2007; Kraus & Chandrasekaran, 2010; Pantev et al., 1998). Cognitive enhancements are found to be particularly prominent for those skills that are important for music practice and performance, as suggested by Schellenberg and Hallam (2005) who posited that the 'power' of music training lies in the 'multimodal' nature of music instruction – the training of various cognitive skills simultaneously, such as abstract reasoning, fine motor skills, and auditory attention.

Musical genre is additionally associated with an impact on cognition, highlighted by Schellenberg and Hallam's (2005) study examining the spatial abilities of ten- and eleven-year-old children after listening to different styles of music. Interestingly, children who listened to contemporary pop music demonstrated the greatest cognitive enhancements rather than the more frequently assumed classical music (e.g. Nantais & Schellenberg, 1999; Thompson, Schellenberg, & Husain, 2001). However, as only spatial abilities were tested, such findings should not be generalised across other cognitive skills. The style(s) of music most appropriate to improving auditory attention skills, for example, may not be contemporary pop music but rather another musical style(s). It is possible that the influence of musical style may correlate with the manner in which pitch, duration, and temporality are neurally processed. Each musical style incorporates characteristic pitches, intensities, and rhythms, thereby potentially influencing the cognitive processing of each style (X. Chen et al., 2012; Eagleman & Pariyadath, 2009; Honing et al., 2014; C.-Y. Lee & Hung, 2008; Röhl & Uppenkamp, 2012). The manner in which these three domains (i.e. pitch, duration, temporality) are processed per each musical style may account for different influences exerted on SAA capacities.

As posited by Weinberger (2004), the brain develops traces regarding the behavioural significance of relevant sounds – a process which is supported by music instruction. Similarly, over time musicians are believed to develop a specialised system to process behaviourally significant aspects of sound, as suggested by K. M. Lee, Skoe, Kraus, and Ashley (2009). This idea of relevant sounds as contributing to successful auditory attention is already established by the filter theory (Broadbent, 1958). Broadbent (1958) suggested that the processing of the most relevant stimuli contributes to SAA abilities, thereby validating K. M. Lee et al.'s findings. If taken in context of Broadbent's postulations, K. M. Lee et al.'s suggestions that music training results in a specialised system for processing aspects of sound, could have further implication for SAA development. Furthermore, this cognitive enhancement identified by K. M. Lee et al. was found to be more advanced in those who began musical training earlier in life, corroborating the findings of others (see Gaab et al., 2005; Gaser & Schlaug, 2003; Pantev et al., 1998; Schlaug et al., 1995).

Working memory constitutes another executive (i.e. cognitive) function which is affected by music instruction. George and Coch (2011) examined this hypothesis by investigating neural and behavioural aspects of working memory in musicians and non-musicians. Their findings indicated better working memory in musicians, in both the visual and auditory domains, in addition to showing increased sensitivity to auditory stimuli than non-musicians. Although their study was conducted with university students, there is little reason why such results shouldn't be the same for children engaged in music training, aside from their immature memory capacities (Gogtay et al., 2004; Rakic, Bourgeois, & Goldman-Rakic, 1994). A longitudinal study examined the impact of musical training on working memory performance in young children (aged seven to eight) with findings showing not only improved working memory functioning, but also improvements in general cognitive functioning (Roden, Grube, Bongard, & Kreutz, 2014).

Zuk, Benjamin, Kenyon, and Gaab (2014) conducted two experiments, one with adults and one with children. Both experiments compared musically trained and untrained participants on measures of executive functioning, including working memory. In both cases, the musically trained participants demonstrated enhanced working memory function. Continuing this research trend, Suárez, Elangovan, and Au (2016) examined differences in working memory function between musicians and non-musicians. The musicians demonstrated heightened working memory ability, yet was limited to specific aspects of working memory, such as spatial memory and visual-motor coordination (much like SAA improvement appears to also be limited by specific variables). However, this study is further limited by its participants, who were all adults – findings may therefore not replicate equally in children.

Taken together, and placed into a broader context, these findings corroborate suggestions of early cognitive psychologists who suggested an influence of memory on attention performance (O'Donnell & Cohen, 1993). Indeed, it has more recently been proposed that working memory implicates auditory attention (Sarter, Givens, & Bruno, 2001) and vice versa.

Music instruction further contributes to spatial development, a capacity correlated with auditory attention (D. C. Miller, 2013). F. Rauscher et al. (1997) compared the effects of two years of musical training on preschool children’s spatial-temporal reasoning, finding significant improvements on spatial-temporal tests for children engaged in musical training compared to controls who received none. The authors suggested that music training produces long-term changes in neural circuitry underlying spatial processing. However, their results should be interpreted with caution as they did not specify how participants were selected, or the manner in which they controlled for differential participant factors, such as cultural background, SES, or home environment (some children may engage in educational activities at home while others may not).

Costa-Giomi (1999) examined nine-year-old children on a spatial temporal task following engagement with musical training. Children who received musical training scored higher than controls on the spatial temporal task, however no major differences were found between the two groups following two years of training. Costa-Giomi (2000) then conducted a follow-up study which revealed that participants who began musical training before age five scored significantly higher on spatial-temporal tasks than those who began later. The influence of age of commencement of musical training therefore plays a role in music's impact on spatial development, just as it plays a role in the development of other cognitive effects (e.g. spectrotemporal processing and neural plasticity) (see Gaab et al., 2005; Pantev et al., 1998; Schlaug et al., 1995). However, F. H. Rauscher and LeMieux (2003) posit that a minimum of two years of musical training are required for spatial abilities to be maintained for a long time period, even after musical training has ceased. It would appear that Rauscher and LeMieux were, at least in part, correct in this hypothesis as the majority of studies investigating correlations between musical training and spatial-temporal processing occurred over periods of two years. It would be interesting to observe the effects of music over a period of three years, or longer, to discover longer-term influences of music on spatial skills.

Cognitive effects: Plasticity of auditory functions

Despite the improvement of general cognitive abilities, plasticity of cognitive auditory functions in particular develop through musical training (Gaser & Schlaug, 2003; Patel, 2012; Putkinen et al., 2014; Strait & Kraus, 2014). Pantev and Herholz (2011) reported the interaction, functional reorganisation, and contribution of sensory modalities to auditory perception of multiple streams of information. They believed that such abilities, to cognitively manipulate incoming sound information, resulted from the multimodal nature of musical training (see Schellenberg & Hallam, 2005). Pantev and Herholz go on to report that multimodal sensorimotor-auditory training, as induced by musical training, resulted in improved neural plasticity, yet also led to more plasticity compared to auditory training only. It is thus posited that music training, involving both the auditory and sensorimotor systems, leads to stronger functional (i.e. cognitive) changes in the auditory cortex than mere auditory training.

Motor and auditory regions of the brain show a degree of overlap, both regions being implicated when playing an instrument. Phillips-Silver and Trainor (2005) presented evidence regarding the shared networks of motor and auditory regions, by conducting a series of experiments with infants in which they were ‘bounced’ (on an adult’s knee) according to a specific rhythmic pattern. Findings indicated that infants preferred listening to the rhythmic pattern to which they were ‘bounced’ rather than newly presented patterns. Phillips-Silver and Trainor therefore postulate that the experience of body movement contributes to musical rhythm perception, a suggestion which is congruent with other studies (J. L. Chen, Penhune, & Zatorre, 2008; J. L. Chen, Zatorre, & Penhune, 2006; Lackner, 1992; Lerdahl & Jackendoff, 1983).

The involvement of the sensorimotor system has further implications, as it demands the utilisation of more attentional resources to best perceive tones. Increased demand is therefore placed on attentional resources, which are divided between the auditory and sensorimotor systems. SAA could then be negatively affected, as it is difficult for children to sustain attention on simultaneous, multiple streams of information (Sussman, Wong, et al., 2007). However, in this case, the multiple streams are aimed at one outcome (i.e. playing a tone/s on an instrument) and may therefore produce better SAA rather than diminishing it. Phillips-Silver and Trainor’s (2005) findings contradict that of Sussman et al. (2007), as they posit shared neural networks of auditory and motor regions, which work in conjunction with each other, specifically in terms of musical rhythmic stimuli. Based on their suggestion, it is therefore unlikely that neural resources are shared, but rather work together to produce one outcome. Indeed, the majority of studies conducted with young children engaged in musical training found improved structural and functional plasticity following training for an extended time period (Fujioka et al., 2006; Habibi et al., 2017; Hallam, 2010; Kraus et al., 2014; Moreno et al., 2009; Putkinen et al., 2014; Schellenberg, 2004; Schlaug et al., 2005; Skoe & Kraus, 2012). Yet these studies focused more on music's impact on neural and cognitive change, not the impact on auditory attention. However, as auditory attention constitutes an executive function, these neural changes will likely exert a degree of influence over SAA.

Another cognitive alteration, specific to the auditory cortex, is the enhancement of neural sound discrimination and better auditory attention. Putkinen et al. (2014), in a longitudinal study, investigated the development of auditory discrimination skills in musically trained and untrained children. Findings indicated that better auditory discrimination skills result from years of musical training and practice, from which highly precise processing of spectral and temporal auditory information develops. Auditory attention also improves by means of musical training and practice, as it plays a significant role in successful music practice (Putkinen et al., 2014). One should keep in mind that although frequency discrimination abilities - to which Putkinen et al. refer to as auditory discrimination - are almost adult-like in childhood, this is probably limited to the discrimination of high frequencies (Bishop et al., 2011; Fischer & Hartnegg, 2004).

Related to this enhanced sound discrimination, is the improved capacity to better perceive basic acoustic features of sound (Carey et al., 2015), with musicians showing more sensitivity to fundamental acoustic parameters (including pitch, loudness, and duration). However, Carey et al. (2015), in contrast to others (e.g. Luria, 1973; Strait & Kraus, 2011), found little evidence to support the idea of musical skills transferring to other domains. In fact, musicians showed only a marginal increase in SAA skills compared to non-musicians. Carey et al. (2015) did nonetheless suggest that the acquisition of musical expertise relies, in part, on SAA skills. They therefore corroborate postulations of Gaser and Schlaug (2003), who posited an influence of SAA on musical expertise, and vice versa. Carey et al.'s findings bring into question the exact nature of music's influence on cognitive skills. While other research has defined a broad plasticity of neural functionalities (Gaser & Schlaug, 2003; Habibi et al., 2017; Hallam, 2010; Schlaug et al., 2005), Carey et al. found only limited changes. Thus, while it can be concluded that musical training does induce functional changes in the brain, the extent of these changes remains to be determined.

Much research evidence investigating correlations between music training and cognitive abilities (which includes SAA) has been determined with adult populations. Evidence may thus only be applicable to this age range and may present differently were the same investigations to be conducted with children, due to their immature auditory structure and function (Bishop et al., 2011; Fischer & Hartnegg, 2004; Hill et al., 2005; Leibold & Neff, 2007; E. Sussman et al., 2007). Yet some of these few studies including child participants have demonstrated neurological and cognitive changes as a result of music instruction. While these changes predominantly only account for enhancements of auditory abilities in general, it is plausible they will further influence SAA, which forms a significant part of audition.

2.8 Conclusion

Context for the present study has been provided through consideration of the anatomy and functioning of the ear and hearing, and of healthy auditory development from infancy through childhood. An overview of research evidence into auditory attention and factors that might influence it, as well as of shared neural networks of language and music and the processing of sound characteristics provides further context and background, in addition to providing further substantiation to the hypothesis that music education exerts an influence on SAA. Research into music's influence on auditory and cognitive abilities in general was also examined as an introduction into how it might similarly affect SAA – an influence which the present review hopes to clarify.

Chapter 3
Research Methodology

3.1 Introduction

The research methodology describes the particular research paradigm, approach and design of the study. Further outlined are techniques that were employed to collect data and the means utilised in efforts to maintain quality and reduce bias. The systematic review allowed for a rigorous process of data retrieval, extraction, and analysis – significant components of a review. Ethical considerations regarding validity and reliability of research, as well as publication bias and plagiarism, are also considered.

3.2 Research paradigm and approach

The study is based in interpretivism, as it focuses on understanding the meanings and purposes people give to their own actions, while recognising the role of the researcher's own interests and values (Smith, 2008). Furthermore, interpretivism develops constructs of what is occurring in a social setting at any given time, yet requires further interpretation based on different interests and purposes. Interpretivists believe that details are important, as meaning is only fully grasped once a detailed account is provided (Bakker, 2010) (such as in the present study). Interpretivist enquirers are obligated to justify the procedures employed to collect data (Smith, 2008) – therefore 'fitting' the systemic review design which requires a detailed explanation of procedures followed.

The present study falls within a qualitative research approach, as qualitative research is concerned with subjective assessments of opinions, attitudes and behaviour. Research is the result of the researcher's insights and impressions (Kothari, 2004). Qualitative research is investigates the 'how' and 'why' of decision making, aiming to determine the meaning of a situation and/or phenomenon (Bricki & Green, 2007). Furthermore, qualitative methods are central to research in education, as well as disciplines in the humanities (such as the arts) (Given, 2008) and is therefore an appropriate research approach for the present study.

3.3 Research design

A systematic literature review involves a methodical and unbiased review of literature (Dempster, 2003) concerning a particular topic of interest, and is designed to locate, appraise and synthesise available evidence in order to provide evidence-based answers to research questions (Dickson, Cherry, & Boland, 2014). Furthermore, systematic reviews are considered the ‘gold standard’ to synthesise findings from various studies investigating the same question, thereby forming the basis for the development of practice guidelines and informing future research recommendations (Shamseer et al., 2015). The establishment of a protocol is an essential component of systematic reviews as it ensures the review is rigorous and explicitly planned (Moher et al., 2015). A protocol was prepared according to the PRISMA-P guidelines (Shamseer et al., 2015), which provide a minimum set of items to be included in the review (see appendix D), such as a rationale and the planned methodological and analytical approach.

