A shared resource for syntactic processing in music and language: Evidence from musicians/non-musicians using local cue manipulation

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ABSTRACT

Patel's (2003) *Shared Syntactic Integration Resource Hypothesis* (SSIRH) claims that music and language are represented separately yet are processed according shared networks. According to the model, music and language place syntactic demands on this limited processing resource. The current study aims to test this hypothesis by combining linguistic ambiguity (sentences based on minimal attachment theory) and musical ambiguity (presentation of a non-diatonic chord sequence). The study extends previous research by manipulating local processing cues and examining musician/non-musician differences. A self-paced paradigm is used to present linguistic and musical stimuli, with on-line and off-line measures taken (response times and question accuracies, respectively). Main findings reveal longer processing times for ambiguous stimuli; a significant yet contrary result for condition (faster response times for concurrent music/language tasks); and a partial effect for local musical cue manipulation. The findings suggest a new direction for research into the SSIRH and possible applied benefits.

KEY WORDS:	MUSIC SYNTAX	LANGUAGE SYNTAX	MINIMAL ATTACHMENT	IMPLICIT MUSICAL PROCESSING	TONAL CENTRES

Introduction

The notion of a shared network between music and language is certainly not unique. Music and language have many similar characteristics, such as rhythm, melody, structure and meaning (Patel, 2008). For example, Patel and Daniele (2003) conducted a study to investigate the rhythmic similarities between language and music in English and French. The findings revealed a similar rhythmic variability in each of the two nation's languages and music; English music and language had significantly higher variability than French. Similar studies have also focused on melody, particularly on phonological skills in children; musical ability and reading skills are related (Patel & Iversen, 2007; Anvari, Trainor, Woodside & Levy, 2002), with musical training significantly improving phoneme detection in children. Further studies have also found linguistic components to influence the classification of songs into particular nationalities (Hannon, 2009). The chief point to note is that research investigating the melodic and rhythmic components of linguistic and musical stimuli has led to support for an overlap in music and language processes.

However, despite research into melodic and rhythmic components of language and music, there exist certain domains that are lacking in empirical studies. Chief among these is the role of syntax. Studies into a syntactical relationship are far from numerous – examples include Koelsch, Gunter, Wittfoth and Sammler (2005), Fedorenko, Patel, Casasanto, Winawer and Gibson (2009), and Slevc, Rosenberg and Patel (2009). These are not the sole examples although the total number is not significantly greater. However, these studies are representative of the general finding, which contends that music and language do indeed share a common neural network. These findings are based on Patel's (2003; 2008) Shared Syntactic Integration Resource Hypothesis (SSIRH), which proposes a conceptual distinction between representations and processes. The SSIRH posits that music and language are stored as separate representations in long-term memory, yet the online activation of items (akin to working memory) is processed within a shared resource. The hypothesis therefore makes the following prediction – in tasks combining music and language syntax there should be a delay in processing, in comparison to the presentation of *only* music or language. This is due to the limited nature of the shared resource. Studies investigating the SSIRH have found precisely that Slevc *et al* (2009) found increased reading times in tasks with concurrently presented music and language, in comparison to the language-only task.

However, an appropriate inspection of music and language syntax cannot yet be made until each domain has received the necessary attention. Therefore, the current section will address the role of syntax in the following manner: First, linguistic syntax shall be discussed; Second, the syntactical nature of music shall be discussed; Third, the syntactical overlap in both domains shall be discussed; Fourth, the role of musicians and non-musicians will be discussed, followed by; Fifth, the rationale for the current study.

Linguistic syntax

Psycholinguistic researchers typically investigate syntax through the use of sentence comprehension. A standard paradigm (a self-paced paradigm) is to present participants with sentences that differ in comprehension difficulty and then measure reading times for certain aspects of the sentence. Researchers also provide a comprehension question to assess participants understanding. The two measures provide researchers with evidence for theories of sentence parsing. However, it is important to distinguish between both measures, as Fedorenko, Gibson and Rohde

(2006