3.4 Data collection techniques

3.4.1 Search strategy

Systematic reviews involve a thorough search of relevant databases to identify appropriate studies to include in the review (Dickson et al., 2014). Electronic databases searched were selected based on relevance to the research questions and field of study, and were limited to those subscribed to by the University of Pretoria, namely, Science Direct, Sage Journals, PsychInfo, Music Periodicals, and PubMed. Primary and secondary search phrases, based on the primary research question, were employed to search each of the five databases. Boolean operators - referring to logical operators ‘and’, ‘or’ and ‘not’, utilised to narrow electronic search results (Bothma, Cosijn, Fourie, & Penzhorn, 2011) - were included to enhance search output (see figure 3). Primary search phrases were: ‘sustained auditory attention characteristics’ and ‘sustained auditory attention development’ (e.g. ‘sustained auditory attention characteristics in children with music training’). Secondary search phrases were: ‘auditory vigilance’ and ‘auditory focused attention’ (used interchangeably with SAA in relevant literature).

Searching altered slightly between each database as search functions varied across each. Some databases allowed for the search strategy to be worded exactly as in the search protocol. However, other databases did not allow for this, and the ‘advanced search’ function was thus used, with sections of the phrases entered separately and Boolean operators selected from a list of predetermined options. Such variations make little difference to citations yielded as the different forms of searching are the ‘same’ but merely arranged into different formats.

Search number	*Search phrase* (with use of Boolean operators 'and', 'or', and 'not')
Primary search phrases	
1	sustained auditory attention characteristics in children with music training
2	(sustained auditory attention NOT auditory selected attention) characteristics in children with (music training OR music instruction)
3	sustained auditory attention development in children with music training
4	(sustained auditory attention NOT auditory selected attention) development in children with (music training OR music instruction)
Secondary search phrases	
5	(auditory vigilance NOT visual vigilance) characteristics in children with music training
6	(auditory vigilance NOT visual vigilance) development in children with music training
7	(auditory focused attention NOT visual focused attention) characteristics in children with music training
8	(auditory focused attention NOT visual focused attention) development in children with music training

Figure 3: A draft search strategy utilised to identify studies across five electronic databases, including primary and secondary search phrases

3.4.2 Study selection

An initial search of the five databases occurred in May 2018, yielding a total of 48 234 citations. Duplicates were eliminated (on 25 May 2018) after which 25 227 citations remained. Studies published prior to 2008 were then eliminated, after which a screening of the titles and abstracts of the remaining citations occurred. The full text of the remaining studies (n=41) was assessed, by both the reviewer and an independent reviewer (in efforts to reduce bias) to determine if they met eligibility criteria. Consensus was reached between the two reviewers regarding the final inclusion of studies (n=10) (see figure 4).

3.4.3 Data management

The referencing program EndNote X7.8 was used to record all citations identified at each stage of the search process. Each database included a function in which to 'export' all identified citations directly into the program. Within EndNote, citations were organised as five individual groups representing each database, divided into eight subgroups, each correlating with the eight searches. EndNote automatically calculated the total number of citations identified per database and search number, as well as identifying all duplicates. Furthermore, EndNote allowed for easy identification and subsequent elimination of all articles published prior to 2008. Data was also recorded electronically on a spreadsheet using Microsoft Excel (2013), noting the date and output of each search and elimination, as a 'back-up' to that in EndNote, in case of any software (or otherwise) issues.

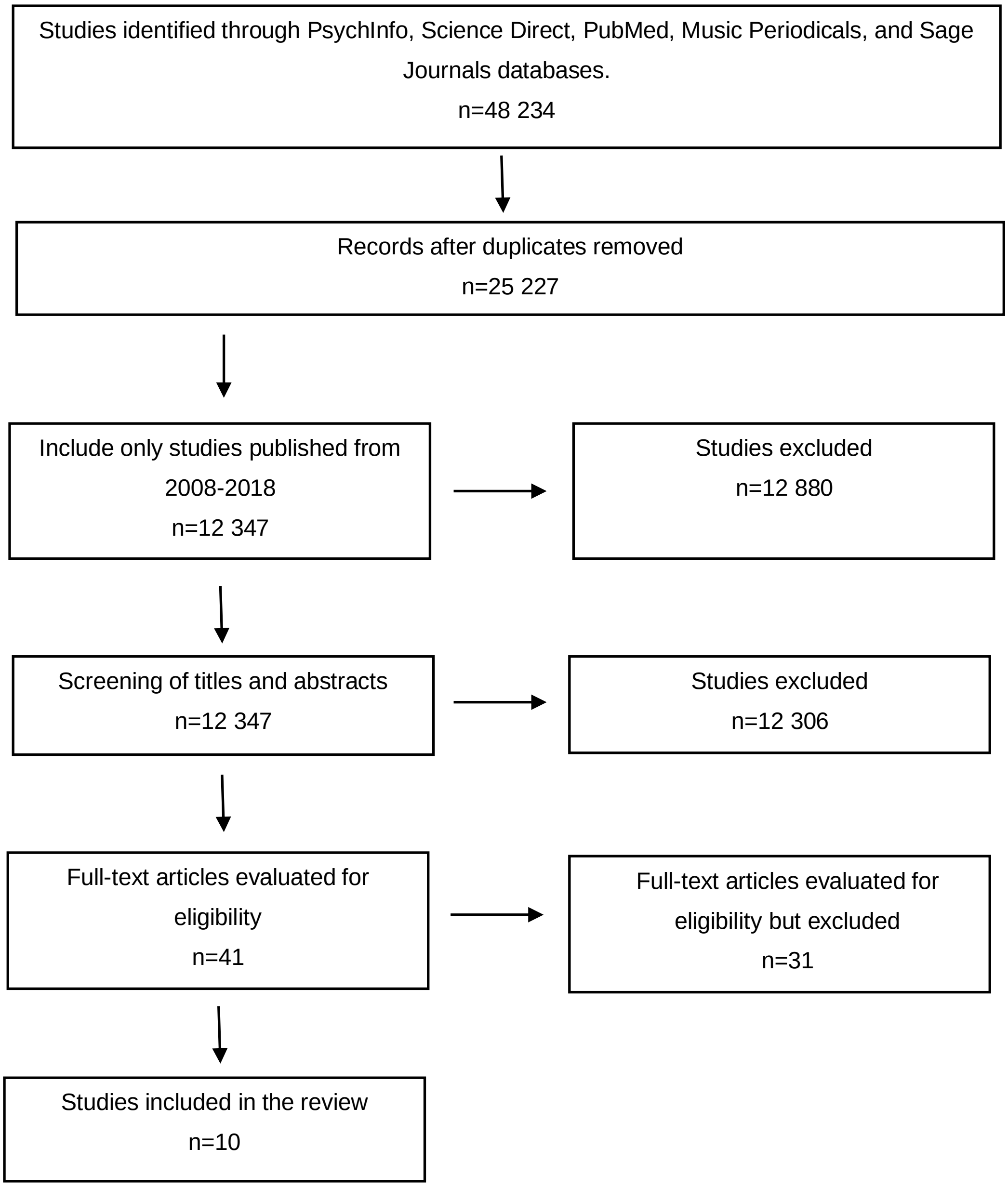

Figure 4: Process of searching databases and identifying studies for inclusion in the review

3.4.4 Eligibility criteria

The final ten studies were selected based on specified inclusion (eligibility) criteria (see figure 5). As few studies met the initial criteria, they were altered during the search process. Criteria were thus broadened to include more studies and render the review more valid. Initially, only children aged between seven and ten years were included, with the lower limit later extended to five years old. Likewise, the context (setting) was initially limited to music training, which was later expanded to also include music tuition.

Participants

Only children aged between five and ten years were included in the study. This age group was selected due to the extensive and significant cognitive development occurring during this period (P. Anderson, 2002; V. A. Anderson et al., 2001; Gogtay et al., 2004; J. K. Moore & Linthicum, 2007; White et al., 2013). Furthermore, the first five school years are encompassed by this age limit, during which time musical tuition typically begins.

Phenomena of interest

The area of study, namely SAA, was chosen based on the limited research evidence available regarding music's impact on SAA in childhood. Moreover, SAA was selected as it contributes significantly to concentration and is closely intertwined with working memory (Buhusi & Meck, 2009; Knudsen, 2007; D. C. Miller, 2013; Pillsbury, 1908; Titchener, 1908; Zatorre, 2007) – factors which play a role in learning and academic abilities.

Context

Academic learning environments, such as schools, constitute the context as it is in these environments in which SAA is predominantly demonstrated. The home environment was excluded as, although children are often required to perform sustained attention tasks at home, it is challenging to measure how this impacts SAA. Both music training and music tuition were included as forms of music exposure.

Outcomes

The outcome of each review study reflects a purely positive correlation between SAA and music, or a positive correlation with associated limitations which may detract from the degree of impact music exerts on SAA. Either outcome is acceptable, as the review aims to explore the nature of correlations found between SAA and music instruction.

Study type and design

Review studies are of a quantitative, qualitative, or mixed method design. Likewise, no limit was placed on the particular study design included.

Publication status

Eligible articles included full-text studies published in peer-reviewed journals. Grey literature and abstracts were excluded.

Language

Only English language studies were included.

Years considered

Publications were only included if published between 2008 and 2018 (the past decade).

Measure of sustained auditory attention

Studies made use of various quantitative instruments and tools, or qualitative methods, to measure levels of SAA. The review included all such measures.

	Include	Exclude
P (**p**opulation)	Children aged 5-10 Normal development	Young children (<age 5), adolescents (>age 10), adults Abnormal development
I (phenomena of **i**nterest)	SAA	Divided auditory attention, Selected auditory attention
Co (**Co**ntext)	Instrument training, general music classroom, general education classroom School, structured learning environment	Background music Home environment
Type of musical instrument	Any	N/A
Language	English	Not English
Article type	Full text only Published, peer-reviewed	Abstracts only Unpublished, grey literature
Date	2008 – present (at time of data collection)	Prior to 2008
Outcomes	Positive or negative	N/A
Study type and design	Qualitative, quantitative, mixed methods Any design	N/A
Measure of SAA	Any	N/A

Figure 5: List of inclusion and exclusion criteria

3.4.5 Data collection process and data items

In order to fully understand each study, an initial reading of the full-text of each occurred, after which a template, based on PRISMA-P guidelines (Shamseer et al., 2015), was created to extract fundamental characteristics of each study. Two templates, differing slightly, accounted for both quantitative (n=5) and qualitative (n=4) studies. Both templates were completed for the mixed methods study (n=1). Descriptive categories and subcategories were generated for all themes identified within each study (see table 1). Categories and sub-categories were assigned to paragraphs during a second full-text reading of each study (with the exclusion of paragraphs that held no relevant information, such as methodology explanations). In terms of data items, information was collected on a) participant ages, intervention, outcomes, study design, setting, context, title, and year of publication; b) correlations between music instruction and SAA, and suggested causes for identified correlations.

A single author was involved in the data collection process, thereby increasing the likelihood of researcher bias. In efforts to reduce bias, templates used to extract data items ensured consistency in data extraction, and was first piloted, to make necessary adjustments before extracting data from each study. Explicit descriptions of each category and sub-category were predefined to ensure paragraphs were assigned to the most appropriate description. Quality assessments for each study were conducted to ensure appropriate reliability and validity. The term 'quality' refers to "[t]he degree to which a study employs measures to minimise bias and error in its design, conduct and analysis" (Greenhalgh & Brown, 2014, p. 64). Using the HTA (Health Technology Assessment) quality checklists for qualitative and quantitative studies, used to evaluate research from a variety of fields (Kmet, Lee, & Cook, 2004), it was possible to assess quality of each study (see table 4). Both checklists were completed for the mixed methods study and the mean score obtained. In efforts to further reduce risk of bias, a second independent reviewer also completed the quality assessments.

3.4.6 Risk of bias

The Cochrane Collaboration tool for assessing risk of bias (Higgins & Altman, 2008) was used to assess risk of bias in each of the quantitative (n=5) studies (see table 2). The tool incorporates a variety of domains including: selection bias, performance bias, attrition bias, and reporting bias. These domains were not suited to the qualitative studies, for which the CASP (Critical Appraisal Skills Programme, 2018) systematic review checklist was used, consisting of a series of ten yes/no questions to assess reliability, validity and objectivity (see table 3). Both tools were completed for the mixed methods study. The risk of bias assessment occurred at study level to inform the reviewer of bias in each study prior to data analysis. Implications of the bias assessments are incorporated in the findings, in terms of influencing weight assigned to each of the ten studies. A major source of uncertainty is the possible exclusion of important data, thereby increasing likelihood of selective reporting. Attempts to reduce this possible bias were accounted for by an in-depth, thematic text analysis, used to assign each paragraph to an appropriate category.

The Cochrane Collaboration tool incorporates six domains of possible bias (see table 2), for which judgements of 'high risk' and 'low risk' (and occasionally 'unclear risk') are made, with evidence from the text to support these judgements. The domains are as follows (Higgins & Altman, 2008):

- Selection bias: Systematic differences between baseline characteristics of participant groups that are compared. Selection bias can be reduced by sequence generation, referring to the establishment of a rule for allocating participants to particular interventions based on a random process, and allocation concealment, referring to the strict implementation of the random allocation procedure.
- Performance bias: Systematic differences between participant groups regarding care provided or exposure to specific interventions. Blinding of study participants and personnel (ensuring no knowledge of which intervention is received) can reduce risk of performance bias.

Table 1: Descriptions of subcategories employed in the data extraction process

Main category code	Subcategory code	Title	Description
1: Correlations between music instruction and enhanced SAA	a	Positive correlation	Evidence indicates a purely positive correlation between music instruction and attention (i.e. music has an impact on SAA).
	b	Positive correlation with associated limitations	Evidence indicates a positive correlation between music instruction and attention, with associated limitations which detract from music's impact.
	c	Influence of external factors	While correlations between music instruction and SAA is indicated, this correlation is substantially influenced by extraneous factors which could impact the evidence providing justification for identified correlation.
2: Reasons suggested for correlations between music instruction and enhanced SAA	a	Neurological bases	Improvements in SAA are accounted for by neurobiological evidence, specifically changes in brain structure and function, most often identified by ERPs and fMRI scans.
	b	General auditory processing skills	Musical training creates enhancements in general auditory processing skills, in turn influencing SAA.
	c	Particular musical aspect/activity	A particular musical characteristic (e.g. rhythm) or activity (e.g. solo performance) improves SAA, rather than music as a whole or other activities.
	d	External rewards/reinforcement	Attention is advanced only in the presence of positive reinforcement or external rewards. Without these incentives, SAA enhancements are not observed.
	e	Degree of participant involvement	The degree of involvement with the music affects SAA improvements made. If not sufficiently engaged with the music, no improvements may occur. Alternatively, a high degree of engagement might lead to observable differences.
	f	Musical genre/style	The specific genre/style of music influences whether SAA is improved or not, based on the inclusion, or lack thereof, of certain musical features.
	g	Other	Other reasons suggested for advancement in SAA due to musical training, not specified in any of the subcategories.

Note: SAA= sustained auditory attention; ERP= event-related potential; fMRI= functional magnetic resonance imaging

- Detection bias: Systematic differences between participant groups in how outcomes are determined. To reduce risk of detection bias, blinding of outcome assessors can prevent knowledge of which participants received which interventions.
- Attrition bias: Systematic differences between participant groups in the amount of withdrawals from the study, influencing incomplete outcome data.
- Reporting bias: Systematic differences between reported and unreported findings. This often arises due to the publication of studies with statistically significant results more than those without, leading to inaccurate descriptions of effects of intervention.

The core criterion of bias in qualitative studies is researcher bias, ascertained by evaluating reliability, validity and objectivity (Hannes, 2011). The CASP checklist for qualitative research consists of a series of ten yes/no questions with options for additional comments to assess reliability, validity and objectivity. The checklist includes three domains (see table 3) (Critical Appraisal Skills Programme, 2018):

- Are the results of the study valid? Six questions: clear statement of the aims; appropriateness of the research method, research design, and recruitment strategy; data collection procedures; and consideration of researcher bias.
- What are the results? Three questions: consideration of ethical issues; rigorous data analysis; and clear statement of the findings.
- Will the results help locally? One question: how valuable the research is.

3.5 Data analysis and synthesis

Thematic text analysis was employed to analyse and synthesise data extracted from each study. Thematic text analysis involves a multi-stage process of categorising text, in which main, topical categories are first determined prior to the development of sub-categories (Kuckartz, 2014). Extracted data was organised into two thematic matrices – one for each main category – to collate data per individual study (horizontal) and per sub-category (vertical) (see figure 6 for an example). Collated data for each study and sub-category was then summarised in prose. Although this two-fold method of collation produced much repetition of data it ensured effective synthesis, allowing for data to be critically interpreted and discussed with reference to appropriate literature.

Table 2: Risk of bias assessment for the quantitative review studies (n=5) and one mixed methods study (n=1) using the Cochrane risk of bias tool

Study	Selection bias		Performance bias	Detection bias	Attrition bias	Reporting bias	Possible bias or limitations identified
	Random sequence generation	Allocation concealment	Blinding of participants (a) and personnel (b)	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	
Sandberg, 2009*	High risk	Unclear risk	Unclear risk	Unclear risk	Unclear Risk	High risk	The researcher was a teacher at the school where the study took place, possibly introducing bias as the researcher may have felt a certain obligation to the school. The researcher also adopted a role as mentor to the classroom teacher, which likely introduced bias due to lack of distinction between roles.
Sportsman, 2011	High risk	Unclear risk	Unclear risk (a), low risk (b)	Unclear risk	High risk	Low risk	Teacher's opinions of the music program may have biased their answers to the survey questions. Participants were not randomly assigned to treatment groups, and attrition occurred.
Wolfe & Noguchi, 2009	Unclear risk	Unclear risk	Unclear risk	Low risk	Low risk	Low risk	Bias may occur as a result of the small sample size and the conditions under which the interventions took place. The possible impact of SES and learning difficulties was not accounted for.
Hyde, Lerch, Norton, Forgeard, Winner, Evans & Schlaug, 2009	High risk	High risk	Unclear risk	Low risk	Low risk	Low risk	Participants were selected based on the condition they had no prior musical training and gave assent themselves to participate in the study.
Khalil, Minces, McLoughlin & Chiba, 2013	Unclear risk	Unclear risk	High risk (a), low risk (b)	Low risk	Low risk	Low risk	All participants attended the same school and had music classes with the same music teacher. Findings were therefore not distributed across several contexts.
Hallberg, Martin & McClure, 2017	Low risk	Low risk	Low risk (a), high risk (b)	High risk	Low risk	High risk	All participants underwent pre- and post-tests to assess attentional control yet following receipt of violin lessons in the intervention group, no post-test assessments were administered.

*Indicates the mixed method study

Table 3: Risk of bias assessment for the qualitative review studies (n=4) and one mixed methods study (n=1) using the CASP checklist

Study	Section A						Section B			Section C
	Is there a clear statement of the aims?	Is a qualitative methodology appropriate?	Is the research design appropriate to the aims?	Is the recruitment /selection strategy appropriate? (selection bias)	Does data collected address the research issue?	Have relationships between the researcher and participants/research been considered?	Have ethical issues been taken into consideration?	Is the data analysis sufficiently rigorous?	Is there a clear statement of findings? (reporting bias)	How valuable is the research?
Sandberg, 2009*	✓	✓	✓	x	✓	x	^	x	x	Implications of the findings and possible contributions to literature are clearly discussed, while suggestions are made for incorporating findings into the classroom.
Strait & Kraus, 2011	✓	✓	^	^	^	^	^	^	✓	Implications of findings and possibilities of future research are discussed.
Williams, 2015	✓	✓	✓	x	N/A	^	✓	N/A	N/A	The possible contribution of the program to is contemplated in detail.
Vargas, 2015	x	✓	^	x	x	x	^	^	x	Contributions to education are discussed, yet not what it may add to existing knowledge or to future research.
Geist & Geist, 2012	✓	✓	^	x	^	x	^	x	^	Potential areas for future research are contemplated, as well as its contribution to existing knowledge.

*Indicates the mixed method study

Note: ✓= yes; x= no; ^= unclear; N/A= not applicable

	Sub-category 1	Sub-category 2	Sub-category 3 etc.
Study 1			
Study 2			
Study 3 etc.			

Figure 6: Example of a thematic matrix

Each study was described according to a set of data items (see table 4), including report, study, and outcome characteristics adapted from PRISMA-P guidelines:

- Report characteristics: Title, author, year and country of publication.
- Study characteristics: Participant demographics and research method/design.
- Outcome characteristics: Type of music instruction and characteristics of SAA.
- Quality indicator scores: The HTA quality indicator score and whether inter-rater agreement was achieved or not.

3.6 Ethical considerations

Prior to commencing the study, ethical clearance was obtained from the ethics committee of the Faculty of Humanities of the University of Pretoria (see appendix A). As the study is a systematic review it did not involve any human participants, however, plagiarism, publication bias, and academic integrity constitute ethical considerations. Validity and reliability, important components of qualitative research (Hannes, 2011), are also considered.

3.6.1 Publication bias

The most prevalent ethical consideration in a systematic review is publication bias, referring to "a systematic error, or deviation from the truth, in results or inferences" (Higgins & Altman, 2008, p. 1). Multiple databases were searched extensively, with both primary and secondary search phrases, to identify the most appropriate studies and ensure consistency across each database. Moreover, review results may be biased due to incomplete or inadequate reporting within the studies themselves (Moher et al., 2015). A bias assessment was therefore completed for each study, based on standardised and approved assessment tools. Initially, it was proposed that the Cochrane Collaboration Tool (Higgins & Altman, 2008) would be used across all studies yet, upon further reflection, its domains were considered inappropriate to assess bias in qualitative studies, for which the CASP checklist (2018) was completed.

3.6.2 Reliability of research

Reliability refers to the “extent to which results are consistent over time” (Joppe, 2000, p. 1), with the core of reliable qualitative research lying in consistency (Carcary, 2009), meaning that investigations of the same phenomenon will lead to the same or similar results (Kvale, 1989). Errors in reliability result from inconsistencies in testing, researcher bias and participant demographics (Rand, 1971 in Brock-Utne, 1996). Consistency (leading to reliability) is achieved when research is verified by raw data, data reductions, and process notes (Campbell, 1997). In addition to consistency, reliability is dependent upon three indicators: methodological coherence (appropriate and thorough collection, analysis, and interpretation of data); researcher responsiveness (ongoing verifications of findings and analyses); and audit trails (transparent descriptions of all procedures and limitations) (P. Miller, 2008a). Reliability in the present study was ensured by:

- Following the guidelines as laid out by the PRISMA-P Statement Checklist (Moher et al., 2015; Shamseer et al., 2015).
- Substantiating all data with appropriate literature.
- Thorough descriptions of each step in the PRISMA-P statement.
- The description of possible limitations and future recommendations to counteract these limitations.

3.6.3 Validity of research

Validity of research, referring broadly to how ‘sound’ a study is, is contingent upon research procedures remaining coherent and transparent, results that are evident, and conclusions which are convincing (P. Miller, 2008b). Validity further describes the ‘appropriateness’ of the processes, tools, and data (Waterman, 2013). Choice of methodology, for example, must ensure identification of findings in the appropriate context for it to be deemed valid (Finfgeld-Connett, 2010). Validity of research also concerns an element of the researcher, regarding observations and interpretations, in which “the researcher is calling what is [tested] by the right name” (Kirk & Miller, 1986, p. 69). Meticulous testing and consideration of the credibility of analytic claims in literature, ensure validity of qualitative research (Peräkylä, 2011). Validity of the present study was ensured by:

- Searching carefully selected electronic databases using both primary and secondary search phrases related to the research questions.
- Selecting and reviewing recently published peer-reviewed articles from accredited journals according to pre-determined inclusion criteria and based on consensus between two independent reviewers.

- A quality assessment for each study included in the review, conducted by two independent reviewers.
- The use of PRISMA-P to guide the study, as appropriate to a systematic literature review.

3.6.4 Plagiarism and academic integrity

The Cambridge English dictionary defines plagiarism as “the process or practice of using another person’s ideas or work and pretending that it is your own”. Another definition of plagiarism is the “use of another writer’s words or ideas without acknowledging the source” (Hodges, Whitten, Webb, & Horner, 1986). Plagiarism is interlinked with the concept of academic integrity, which describes a set of ethical principles to which all researchers ascribe to (Jones, 2011), such as honesty, fairness, responsibility, respect and trust (University of Newcastle website). Academic dishonesty results from plagiarised work, therefore, by ensuring efficient citing, academic integrity is maintained (Jones, 2011). The present study has maintained academic integrity by ensuring the ideas of others are cited correctly, and a complete reference list is included.

3.7 Conclusion

The current chapter provides an account of the pragmatic framework and qualitative approach of the study, in addition to detailing procedures involved in collecting data. As a systematic review, data collection entailed certain steps to ensure sufficient data was obtained, based on PRISMA-P guidelines, including an extensive search strategy of appropriate databases; study selection procedures with eligibility criteria; data extraction techniques; and quality and risk of bias assessments. Ethical considerations, such as validity, reliability, and academic integrity were further discussed. The following chapter presents the procedures followed and the resultant findings.

Chapter 4
Procedure and Findings

4.1 Introduction

Procedures employed to determine characteristics of each study and to assess risk of bias within and across the studies are described. Additionally, confidence in cumulative outcomes was determined. The findings consider individual characteristics of the review studies and their implications. Further presented are findings obtained within each study in relation to the themes identified in thematic text analysis. These themes are based on the research questions, and the findings therefore reveal preliminary answers to the research questions.

4.2 Procedure

A total of ten studies were identified to be included in the review based on eligibility criteria. Each study was summarised based on a series of study characteristics (see table 4), including report, study, and outcome characteristics. Data was extracted by means of thematic text analysis, which was then collated and synthesised into workable findings. An assessment of the confidence in cumulative evidence was also conducted.

4.2.1 Study characteristics

Characteristics of the review studies include report, outcome and study characteristics (see table 4). Nine studies were conducted in a developed country, namely the USA, while the remaining study was conducted in a developing country, namely Brazil. Three of the studies reported participants with a low SES while six recruited participants from public schools in the USA with low to middle SES. Participant ages ranged from five to eighteen years of age across all ten studies. Only data for participants aged between five and ten years was included in the study, as defined by eligibility criteria. The total number of participants varied widely across studies, ranging from 28 to 117. Two studies (Hallberg et al., 2017; Hyde et al., 2009) reported that participants had no prior musical training while one study (Khalil et al., 2013) reported participants with previous musical training.

Four studies were review studies, one was a longitudinal study and another a randomised-control study. Two studies employed a pretest-posttest design, another two incorporated between-subject comparisons, while one used within-subject comparisons. The longitudinal study (Hyde et al., 2009) constituted the longest intervention of fifteen months, while the randomised-control study (Hallberg et al., 2017) incorporated the shortest intervention of five weeks. The longitudinal study (Hyde et al., 2009) had the second least number of participants (31) while the quasi-experimental design (Sportsman, 2011) included the greatest number of participants (117). It is interesting to note that this study had (and maintained) the highest number of participants over a period of one year, as musical training involves a high level of commitment and practising (Ericsson, Krampe, & Tesch-Römer, 1993; Sloboda, Davidson, Howe, & Moore, 1996) which few are willing to continue for extended periods of time. It is thus not surprising that the longitudinal study (Hyde et al., 2009), occurring over a period of 15 months, had such few participants.

Five of the studies conducted their investigations in the school (group) music classroom, three in the general classroom, three in group instrumental lessons, and two in individual instrument lessons. There is a degree of overlap among these contexts, with some studies (e.g. Geist & Geist, 2012; Hyde et al., 2009; Sportsman, 2011) employing more than one. The form of music instruction thus differs across the studies which is likely to influence review findings. Furthermore, it presents difficulties in comparing findings across studies, as it introduces a lack of consistency across contexts.

Characteristics of SAA examined in the ten studies include engagement, focus, attentiveness, vigilance, concentration, attention behaviour, and attentional control. The investigation of these characteristics varied across the studies, with five focusing on general auditory skills and five on auditory attention. The primary focus of most of the studies is on neurological aspects of auditory abilities, perhaps as neural functioning is more measurable than levels of SAA.

Nine of the studies had an HTA rating higher than 0.5, indicating a good quality of research as these scores represent more than half of the total score (i.e. 1). All except one study (i.e. Wolfe & Noguchi, 2009) had an inter-rater agreement higher than 50 percent. This study thus remains a cause for concern, as well as the general lack of inter-rater agreement. Although an agreement higher than 50 percent is acceptable, ideally it should be at 70 percent or higher , achieved by only two studies (i.e. Hallberg et al., 2017; Williams, 2015). Overall, individual quality of the studies is adequate despite lack of agreement between the reviewers, as the overall mean score is greater than 0.5.

Table 4: Report, study, and outcome characteristics of each of the ten studies, further indicating quality score

Report characteristics		Study characteristics			Quality indicator score		Outcomes	
Title	**Study: Author's, year and country**	**Participant age range & gender**	**Number of participants (incl controls)**	**Research method**	**HTA quality indicator score***	**% of inter-rater agreement**	**Form of music instruction**	**Characteristics of SAA**
Music as a resource to develop cognition	Vargas, 2015, Brazil	N/A	N/A	Review article of the impact of music on human development	0.35	60	Class music	AP, neural auditory development, audition
Bridging music neuroscience evidence to music therapy best practice in the early childhood classroom: Implications for using rhythm to increase attention and learning	Geist & Geist, 2012, USA	N/A	N/A	Review article on the impact of rhythm on brain processes, attention and learning	0.55	60	Class music, general education classroom	Neural auditory development, AP, engagement, AA
Playing music for a smarter ear: Cognitive, perceptual and neurobiological evidence	Strait & Kraus, 2011, USA	N/A	N/A	Review article of the impact of music on cognitive, perceptual and neurobiological development	0.68	60	Clinical setting	Auditory perception, cortical evoked potentials, auditory function, AA, AP, auditory acuity
The development of a music program to improve the attention span of school-aged children	Williams, 2015, USA	9-18 years	N/A	Extended review article on the influence of music on attention span, with a theoretically based proposed program based on the literature	0.9	70	Class music, after-school music program	Attention span, concentration, engagement, focus, vigilance, cortical arousal, alertness, AP
Get moving! The effects of music and movement on student attention and engagement	Sandberg, 2009, USA	6-7 years	28	Mixed methods approach with a non-randomised controlled trial, direct observations and a summary interview protocol	0.53	69	General education classroom	Engagement, focus, AB, AA

Development of musicianship and executive functioning among children participating in a music program	Sportsman, 2011, USA	7-9 years, NR	117 (C=39, I=78)	Quasi-experimental design over 1 year with between-subject comparison	0.77	57	Music class, individual instrument lessons, small group instrument lessons, large ensembles	AA, AB, AC
The use of music with young children to improve sustained attention during a vigilance task in the presence of auditory distractors	Wolfe & Noguchi, 2009, USA	5-5.5 years, M & F	76	Multi-sample, independent group design with between-subject comparison	0.59	43	General education classroom	Attentiveness, focus, engagement, vigilance
Musical training shapes structural brain development	Hyde, Lerch, Norton, Forgeard, Winner, Evans & Schlaug, 2009, USA	NR, M & F	31 (I=15, C=16)	Longitudinal study over 15 months, with a pretest-posttest design	0.72	57	Class music, individual instrument lessons	AP, auditory cortical response
Group rhythmic synchrony and attention in children	Khalil, Minces, McLoughlin & Chiba, 2013, USA	7-12, M & F	102	Within-subject experimental design	0.69	50	Small group instrumental lesson	Auditory attendance, AB, engagement
The impact of music instruction on attention in kindergarten children	Hallberg, Martin & McClure, 2017, USA	5-6 years, NR	48 (I=26, C=22)	Randomised pretest-posttest control group design	0.78	90	Group violin lessons (Suzuki violin method)	AA, AC

*Highest achievable score is 1. Represents the mean value obtained by two reviewers.

Note: SAA= sustained auditory attention, HTA= health technology assessment, N/A= not applicable, NR= not reported, I = intervention group, C= control group, M= male, F= female, AA= auditory attention, AP= auditory processing, AB= attention behaviour, AC= attentional control

4.2.2 Risk of bias within and across studies

The Cochrane Collaboration tool for assessing risk of bias was used to assess risk of bias within each of the quantitative (n=5) studies (see table 2). The qualitative (n=4) studies were assessed by means of the CASP checklist for qualitative studies (see table 3), while the mixed method study (see table 2 and 3) was assessed by a combination of both the Cochrane tool and CASP checklist.

Although no limit was placed on the inclusion on studies based on their bias ratings, these ratings should be considered, as indicative of some studies being more reliable than others. The quantitative studies (n=5) were predominantly at a low risk of bias, however, all except one (Wolfe & Noguchi, 2009) had at least one domain rated as high risk of bias. Similarly, all except one (Hallberg et al., 2017) had at least one rating of unclear risk. Although ratings of high and unclear risk are cause for concern, the quantitative studies all had similar ratings of low risk to counteract these bias ratings. Holistically, each quantitative study has a low risk of bias. Nonetheless the particular domain(s) within each study with a rating of high risk remains a cause for concern and should be taken into account in reviewing findings from the respective studies. Across all five studies, each domain for risk of bias is represented as ‘high’ at least once, with random sequence generation identified as ‘high’ or ‘unclear’ risk within each study. Continuing to examine the studies holistically, domains which presented at a ‘high’ or ‘unclear’ risk of bias, include selective reporting, allocation concealment, and incomplete outcome data (appearing twice) and blinding or personnel and participants (appearing once).

The qualitative studies (n=4) proved more problematic than the quantitative studies, in terms of reliability and validity. Indeed, the majority of studies resulted in a ‘no’ response to the ten questions in the CASP checklist. Of particular concern are the questions relating to selection bias, reporting bias, and ethical considerations. Risk of bias in these areas is problematic, particularly in qualitative studies. However, all except one (Vargas, 2015) of the qualitative studies obtained a high quality (HTA) score, therefore indicating good quality despite perhaps lacking in reliability. Such risk of bias does not discount their findings, but merely indicates that results should be interpreted with caution. Furthermore, it highlights the need for more reliable and trustworthy research in this area of interest.

4.2.3 Confidence in cumulative evidence

The quality (and consequently confidence) in cumulative evidence of outcomes across studies was determined by the GRADE approach, which provides a system to rate quality of evidence in systematic reviews (Guyatt et al., 2011). However, unlike quality scores, GRADE remains applicable regardless of the rating of evidence (Guyatt et al., 2011). The GRADE process begins by determining primary outcomes for which assessments are to be made. Randomised controlled trials (RCTs) begin with a set rating of high-quality evidence while observational studies begin as low-quality evidence (Guyatt et al., 2011). Ratings are either upgraded or downgraded based on a set of eight criteria (Ryan & Hill, 2016). Evidence is rarely upgraded as only studies with no significant threats to validity are upgraded. The eight criteria are as follows:

Downgrading

- Risk of bias: What are the limitations?
- Inconsistency: How consistent are the results?
- Indirectness: How do these results apply to the review question?
- Imprecision: How precise is the effect size?
- Publication bias: Are all relevant studies included?

Upgrading

- Large magnitude of effect: Do studies yield large and consistent estimates of the magnitude of effect?
- Dose response: Is a dose-response gradient present?
- Effect of all plausible confounding factors: Is plausible confounding working against the direction of the observed effect?

Outcome	**Quality of evidence**
Correlations between music instruction and SAA in children (category 1)	
Positive correlations	⊗○○○
Correlations with associated limitations	⊗○○○
Influence of external factors	⊗○○○
Causes suggested for the identified correlation between music instruction and enhanced SAA (category 2)	
Neurological bases of attention	⊗⊗○○
Development of general auditory abilities	⊗○○○
Particular musical characteristic	⊗⊗⊗○
Auditory distractors	⊗○○○
External rewards/reinforcement	⊗⊗⊗○
Degree of participant involvement	⊗⊗○○
Musical genre/style	⊗○○○
Other	⊗⊗○○

Note: ⊗○○○= very low; ⊗⊗○○= low; ⊗⊗⊗○= moderate; ⊗⊗⊗⊗= high

Figure 7: GRADE assessment for the quality of evidence per each outcome

Primary outcomes were identified as the two main themes employed during the data extraction process, while secondary outcomes were represented by their appropriate sub-themes (i.e. sub-categories). They are thus: correlations between musical instruction and enhancement of SAA; and causes suggested for the identified correlation. Grading was performed for each secondary outcome (i.e. subcategory) as recommended by GRADE protocol (Ryan & Hill, 2016) (see figure 7).

4.3 Findings: Overview of the ten review studies

Each study is summarised based on data extracted according to the pre-determined themes, which are aimed at answering the research questions. From these summaries it is possible to compare findings across the studies and identify common themes, which are discussed in the following chapter.

Study 1: Vargas, M. E. R. (2015). Music as a resource to develop cognition. *Procedia - Social and Behavioral Sciences, 174*, 2989-2994

Vargas's study posits, and provides evidence from literature, for positive correlations between formal music education and attention. Musical games and activities are reported to activate systems of attentional control, the most effective activity being playing a musical instrument. Reasons posited for gains in attention as a result of music education are attributed to changes in neurological function and general attentional control. This study cites evidence which suggests that music enhances neural connections (which simulate cognition) and activates attention systems. Musical activities, such as moving to music and composing songs, are especially useful in activating these systems, while playing musical instruments develops attention functions, such as SAA. Vargas concludes that music tuition contributes to overall cognitive development, which accounts for enhancements of SAA, as SAA is considered an executive (i.e. cognitive) function.

Study 2: Geist, K., & Geist, E. A. (2012). Bridging music neuroscience evidence to music therapy best practice in the early childhood classroom: Implications for using rhythm to increase attention and learning. *Music Therapy Perspectives, 30*(2), 141-144

According to Geist and Geist music tuition has a positive impact on attention, with rhythm exerting a particular influence, as identified through appropriate literature. They postulate that steady beat facilitates various brain processes and improves engagement with tasks, promoting attention and learning. They suggest that rhythmic stimuli alter neural processes and structures, thereby optimising brain functions and promoting attention and focus. Geist and Geist therefore propose that exposure to steady beat and rhythmic stimuli as part of formal music education can be used as a means to enhance student's engagement and focus outside the music class.

Study 3: Strait, D., & Kraus, N. (2011). Playing music for a smarter ear: Cognitive, perceptual and neurobiological evidence. *Music Perception: An Interdisciplinary Journal, 29*(2), 133-146

Positive correlations between music training and attention development are suggested by Strait and Kraus, who refer to enhancements in auditory processing. They propose that music shapes sensory and cognitive auditory function and causes neuronal alterations, leading to: enhanced pitch discrimination; quicker auditory brainstem responses; and advanced auditory acuity – functions which contribute to SAA (Gaser & Schlaug, 2003; Habibi et al., 2017; Hallam, 2010; Schlaug et al., 2005; Skoe & Kraus, 2012). Music's capacity to shape brain structure and function is attributed to its attentional demands, multisensory nature, rhythmic organisation and complex sound structures. Strait and Kraus suggest that some of these enhancements are transferred to alternative domains, increasing ability to perceive and neurally process sound in general, and thereby resulting in improved listening skills. This study further postulates strengthened cognitive control over auditory attention as a result of music training, facilitated by top-down modulation of auditory stimuli which improves sound processing at low-level sensory centres. However, despite these positive correlations, disagreement regarding the association between music training and cognitive abilities remain, with some negative associations also found. For example, it is posited that neural cortical and subcortical enhancements of music training are limited to the particular timbre of an individual's musical instrument and the age of commencement of music training (Strait & Kraus, 2011).

Study 4: Williams, A. D. (2015). *The development of a music program to improve the attention span of school-aged children*. (Unpublished doctoral thesis). Capella University, Minneapolis, Minnesota

This study proposes that positive correlations between music tuition and auditory attention are associated with certain limitations. In terms of purely positive correlations, Williams proposes that (based on appropriate literature) playing an instrument enhances concentration and focus over time, by influencing neural structure and function. Yet such gains are limited to the playing of particular musical instruments and exclude other musical activities. Music's impact is further limited by external factors such as individual 'taste' in music, the volume at which sound is heard, and cultural orientations. Williams suggests that the opportunity to select one's own style of music allows for more involvement in the learning process, which could lead to more substantial SAA enhancements. Additionally, Williams posits that particular genres are more conducive to enhancing SAA than others, due to the inclusion of specific musical characteristics which stimulate neural regions associated with attention. Similarly, the form, structure and style distinguishing each genre is likely to also play a role in the extent of music's effect on SAA. Optimal levels of arousal (a component of attention) are proposed as being created through music, activating attention regions of the brain. However, such arousal is only activated by specific musical characteristics, such as low-tempo and midrange pitch, according to Williams conclusions.

Study 5: Sandberg, H. F. (2009). *Get moving! The effects of music and movement on student attention and engagement*. (Doctoral thesis). Available from ProQuest Dissertations and Theses database. (UMI No. 3354460)

Sandberg proposes that formal music education, specifically music and movement activities, facilitates attention and engagement by equipping the brain for higher order skills and creating optimal internal learning conditions. Such optimal learning conditions are reported as developing from the engagement of both brain hemispheres. Music develops improved hemispheric communication, which creates more meaningful learning opportunities and activates multiple brain regions involved in SAA. Any activities involving music and movement require engagement of the whole child, thereby stimulating the body's natural motivators, improving energy levels, enhancing spatial awareness, and increasing memory capabilities. In this manner, the study proposes, music contributes to improved overall development and better SAA and learning.

Study 6: Sportsman, E. L. (2011). *Development of musicianship and executive functioning among children participating in a music program*. (Unpublished doctoral thesis). Michigan State University, East Lansing, Michigan

Sportsman examined the impact of ten different musical activities on executive functions, including SAA, finding that some activities promote SAA, while others do not. Active music listening and solo performance, for example, improve attention while passive music listening, and individual call-and-response do not. Moreover, these improvements in attention were found to not transfer to settings outside the music classroom. Sportsman attributes such a lack of transfer to factors in the external environment which exert an effect on neural development, and therefore by extension, on attention skills. The study proposes that the provision of external rewards/reinforcement is responsible for the enhancement of SAA, as focused attention is required to be successful in all ten activities. For example, unison call and response requires focus to ensure synchrony with others, which is reinforcing. Similar effects are produced by singing, chanting or playing in unison or in parts; warm-up exercises; solo performance; and active music listening. Sportsman concludes that while music does aid in enhancing SAA, this is limited by the type of musical activity and the influence of external variables.

Study 7: Wolfe, D. E., & Noguchi, L. K. (2009). The use of music with young children to improve sustained attention during a vigilance task in the presence of auditory distractions. *Journal of Music Therapy, 46*(1), 69-82

According to Wolfe and Noguchi, singing songs aids in increasing focus, engagement and attention span in children. However, they suggest that distracting, external sounds disrupt attention and therefore determine the degree to which music improves SAA. The most success in promoting SAA, they believe, occurs when extraneous sounds are masked – yet in most ‘real-life’ situations this is almost always impossible. Wolfe and Noguchi therefore suggest the use of specific musical features to promote improved SAA, for example, they posit that the music should be interesting and engaging; contain repetitions; have a moderately fast tempo; and have clearly articulated lyrics. Additionally, SAA is only encouraged if the child is developmentally prepared, actively engaged with the music, and has previously developed listening behaviours. Thus, Wolfe and Noguchi postulate that while music does help improve SAA, it is dependent on a number of factors.

Study 8: Hyde, K. L., Lerch, J., Norton, A., Forgeard, M., Winner, E., Evans, A. C., & Schlaug, G. (2009). Musical training shapes structural brain development. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience, 29*(10), 3019-3025

Hyde et al. suggest that musical training does stimulate cognitive development and a variety of extra-musical skills, which may not necessarily include SAA. Learning to play a musical instrument, for instance, results in structural brain plasticity and positive brain deformations in the auditory regions, while music tuition develops enhanced auditory rhythmic and melodic discrimination skills. Hyde et al. found that neurological structures are influenced by music, such as changes evoked in the right primary auditory regions – changes which are correlated with improved listening skills and behavioural improvement on auditory tasks. Neural functions were also found to be affected by music, specifically those important to musical performance and auditory processing. Of especial significance are neural regions involved in playing musical instruments, which are highly susceptible to plasticity, and are therefore easily altered by music training. Hyde et al. thus provide evidence for positive correlations between music training and SAA yet is highly sceptical of this correlation due to the significant impact of many extraneous variables which detract from the influence music has on SAA.

Study 9: Khalil, A. K., Minces, V., McLoughlin, G., & Chiba, A. (2013). Group rhythmic synchrony and attention in children. *Frontiers in Psychology, 4*, 564

Although a clear correlation between attention behaviour and rhythmic synchrony was found, Khalil et al. highlight the significant difference between correlation and causality, stating that while correlations were indeed identified, this does not indicate causality. Moreover, this study suggested that one specific musical characteristic exerts a substantial effect on SAA, namely, rhythm. An additional, highly susceptible factor is synchronicity; a factor which they combined with rhythmic ability to test their hypothesis that musical rhythm enhances attention. The ability to effectively synchronise with others is closely related to the ability to control attention - better synchronisers maintain attention better and for longer periods of time. Moreover, the generation of rhythmic expectation regulates the link between synchronicity and attention. Khalil et al. therefore, conclude that musical activities focusing on rhythm and the generation of synchrony are best suited to promoting SAA in children, and exert a positive impact on SAA.

Study 10: Hallberg, K. A., Martin, W. E., & McClure, J. R. (2017). The impact of music instruction on attention in kindergarten children. *Psychomusicology: Music, Mind, and Brain, 27*(2), 113

This study found evidence of a positive correlation between musical training and improved SAA, yet Hallberg, Martin and McClure suggest it is limited to individual instrumental training. Learning to play an instrument develops attention behaviours, such as extended concentration, however, the authors propose that the degree of development of attention behaviour is determined by the age of commencement of music training. Hallberg, Martin and McClure therefore conclude that learning to play a musical instrument does enhance SAA, but also mention certain limitations which might influence the degree of enhancement music has on SAA.

4.3 Conclusion

In sum, the findings provide evidence of a positive correlation between music instruction and SAA in children, albeit it appears to be limited by particular environments and variables. However, in order to fully comprehend the data and its significance, comparisons and interpretations should be drawn. In the following discussion the data will be further explored in relation to relevant literature to affirm (or repute) review findings and to consider the findings within a broader context.

Chapter 5
Discussion

5.1 Introduction

The discussion considers the findings in context of appropriate literature in order to affirm (or dispute) these findings and to place it within a broader framework. Furthermore, comparisons between the systematic review studies are drawn to determine primary correlations between SAA and music instruction, as well as the predominant causes suggested for the identified correlations. The discussion further considers how study characteristics, such as participant demographics and GRADE ratings, might influence results. Limitations across and within the ten studies are identified and their possible influence is also considered.

Note: All studies included in the systematic review are indicated by an asterisk (*)

5.2 Correlations between music instruction and sustained auditory attention in five to ten-year-old children

In answer to the primary research question, ‘does music instruction lead to enhanced sustained auditory attention in typically developing five- to ten-year-old children’, all ten studies cited a positive correlation between music and SAA, however eight of the ten studies (excluding Sandberg*, 2009 and Vargas*, 2015) suggested that these correlations only occur due to the presence of particular variables. Academic disagreements regarding the correlation between music and SAA is thus present, as some researchers posit a positive impact of music on SAA while others only find evidence of limited impact. Thus, although there is evidence for positive correlations between music instruction and SAA, there remains some dissension. Yet none of the studies indicated that music exerts no impact on SAA – cases in which limited musical influence was identified occurred in combination with more positive influences. It is therefore concluded that music instruction does enhance SAA in children, but only to a limited degree, and in particular settings or in association with specific variables (e.g. type of musical activity).

External, environmental factors, such as distracting, extraneous sounds and cultural orientations, might influence the degree to which music enhances SAA in children. Such factors may have thus interfered with each of the ten studies’ findings. Vargas* (2015), for example, emphasised the role of cultural and social contexts in children’s cognitive development, a claim also supported by Williams* (2015). Strait and Kraus* (2011) and

Sportsman* (2011), meanwhile, both recognised the impact of complex sound environments on neural development and, by extension, SAA. The complex sound environments to which they referred involved multiple sound streams, which require certain auditory skills (e.g. hearing speech-in-noise) for improvements in SAA to be made. However, children remain developmentally unprepared for many of these more mature auditory skills (Sussman, Wong, et al., 2007).

The volume at which music is heard further affects the degree of impact music exerts on SAA, as inferred by both Williams and Wolfe and Noguchi* (2009). Their findings support suggestions made by Dean et al. (2011) who found that sound intensity influences attention responses. Moreover, the louder a sound is, the longer it is perceived to be (Xuan et al., 2007), perhaps influencing correlations found between music and SAA. It is plausible that louder sounds, perceived as longer, may therefore disrupt ability to sustain attention for long periods of time. Neither study (i.e. Williams, 2015; Wolfe & Noguchi, 2009) considered the possible influence of loudness on SAA levels, which may have impacted their findings. Dean et al. additionally noted an effect of sound intensity on arousal, a significant aspect of attention (Posner & Petersen, 1990). If applied to the review studies (i.e. Williams, 2015; Wolfe & Noguchi, 2009), it may be that the volume at which music was presented to participants impacted their state of arousal, which in turn might have increased or decreased SAA levels measured. Future research should therefore try to account for the influence of loudness levels of music, by ensuring consistency in the volume at which they present music to participants. Music educators should also consider such variables when presenting musical pieces to children, in active listening activities or otherwise. Nonetheless, even by ensuring music is played at ‘medium’ loudness (i.e. intensity), individuals perceive loudness differently (Asutay & Västfjäll, 2012; Belin et al., 1998; Lipscomb & Hodges, 1999; Röhl & Uppenkamp, 2012), and this external variable can therefore only be managed to a certain extent.

One of the prevailing variables across the ten studies affecting music’s impact on SAA is the issue of formal class music (i.e. music education) versus learning to play an instrument (i.e. music training). For example, Vargas* (2015) proposed that music training does enhance SAA, however, suggests that this predominantly occurs as a result of playing an instrument and that SAA enhancements are less pronounced as a result of music education. Vargas’s sentiments are supported by Williams* (2015), Hyde et al.* (2009), and Hallberg et al.* (2017). Yet Sandberg* (2009) suggested the contradictory idea that class music does facilitate improved SAA. However, Sandberg’s study only measured the effects of class music on SAA without testing effects of music training. Perhaps if Sandberg had measured effects of music training on SAA, findings would corroborate that of the others (e.g. Hallberg et al., 2017; Hyde et al., 2009; Vargas, 2015; Williams, 2015), in that music training would result in greater SAA effects than music education alone. Additionally, were Sandberg to include music training in their testing, perhaps they would have found more evidence of SAA transferring to skills outside the music classroom. Literature provides evidence to support the idea that music training exerts a greater impact on SAA than formal music education (S. Brown et al., 2004; Fujioka et al., 2006; Schlaug et al., 2005). Connected to this dilemma of music education versus music training, are characteristics of musical activities – group or individual; passive or active; listening or singing/playing. These characteristics constitute another variable which may influence the effect music has on SAA.

Sportsman* (2011), for example, proposed that the activities affecting SAA the greatest included: unison call and response; playing, singing, or chanting in unison or in parts; active music listening; warm-ups; solo performance; and individual instrument lessons (see list of definitions) – all of which require SAA in order to be successful in the task and to achieve synchrony. Other musical activities investigated by Sportsman, such as passive music listening and individual call and response, were found to have little impact on SAA as they do not require sustained attention to be successful. It is thus recommended that future research ensures consistency regarding whether music training or formal music education is used to measure degree of enhancement of SAA. Consistency will allow for more comparable findings across studies, in addition to maintaining reliability of results (Carcary, 2009). The same notion of consistency applies to specific musical activities employed. Moreover, maintaining consistency will enable researchers to determine the form of music instruction (i.e. music training or music education) and type of music activity which lead to the greatest enhancements of SAA.

Findings obtained within this outcome all received a GRADE rating of very low, despite all having a satisfactory HTA quality rating. Although indicating a low level of confidence in these findings, it is possible that such ratings were obtained as none of the studies addressed the research topic directly, as from the HTA ratings they were of a moderate to high quality level. Although not refuting these findings, it is problematic when considering such an indication of weight to this outcome. While the GRADE ratings should not repudiate the findings, they should be taken into consideration in interpreting these results. The level of GRADE ratings is further indicative of the need for more measurable and quantifiable research within the field of interest.

5.3 Proposed causes for correlations between music instruction and sustained auditory attention

A variety of potential causes were cited by the ten studies to account for the effect that music has on SAA. Each study cited neurological reasons for improvements in auditory abilities and SAA as a result of music instruction. The review studies' findings are corroborated by other studies which also cite neurological reasons for SAA enhancements by music instruction (e.g. Fujioka et al., 2006; Habibi et al., 2017; Schlaug et al., 2005). Brain plasticity is identified as one of the key contributors to SAA enhancement as music exerts a particular influence on plasticity of auditory regions (Chen, Penhune, & Zatorre, 2008; Fujioka et al., 2006; Habibi et al., 2016; Meyer e al., 2011; Pantev & Herholz, 2011; Pantev et al., 1998; Putkinen et al., 2014; Strait, Slater, & Kraus, 2014; Trainor, Shahin, & Roberts, 2003). Four of the review studies (Geist & Geist, 2012; Hyde et al., 2009; Strait & Kraus, 2011; Williams, 2015) supported the findings of Pantev and Herholz (2011) who suggested that changes in brain structure and function occur as a result of music training.

Music education tasks, such as composing songs and critically listening to music, stimulates and changes neural function, including in the auditory region, and thus contributing to improvements in attention (Vargas*, 2015). Williams* (2015) posited that music generates optimal levels of arousal which stimulate neural regions responsible for SAA, and thereby improve it. These findings corroborate the idea of the extensive role arousal plays in sustaining attention (Langner & Eickhoff, 2013). Strait and Kraus* (2011), meanwhile, suggested the development of enhanced cognitive control over SAA as a result of improved top-down modulation of auditory stimuli. The ten systematic review studies therefore suggest some degree of enhanced neural functioning as contributing to improved SAA, and thereby affirm findings of earlier studies (e.g. Gaab et al., 2005; Pantev et al., 2001; Schlaug et al., 1995).

The notion of external reinforcement and/or rewards was identified as a potential cause of enhanced SAA in children. Sportsman* (2011) found that children were more successful in musical tasks when they maintained attention for prolonged periods of time, in the presence of external reinforcement (such as feedback or achieving musical harmony) for being successful. In this case, although music leads to enhanced SAA, it is based on the provision of external rewards/reinforcement, rather than on an intrinsic motivation to sustain attention. Therefore, despite resulting in a positive correlation, the cause for this correlation implies a limitation. This limitation presented by the promise of external rewards and/or reinforcement following a period of sustained attention, is substantiated by several other studies measuring the effect of external motivation (as provided by rewards) on attentional control and performance (Jimura, Locke, & Braver, 2010; Kistner, 1985; Pessoa, 2009; Worland, North-Jones, & Stern, 1973). Jimura, Locke and Braver (2010) claim that rewards can facilitate processes required for goal achievement by engaging control mechanisms (such as attentional control) of the brain, while Kistner (1985) suggests that rewards lead to faster, albeit less accurate, performance on tasks. Taken together, the findings of all these studies points to an increase in SAA in the presence of external motivation as provided by rewards.

Achieving synchrony is posited as another cause for the correlation between music and SAA. Sportsman* (2011) suggests that achieving synchrony with others in a musical context, such as singing or playing in harmony or in unison, is intrinsically rewarding. In order to obtain this synchrony, SAA is required to ensure one is attending to what peers are singing or playing (Sportsman, 2011). Not attending to what peers are doing will disrupt synchrony and may in some circumstances be noticeable that it can be embarrassing for the child. The notion of embarrassment suggests a further idea of social cohesion as promoting SAA. Sportsman’s suggestion of synchrony is supported by Khalil et al.* (2013) who found that better synchronisers demonstrate better SAA, as attending to what the instructor and peers are doing is necessary to achieve synchrony.

It is postulated that particular musical characteristics enhance SAA more than others, constituting a potential underlying source of SAA enhancements. Three of the review studies (i.e. Geist & Geist*, 2012; Khalil et al.*, 2013; Sandberg*, 2009). identified rhythm as having a highly influential effect on SAA. Geist and Geist (2012) suggested that steady beat – intrinsically linked to rhythm - impacts neural processes to such an extent that music therapists frequently use rhythm-based techniques to promote client’s SAA. Musical rhythm is described as “the way [musical] events are ordered in time” (Honing et al., 2014, p. 305) while musical beat describes the perceived underlying regularity in time, which is a “regularly recurring salient movement in time” (Honing et al., 2014, p. 305). In context of these definitions, the substantial impact of rhythm on SAA is significant when considered within the framework of Buhusi and Meck’s (2009) findings, in which they postulated shared neural circuits between time perception and attention. Grondin and Rammsayer (2003) suggested similar findings, stating that attention mechanisms are important for temporal information processing. Both Buhusi and Meck, and Grondin and Rammsayer, suggest links between attention and time perception, interesting in context of SAA which involves sustaining attention for extended periods of time. The highly influential role of rhythm and beat on SAA thus appears to be related to time perception and processing.

Regarding music characteristics, Williams* (2015), based on research by Levitin (2007), suggested that low tempo and mid-range pitch exert a particular influence on SAA. Low tempo is posited to create optimal levels of arousal to enhance attention, while mid-range pitch is successfully stored in short-term memory for further processing (Williams, 2015). Moreover, the effect of pitch on SAA should be considered within developmental characteristics of the auditory development of children. Based on their potential immaturity in resolving and discriminating low frequencies (Hartley et al., 2000) it is inferred that for any improvements in SAA to be made, tones should remain in the upper frequencies, in order that children may distinguish between, and isolate, individual tones.

It was posited that specific musical genres, such as blues, jazz, and country/folk music, which incorporate these characteristics of low tempo and mid-range pitch, are more effective in enhancing SAA than other musical genres (Williams*, 2015). None of the remaining nine studies considered the possible effect of musical style on attention. It thus raises the question as to how specific musical genres might impact musical correlations with SAA and the need to consider that perhaps only a limited number of musical styles enhance SAA, specifically relating to elements of pitch, duration, and loudness.

William's* (2015) suggestion that mid-range pitch is highly effective in enhancing SAA is supported by studies examining pitch discrimination abilities of children, which imply that children's ability to discriminate between and identify low frequencies remains immature, while discrimination of high frequencies is mature quite early in life (Fischer & Hartnegg, 2004; Hill et al., 2005). However, 'mid-range' pitch denotes a broad range of frequencies which could include some low frequencies. Perhaps then, older children will respond better to music of mid-range pitch than younger children, who may have difficulty resolving frequencies within the range of middle pitches. Williams' finding that moderately fast tempo yields substantial SAA enhancements relates to Hemmes et al.'s (2004) finding that perceived duration diminishes under tasks involving attentional resources, due to resource sharing effects. Thus, the use of moderately fast tempo may ensure that music is not perceived to be overly long in duration, and attention in turn, might be maintained for extended periods as attentional resources remain focussed on a couple of tasks only.

Wolfe and Noguchi* (2009) suggested that in order for music to have an effect on children's SAA it should possess the following qualities: be interesting and engaging to the child; contain repetitions; have a moderately fast tempo (supporting suggestions made by Williams*, 2015); and have clearly articulated and understandable lyrics (if included). The inclusion of lyrics sparks some disagreement as Wolfe and Noguchi claim that given the afore-mentioned criteria are met, music can contain lyrics, while Williams (2015) proposes the use of purely instrumental music as he posits that lyrics disrupt SAA. Both claims have been validated (Besson, Chobert, & Marie, 2011; S. Brown et al., 2004; Callan et al., 2006; Fedorenko et al., 2009; Kunert et al., 2015; Schön et al., 2010; Zioga et al., 2016), making it challenging to assess which type of music best improves SAA.

Indeed, it is postulated that singing should be emphasised as a musical activity as it stimulates multiple brain networks (Schön et al., 2010), thereby potentially engaging the child more and facilitating SAA. Moreover, it is hypothesised that harmonies should remain consonant (rather than dissonant) (Callan et al., 2006), while lyrics should remain simple and understandable as unexpected words may cause difficulties in both music and linguistic processing (Wolfe & Noguchi, 2009). Processing difficulties increase the difficulty of the task and could potentially disrupt SAA. Therefore, if lyrics are included, they should comply with suggested criteria in order to exert any effect on SAA. Conversely, S. Brown et al. (2004) suggest that if musical tasks involve language (i.e. lyrics), neural networks will overlap, limiting attentional resources – corroborating claims of Williams (2015). These opposing views therefore require a solution, regarding which type of music (i.e. purely instrumental or songs with lyrics) best enhance SAA. Perhaps a tentative answer can be found in the work of Kunert et al. (2015) who state that although sharing neural resources, speech and music remain individual domains and maintain individual processing mechanisms – resource sharing is thus not 'overloaded' and language and music can therefore 'co-exist'.

Several factors are suggested to account for limitations associated with correlations between music instruction and SAA, which demand the provision of particular variables for enhancements in SAA to occur. For example, Sportsman* (2011) found that a number of musical activities do not enhance SAA in any capacity, such as passive music listening which does little to sustain attention and affords frequent distraction; and individual call and response, during which attention is only required when it is one's turn to respond. Furthermore, Strait and Kraus* (2011) proposed that any cortical or subcortical enhancements of music instruction are limited to the particular timbre of one's instrument of expertise. Thus, if one's instrument is the piano for example, fine-tuned auditory acuity to the sound of the piano will develop yet when exposed to the sound of a different instrument this acuity will diminish (Strait & Kraus, 2011). This has implications for SAA enhancements as it suggests these gains will only occur if an individual continues training with a specific instrument. It further suggests that group or ensemble settings could impact the development of SAA skills as such settings involve multiple timbres sounding simultaneously.

External, environmental variables can exert influential effects on SAA, either improving or detracting from it. Individual differences in attention abilities result from genetic makeup of individual children, which may influence the impact music instruction has on SAA. Khalil et al.* (2013) recognised the possibility of the influence of genetic makeup, suggesting that those with poorer attention skills may have been less engaged during testing and thus negatively influenced their findings. If this is indeed the case it presents challenges to the measuring of SAA enhancements, as genetic factors are static and cannot be altered. Future research then would need to conduct a series of pre-tests to determine a baseline of individual's attention abilities in order that SAA enhancements could be successfully measured.

Similar to the variable of genetic factors is that of the age of commencement of music instruction. Occurring on a continuum, this variable could support either a purely positive correlation between SAA and music, or one with associated limitations. Two of the ten studies (i.e. Hallberg et al.*, 2017; Strait & Kraus*, 2011) advocated age of commencement of music training as affecting SAA, proposing that this variable predicts subcortical advancements made in responding to sound stimuli, and is thus also critical to any improvements made in maintaining attention. Several other studies (e.g. Gianvecchio & French, 2002; Ridderinkhof & Van der Stelt, 2000; Rueda et al., 2004; Van der Molen, 2000) corroborate Hallberg et al.'s (2017) and Strait and Kraus' (2011) proposals of the substantial effect of age of commencement of music instruction. Moreover, the earlier music training begins, the longer the duration of musical training, leading to more auditory gains, and thus implying that by starting musical training earlier in life neurological structure and function may be more heavily influenced.

The presence of extraneous, external sounds may also influence degree of SAA enhancements. Wolfe & Noguchi* (2009) employed the use of headphones when measuring levels of attention among children to mask potentially distracting sounds. In a 'real-life' context, however, this is almost impossible to ensure. Therefore, the effect of distracting sounds on SAA remains to be determined. If taken in context of the related concept of 'on and off sounds' (Davis & Silverman, 1978), however, some light may be shed on this limiting variable. It is possible that extraneous sounds will interfere with the maintenance of sound over time. If a child is listening to a teacher speak in a monotonous tone, for example, this sound might diminish into the background after a time. Conversely, it is probable 'on and off' sounds could promote SAA, as distracting sounds might disappear into the background, thereby improving maintenance of attention. Future research should take this effect into account when measuring levels of SAA.

Degree of participant involvement – referring to the extent to which individuals actively engage in a musical task (Sportsman*, 2011) – exerts a slight influence on SAA, with the basic notion that the more actively engaged one is the more attention is enhanced (Gordon, 2007; Sandberg*, 2009; Strait & Kraus*, 2011; Wolfe & Noguchi*, 2009). Active engagement with the task can also be referred to as the use of effort. Such an idea, then, supports W. James (1890) much earlier claims of effort being a driving force of sustained attention. Strait and Kraus (2011), for example, found that SAA enhancements developing from music training are a result of focused and consistent active interaction (or effort) with sound stimuli. Furthermore, interaction increases if children are provided the opportunity to select the style of music or the activity, as postulated by Williams* (2015). It is therefore suggested that music teachers actively involve students at all stages during each musical activity yet maintain a degree of control so as to allow for the provision of other variables which best promote SAA.

The causes identified across the review studies accounting for the correlations between SAA and music instruction are numerous. Yet it is possible to manipulate some of these influential variables, to a degree, to create environments most conducive to enhancing SAA. Music educators should therefore consider such factors in planning and executing their lessons, should they wish to utilise music to improve children's SAA.

The GRADE ratings for this outcome varied from very low to moderate. Considering that a rating of 'high' is difficult to obtain, such a distribution of ratings is promising. It is plausible that the varied ratings account for the weight attributed to the different causes identified as leading to correlations between music instruction and SAA. For example, the particular musical aspect or activity as a cause of the correlation between music and SAA had a higher GRADE rating than that of the particular musical genre used. It could be speculated that some of the causes identified hold more weight than others, thereby indicating which factors are more likely to lead to SAA improvements.

5.4 Limitations of review studies

Although each of the ten studies support the hypothesis that music instruction enhances sustained auditory attention in children (some with associated limiting variables), several limitations within the studies themselves should be considered. These limiting factors impacted results of each study and therefore impact overall review findings. Participant demographics account for the majority of these limitations, while others include eligibility criteria, and musical aspects of experiments conducted.

All the quantitative studies (n=5) and the mixed method study (n=1) conducted testing at public elementary schools in the USA, each which are likely to be at a low poverty level (American Psychological Association, 2019). There are thus similarities in SES between the participants, allowing for comparable findings across the studies. SES may impact participant response to musical training (Noble, McCandliss, & Farah, 2007) and may therefore also have influenced study findings. Furthermore, the predominantly low SES of participants across the studies is applicable to South Africa in which many citizens are from lower income backgrounds (Statistics South Africa, 2015). Were these same tests to be administered to children with a higher SES, results may present differently, as SES is associated with children’s neurocognitive abilities (Noble et al., 2007) including their executive functioning skills, with SES accounting for significant variation in working memory and cognitive control composites (Noble et al., 2007). Moreover, Noble et al. (2007) also found that school quality influences executive functioning, hence the consideration of the impact of testing at public schools. As with SES, were similar testing to occur with children at private schools – or even public schools in a different country in which educational quality may differ – findings may be quite dissimilar. In addition to the SES and schooling of participants, gender distribution may also affect results, as males demonstrate more left hemispheric processing of music while females show more bilateral processing (Koelsch et al., 2003). Only three of the ten studies (Hallberg et al., 2017; Khalil et al., 2013; Wolfe & Noguchi, 2009) reported total distribution of male and female participants, while only the study by Hyde et al.* (2009) recognised gender as a possible covariate. Gender may thus influence the particular effect music has on SAA and should be included as an independent variable in future research.

As indicated in the findings of the present study, the form of music instruction influences the degree to which musical training affects SAA in children. Sportsman* (2011), for example, found that individual and group music classes differ in the extent to which they promote attention. Interventions utilised across the quantitative review studies varied as individual or group activities, and it is thus probable that the type of activity used influenced the extent of SAA enhancements realised, if any. Of the quantitative studies, three included group music lessons (i.e. Hallberg et al., 2017; Khalil et al., 2013; Sandberg, 2009; Sportsman, 2011) while only one employed individual instrument lessons (i.e. Sportsman, 2011). The mixed method study (i.e. Hyde et al., 2009) employed a combination of both, with the intervention group receiving individual music lessons and the control group class music lessons. It is possible that review results were influenced by such a difference in setting across the various studies, as the form of musical activity affected individual study results.

Further related to the particular intervention employed is the duration of the intervention and the musical style utilised. As noted by appropriate literature, the duration of musical training impacts the degree of neural and cognitive changes made (Schlaug, 2015). Findings obtained by Hallberg et al.* (2017) over a period of five weeks will thus differ to that obtained over a period of fifteen months by Hyde et al.* (2009). Participants in the latter study were afforded increased opportunity to demonstrate typical enhancements made as a result of music instruction, while participants from the former were denied sufficient time to demonstrate such enhancements.

As to the type of music utilised, this may have an impact on the degree of improvements in SAA, as particular musical styles and characteristics (such as tempo and rhythm) may influence auditory abilities more than others (Clayton et al., 2015; Helfrich et al., 2018; Strait et al., 2011; Williams*, 2015). One study employed the Suzuki violin method (Hallberg et al.*, 2017) which uses set musical pieces, based on Western art music, to teach the violin (Kendall, 1973). Meanwhile, Khalil et al.*, 2013 employed the vastly different Gamelan-based music (Harnish, 2013). Hyde et al. focused on group music lessons in which participants were required to sing and play with drums and bells, therefore demonstrating some similarities to Gamelan music. Wolfe and Noguchi* (2009) utilised children's songs, while Sandberg* (2009) used a combination of singing, chanting and rhyming. Each study used different types of musical interventions, which may stimulate specific neural regions (Schellenberg & Hallam, 2005). It is possible that some of these interventions influenced SAA more than others, determining conclusions made regarding how music instruction affects SAA. Despite the contrasting musical activities, all agreed that rhythm specifically exerts a substantial effect on SAA. It is thus implied that musical styles with a greater emphasis on rhythm, such as Gamelan music, may have a greater impact on SAA.

Limitations in the qualitative review studies (n=4) are related to research quality and validity (as determined by the HTA quality checklist and CASP checklist respectively) and the context of each study. None of the qualitative studies discussed SAA directly, but rather interrelated aspects that directly and/or indirectly impact SAA. For example, Geist and Geist* (2012) focused on clinical music therapy practices and its implications thereof in the early childhood classroom. Vargas* (2015) investigated the use of music as a means to develop cognition, while Strait and Kraus* (2011) concentrated on the contribution of music to working memory and attention. Williams* (2015) assumed a different approach, conceiving and proposing a program to improve brain activity for focused attention. This study is of particular concern as the proposed program has not yet (to the reviewer's knowledge) been piloted and therefore remains theoretical.

Meanwhile, the mixed methods study (Sandberg*, 2009) investigated concentration and engagement (elements of SAA) in learning. Each study thus assumed a different area of focus, with none discussing SAA directly although their content constituted elements of SAA. There is therefore much opportunity for future research to investigate the role of music in improving SAA specifically. The fact that none of the qualitative studies investigated SAA directly begs the question as to their inclusion in the review. Not one study exactly met the initial inclusion criteria, which was thus broadened to include more studies in efforts to make the review more valid. However, these four qualitative studies do contribute to answering the research questions as although not investigating SAA specifically, they all examined elements of SAA. The quantitative studies also contribute much to the review findings, despite their limitations. While of concern to the present review, limitations of the ten individual studies do not dispute the findings of the overall review yet raise concerns that should be addressed in future research.

5.5 Conclusion

The discussion compared findings of the ten studies included in the systematic review and considered them in context of relevant literature, in order to place review findings within a broader scope. While the findings are predominantly corroborated by literature, some offer new suggestions, while still others are negated. This has caused many questions to arise regarding the topic of correlations between music instruction and sustained auditory attention, providing multiple opportunities for future research. While it is clear that the ten studies all identify a positive correlation between musical instruction and SAA, further corroborated by other literature, this correlation is rather complex. Indeed, the influence of particular variables is the predominant determining factor of the impact music will have on SAA in children. Yet despite these promising findings, participant demographics and other limiting variables must be taken into account and their possible effects considered. The following chapter provides a concise overview of the present study and provides final answers to the research questions.

Chapter 6
Summary and Conclusion

6.1 Introduction

A systematic literature review of recent research evidence was conducted to investigate whether music instruction leads to enhanced sustained auditory attention in five to ten-year-old children. The literature review in chapter two provided context and background to the study, including a thorough review of relevant research findings related to the impact of music on auditory abilities and attention. An extensive research methodology was conducted based on PRISMA-P guidelines, including: a search strategy of appropriate electronic databases; a list of eligibility criteria to define studies for inclusion; a study selection process; data collection processes; and risk of bias and quality assessments. Thematic text analysis was employed to extract data according to two primary themes (i.e. categories) and appropriate sub-categories, collated and synthesised within two respective thematic matrices, from which summaries of each study were created. Findings were established through comparisons of data from the ten studies, and further discussed in relation to appropriate literature. It was concluded that while music instruction does enhance SAA in children, this is limited by the presence of specific variables.

6.2 Answering the research questions

The secondary research question will be dealt with first, where after the primary research question will be discussed.

6.2.1 Secondary research question: What causes are suggested in recent research evidence for correlations between music instruction and enhanced sustained auditory attention?

Each study suggested possible causes for the identified correlation between enhanced SAA and music instruction, primarily referring to neurobiological factors. Biologically, music instruction enhances cortical evoked potentials; creates faster and more robust auditory brainstem responses; and prepares auditory cognitive networks for cross-domain auditory processing. Structural differences in the auditory regions are also found and are associated with better listening skills and behaviour on auditory-musical tasks. It is proposed that neural plasticity is induced by playing musical instruments, which enhances neural connections and activates attention systems. As music is an auditory stimulus it inherently exerts a degree of control over attention, such that playing an instrument aids in both controlling and enhancing attention functions, as a result of top-down control over auditory processing. The musical characteristic of rhythm exerts a significant effect on children's auditory attention. Steady beat, for example, has a substantial influence on neural processes, resulting in better engagement and focus. Additional musical characteristics that induce effective changes in attention include low-tempo and mid-range pitch.

Some musical activities require SAA to successfully complete or participate in the task and to garner external recognition or reinforcement. 'Fitting in' harmoniously with others is naturally reinforcing, a trait of most musical activities, and further leads to the achievement of synchrony with others, which is also highly related to auditory feedback processes. However, recognition and reinforcement may become the motivating factor to sustain attention, rather than improved attention skills. Moreover, more active engagement with the musical task increases the probability of SAA improving. Ways to promote active engagement include allowing children to be involved in the musical process, such as by selecting musical pieces. Yet in this case, the choice of musical genre from which to choose should be limited, as musical style also has an effect on SAA - some styles possess musical characteristics which are more conducive to enhancing SAA than others.

Inherent factors, such as genetic make-up, may also influence SAA enhancement, as some children may possess (genetically determined) attention difficulties while others do not. Furthermore, some individuals demonstrate greater responses to musical stimuli than others. Likewise, age of commencement of music instruction determines the duration of exposure to music and predicts subcortical responses to sound stimuli. It is a common conception that the earlier one begins music instruction, the greater the benefits will be. The inclusion of lyrics in singing songs may either detract from or enhance SAA, as literature presents opposing views regarding this factor. It appears, however, that the majority of literature points towards singing songs with lyrics as contributing to SAA enhancement. In addition, extraneous, distracting sounds may limit the degree of SAA enhancements made as a result of music instruction, however more research into this variable needs to be conducted before definitive conclusions can be made.

Possible causes for the correlation between improved SAA and musical training are complex and cannot be precisely defined. Multiple factors interact to contribute to attention skills, while simultaneously detracting from them. There is a deep-rooted neurological cause for SAA improvements, due to the plasticity induced by music instruction, yet other external and internal (e.g. genetics) factors also play into the mix. While it remains difficult to pinpoint a series of definitive causes, it is possible to identify the most prevalent causes for enhanced SAA by identifying prevailing factors across all ten studies.

6.2.2 Primary research question: To what extent does music instruction lead to enhanced sustained auditory attention in typically developing five to ten-year-old children, as suggested by recent research evidence?

Overall, a predominantly positive correlation between music instruction and the enhancement of SAA in children was identified across all ten studies yet were all limited by various factors. Music contributes to the child's overall development by moulding sensory and cognitive functions in the brain. Musical games and activities, such as active music listening and solo performance, are often best suited to stimulating such plasticity. Indeed, children with musical training demonstrate strengthened auditory acuity, with heightened pitch discrimination, both within and outside the music domain, and exhibit optimal neural states for developing attention.

Specific musical characteristics, such as rhythm, are especially influential. However, playing musical instruments constitutes the most effective activity by which to advance SAA, creating structural brain plasticity in the auditory region, and developing auditory rhythmic and melodic discrimination capacities. Yet some musical activities (e.g. passive music listening) appear not to enhance SAA. The external environment also exerts a prevailing influence on the developing child, including cognitive and executive functioning. Complex sound environments might cause difficulties in focusing on a single auditory stream such that what is heard depends on how well one is listening. Differing musical forms vary in the extent to which they enhance SAA, for example, music performance may affect SAA to a greater extent than group music classes, as practicing an instrument develops elements of attentional control. Other variables, such as demographic factors, all influence the degree of SAA enhancements made. It is therefore concluded that although music instruction does enhance SAA, several variables may limit this process.

6.3 The value of the systematic review

The systematic review highlights knowledge gaps and thus reveals areas of research requiring more investigation. Furthermore, it provides a greater understanding of sustained auditory attention and its development in childhood. The findings of the review revealed positive correlations between music instruction and SAA in childhood, and possible causes leading to these improvements. Although the precise impact of music on SAA remains unclear, due to associated limiting variables identified in several of the studies, music educators may be able to utilise these results to contribute to SAA development of children. The particular variables identified that do lead to enhancements in SAA could be incorporated into music classrooms as a means by which to promote SAA and its various elements. Furthermore, the current study is applicable to connected disciplines, such as music psychology and cognitive psychology, and highlights how music instruction impacts the overall neurological structure and functioning of the child's brain. It is hoped that research such as this systematic review may provide evidence for advocating the importance of including (and emphasising) music as part of the school curriculum.

6.4 Limitations of the study

Challenges emerged with the search process in which many of the initial search results were eliminated as they did not meet eligibility criteria. However, this resulted in the identification of too few studies, such that inclusion criteria were broadened, to allow for the inclusion of more studies in an effort to make the review more viable. Furthermore, the search process was limited to five electronic databases which, if expanded, may have yielded more results, despite these databases being deemed as most applicable to the field of interest. The majority of the ten studies included for review indirectly addressed the primary research question, therefore findings were extracted from the text based on interrelated elements to sustained auditory attention, or on enhancements of attention in general. In assessing the risk of bias and quality of each study, no limit was placed on which ratings to include or exclude, as it would have reduced the number of studies for inclusion in the review. Fewer studies render the review less valid, thus the inclusion of all studies despite their ratings. The form of music instruction varied widely across the studies, differing between musical training and formal music education. Initially, the study focused on only musical training, yet once again, these criteria limited the number of included studies severely, such that eligibility criteria were expanded to include both forms of music instruction.

6.5 Recommendations for future research

The review provides a foundation on which a quantitative study could be based, specifically listing variables to take into consideration in measuring SAA improvements. A quantitative study could lead to more accurate, statistical findings into the effect music has on SAA in children. While the present review has highlighted a knowledge gap in terms of the indirect impact of music instruction on SAA in children, future research should aim to address these 'gaps' by testing the impact of music instruction on SAA directly, rather than testing for improvements in general auditory attention abilities. Furthermore, were such examinations to occur among children from countries other than the USA or from high socioeconomic backgrounds, results may differ significantly to that identified in the review. Many of the studies identified in the initial search were directly related to the research question yet included participants of ages outside that specified in inclusion criteria, namely, adolescents and adults. While it remains unclear as to why research into the effect of music on SAA has predominantly occurred among older populations, it identifies another knowledge gap which future research can attempt to ‘fill’.

The form of music instruction varied across the studies, between general music classes and instrument lessons, and between group or individual classes. Future research could explore which form of training results in the most prominent SAA advances, if any, and provide suggestions as to why some exert more of an influence than others. Indeed, future research should ensure consistency in forms of music instruction used when comparing findings, to pinpoint specific outcomes. Moreover, the present study proposed that particular musical characteristics – present in specific musical styles – have more of an impact on SAA than others. The exploration of which musical characteristics and related musical styles lead to more SAA enhancement than others, and whether this is determined by specific musical characteristics or by other factors, constitutes yet another potential research area.

6.6 Conclusion

The present study aimed to explore whether music instruction results in enhanced sustained auditory attention in typically developing five to ten-year-old children. By means of an extensive search process, ten studies meeting a list of eligibility criteria were identified. A data extraction process followed – including thematic text analysis and the development of thematic matrices – in which data from the ten studies was collated and analysed. Findings revealed that while music instruction does correlate with enhanced SAA in children, this is dependent on the provision of specific variables, such as the employment of specific musical characteristics. Various causes were suggested for gains made in SAA, most prevalent being neurobiological changes, improved auditory attention in general, and the age of commencement of music instruction.

Alternatively, causes attributed to limited SAA enhancements were also suggested, such as the presence of external reinforcement/rewards. It can thus be concluded that music instruction does have a positive correlation with SAA in children, thereby affirming the initial hypothesis, yet are limited by specific contexts and variables. The importance of music instruction should thus not be underestimated, and should be considered by parents, educators and policymakers as a means by which to contribute to the development of sustained auditory attention and the holistic development of the child.

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Appendix A: Ethical clearance form

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Research Ethics Committee

2 July 2018

Dear Ms Monnig

Project:	**Examining the relationship between musical training and auditory sustained attention in seven-to ten-year-old children**
Researcher:	**C Monnig**
Supervisor:	**Dr C Panebianco**
Department:	**Music**
Reference number:	**13024372 (GW20180623HS)**

Thank you for the application that was submitted for ethical consideration.

The **Research Ethics Committee** notes that this is a literature-based study and no human subjects are involved. The application has been **approved** on 28 June 2018 along these guidelines, data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. However, should the actual research depart significantly from the proposed research, a new research proposal and application for ethical clearance will have to be submitted for approval.

The Committee requests you to convey this approval to the researcher.

We wish you success with the project.

Sincerely

Prof Maxi Schoeman
Deputy Dean: Postgraduate Studies and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail:tracey.andrew@up.ac.za

CC: Dr C Panebianco (Supervisor)
Prof A Johnson (HoD)

Appendix B: Reasons given for the inclusion and exclusion of studies in the review

Year	Journal	Article title	Author(s)	Included(✓) /Excluded(x) /Unsure(?)	Reasons for exclusion
2008	Journal of Cognitive Neuroscience	Enhancement of auditory-evoked potentials in musicians reflects an influence of expertise but not selective attention	Baumann, S., Martin, M., Jäncke, L.	x x	Participants are adults; the focus is on selected attention. Adult participants, not children.
		Moving on time: Brain network for auditory–motor synchronisation is modulated by rhythm complexity and musical training	Chen, J. L., Penhune, V. B., Zatorre, R. J.	x x	Participants are adults (19-32 years); attentional capacity was not the focus. Not SAA; adult participants.
	Early Childhood Education Journal	Parental perceptions of music in storytelling sessions in a public library	de Vries, P. A.	x x	Participants are too young (0-5 years); main focus is literacy benefits of music training. Participants too young; mot music training; limited mention of attention.
	Psychology and Ageing	Exercising your brain: A review of human brain plasticity and training-induced learning	Green, C. S., Bavelier, D.	x x	Limited discussion on the musical benefits for children. Not children participants; no SAA mentioned.
	Thesis	Attention to changes in chord complexity by non-musicians: An event-related potential study	King, B. O.	x x	Participants too old (>18 years). Not children participants; no SAA mentioned.
	Child Language Teaching and Therapy	Children's reading comprehension and narrative recall in sung and spoken story contexts	Kouri, T., Telander, K.	? x	Focus on music's impact on speech and language processing; not musical training but general use of music. No SAA included; music in general not music lessons.
	Current Opinion in Neurobiology	Music perception, pitch, and the auditory system	McDermott, J. H., Oxenham, A. J.	x x	Discusses pitch perception and neural processing of pitch; no mention of attentional capacity. No SAA mentioned; no discussion of children and music.
	Thesis	Musical training enhances brainstem and cortical representation of speech and music	Musacchia, G. A-E.	x x	Adult participants (mean age 26 years); limited discussion of music's effect on attention. Not SAA specifically; adult participants.
	Trends in Cognitive Neuroscience	Music, language and cognition: Unresolved issues	Schellenberg, E. G., Peretz, I.	x x	Discussion on current research trends of music's impact on cognitive function, rather than a study of its own; no SAA discussed. No mention of SAA.
	Thesis	Differences in student academic achievement between students who participate in music programs and students who participate in athletic programs	Shropshire, W. B.	x x	Participants are too old (16-18 years); limited discussion of SAA. High school participants; no SAA mentioned.

2009	Thesis	Mozart effect: Exploring the relationship between classical music and improvement in the spatial-temporal cognitive abilities of elementary school children	Ader, M. J.	x x	Investigates the impact of music on children's cognitive abilities, but excludes auditory attention. No SAA mentioned.
	Emotional and Behavioural Difficulties	The rhythm's gonna get ya: Background music in primary classrooms and its effect on behaviour and attainment	Bloor, A. J.	x x	No mention of how musical training impacts attention. No SAA mentioned.
	Psychomusicology: Music, Mind and Brain	My life in music cognition research	Dowling, W. J.	x x	No mention of the influence of music on SAA; studies discussed referenced participants who are too old. The author's personal life story.
	The Journal of Neuroscience	Musical training shapes structural brain development	Hyde, K. L., Lerch, J., Forgeard, M., Winner, E.	✓ ?	Not SAA specifically.
	Research Studies in Music Education	Underlying mechanisms linking music education and cognitive modifiability	Portowitz, A., Lichtenstein, O., Egorova, L., Brand, E.	x ?	Focuses on social benefits of music training, rather than cognitive influences. No mention of SAA specifically.
	Thesis	Get moving! The effects of music and movement on student attention and engagement	Sandberg, H. F.	✓ x	No specific reference to SAA.
	Journal of Attention Disorders	Vigilance and sustained attention in children and adults with ADHD	Tucha, L., Tucha, O., Sontag, T. A., Walitza, S., Laufkötter, R., Linder, M., Lange, K. W.	x x	No discussion into music's impact on SAA. Deals with ADHD and not SAA.
	Journal of Music Therapy	The use of music with young children to improve sustained attention during a vigilance task in the presence of auditory distractions	Wolfe, D. E., Noguchi, L. K.	✓ ✓	
	Music Periodicals	The effect of music on peer awareness in preschool age children with developmental disabilities	Sussman, J. E.	x x	Participants all have developmental disabilities; no mention of music's influence on SAA. Some participants younger than age 5; not music lessons but background music.
	Contributions to Music Education	Effect of voice-part training and music complexity on focus of attention to melody or harmony	Williams, L. R.	x x	Participants are too old; they are university students. Participants too old.
2010	Thesis	Attentional and affective responses to complex musical rhythms	Chapin, H. L.	x x	Participants are too old (20-46 years). Participants too old.
	Thesis	Effects of background music on preschoolers' attention	Dartt, K. M.	x x	Participants are too young (3-5 years); background music not musical training. Participants too young.
	Nature Reviews Neuroscience	Music training for the development of auditory skills	Kraus, N., Chandrasekaran, B.	x	Limited discussion of music's influence on SAA; focuses on neurological changes and

				x	improved speech processing. No SAA but general neural functions.
	Hearing Research	Musical experience shapes top-down auditory mechanisms: Evidence from masking and auditory attention performance	Strait, D. L., Kraus, N., Parbery-Clark, A., Ashley, R.	x x	Participants are too old (18-40 years). Participants are adults.
	Medical Problems of Performing Artists	How and why musicians are different from nonmusicians: A bibliographic review	Dawson, W. J.	x ?	No mention of SAA. Only one small relevant paragraph.
2011	Music Perception	Playing music for a smarter ear: Cognitive, perceptual and neurobiological evidence	Strait, D., Kraus, N.	✓ ✓	
	European Journal of Neuroscience	Musical training modulates encoding of higher-order regularities in the auditory cortex	Herholz, S. C., Boh, B., Pantev, C.	x x	Participants are too old (27 years old). Adult participants; SAA not speculated.
	Experimental Brain Research	Dynamic allocation of attention to metrical and grouping accents in rhythmic sequences	Kung, S-J., Tzeng, O. J. L., Hung, D. L., Wu, D. H.	x x	Participants are too old (18-27 years). Limited discussion of SAA; adult participants.
	European Journal of Neuroscience	Long-term exposure to music enhances the sensitivity of the auditory system in children	Meyer, M., Elmer, S., Oechslin, M. S., Ringli, M., Baumann, S., Jancke, L.	x ?	No discussion regarding music's influence on SAA in children. No SAA mentioned but other relevant information.
2012	Music Therapy Perspectives	Bridging music neuroscience evidence to music therapy best practice in the early childhood classroom: Implications for using rhythm to increase attention and learning	Geist, K., Geist, E. A.	? ✓	No mention of SAA specifically.
	Thesis	Development of musicianship and executive functioning among children participating in a music program	Sportsman, E. L.	✓ ✓	
2013	Journal of Music Therapy	Psychometric validation of a music-based attention assessment: Revised for patients with traumatic brain injury	Jeong, E.	x ?	Participants are too old. Participants are too old but discusses much SAA.
	Frontiers in Psychology	Group rhythmic synchrony and attention in children	Khalil, A. K., Minces, V., McLoughlin, G., Chiba, A.	✓ ?	The study discusses focus more than SAA.
2014	Psychomusicology	A meta-analysis of the effectiveness of music interventions for children and adolescents with attention-deficit/hyperactivity disorder	Maloy, M., Peterson, R.	x ?	Participants suffer from ADHD. Deals with ADHD, not SAA.
	Journal of Music Therapy	Construct validity and reliability of the music attentiveness screening assessment (MSAA)	Waldon, E. G., Broadhurst, E.	x x	Investigates the validity and reliability of a test used to measure attentiveness to music. Focuses on ways of measuring SAA.
	The Journal of Neuroscience	Size and synchronization of auditory cortex promotes musical, literacy, and attentional skills in children	Seither-Preisler, A., Parncutt, R., Schneider, P.	x x	Focuses on anatomical brain structures and how they are influenced by music; no mention of SAA. Participants have ADHD.
2015	Procedia - Social and	Music as a resource to develop cognition	Vargas, M. E. R.	?	Focuses on music's contribution to human

	Behavioural Sciences			✓	development as a whole. A small section discusses SAA.
2016	Thesis	The development of a music program to improve the attention span of school-aged children	Williams, A. D.	? ✓	It presents no findings as it is a proposal which has not been piloted; participants range from 9-18 years.
	Neurocase	El Sistema-inspired ensemble music training is associated with changes in children's neurocognitive functional integration: preliminary ERP evidence	Hedayati, N., Schibli, K., D'Angiulli, A.	? x	While considering music's impact on SAA, it is more focused on the neurological bases of this. Neurological changes as a result of music.
2017	Psychomusicology	The impact of music instruction on attention in kindergarten children	Hallberg, K. A., Martin, W. E., McClure, J. R.	✓ ✓	
	PloS One	Positive valence music restores executive control over sustained attention	Baldwin, C. L., Lewis, B. A.	x x	Participants are too old (average age 21 years). Adult participants.

Note: All text in red indicates the independent reviewer's reasons

Appendix C: HTA Quality Rating Checklists*

HTA checklist for assessing the quality of quantitative studies					
Criteria		Yes (2)	Partial (1)	No (0)	N/A
1	Question/objective sufficiently described?				
2	Study design evident and appropriate?				
3	Method of subject/comparison group selection *or* source of information/input variables described and appropriate?				
4	Subject (and comparison group, if applicable) characteristics sufficiently described?				
5	If interventional and random allocation was possible, was it described?				
6	If interventional and blinding of investigators was possible, was it reported?				
7	If interventional and blinding of participants was possible, was it reported?				
8	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported?				
9	Sample size appropriate?				
10	Analytic methods described/justified and appropriate?				
11	Some estimate of variance is reported for the main results?				
12	Controlled for confounding?				
13	Results supported in sufficient detail?				
14	Conclusion supported by the results?				

HTA checklist for assessing the quality of qualitative studies				
Criteria		Yes (2)	Partial (1)	No (0)
1	Question/objective sufficiently described?			
2	Study design evident and appropriate?			
3	Context for the study clear?			
4	Connection to a theoretical framework/wider body of knowledge?			
5	Sampling strategy described, relevant and justified?			
6	Data collection methods clearly described and systematic?			
7	Data analysis clearly described and systematic?			
8	Use of verification procedure(s) to establish credibility?			
9	Conclusions supported by the results?			
10	Reflexivity of the account?			

*For a more detailed explanation of the criteria in each checklist, and the scoring process, see Kmet et al. (2004)

Appendix D: Evidence of item checklists from PRISMA-P

(Shamseer et al., 2015)

	Section and topic	Checklist item	Evidence in study (section)
Administrative information	Title identification	Identify the report as a protocol of a systematic review	Title page
	Title update	If the protocol is for an update of a previous systematic review, identify as such	N/A
	Registration	If registered, provide the name of the registry (such as PROSPERO) and registration number	N/A
	Authors contact details	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of corresponding author	i
	Authors contributions	Describe contributions of protocol authors and identify the guarantor of the review	i
	Amendments	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise, state plan for documenting important protocol amendments	N/A
	Support sources	Indicate sources of financial or other support for the review	N/A
	Sponsor	Provide name for the review funder and/or sponsor	N/A
	Role of sponsor or funder	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol	N/A
Introduction	Rationale	Describe the rationale for the review in the context of what is already known	1.1
	Objectives	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	1.2; 1.3
Methods	Eligibility criteria	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for eligibility for the review	3.4.4
	Information sources	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers or other grey literature sources) with planned dates of coverage	3.4.1; 3.4.2
	Search strategy	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	3.4.1; figure 3
	Data management	Describe the mechanism(s) that will be used to manage records and data throughout the review	3.4.3
	Selection process	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is, screening, eligibility and inclusion in meta-analysis)	3.4.2
	Data collection process	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators	3.4.5
	Data items	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned data assumptions and simplifications	3.4.4; 3.4.5
	Outcomes and prioritisation	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	1.3; 3.5; table 1
	Risk of bias in individual studies	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used in data synthesis	3.4.6; 4.2.2
Methods Continued	Data synthesis	Describe criteria under which study data will be quantitatively synthesised	N/A
		If data are appropriate for quantitative synthesis, describe planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency	N/A

		Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)	N/A
		If quantitative synthesis is not appropriate, describe the type of summary planned	3.5
	Meta-bias(es)	Specify any planned assessment of meta-bias(es) (such as publication bias across studies, selective reporting within studies)	3.6
	Confidence in cumulative evidence	Describe how the strength of the body of evidence will be assessed	4.2.3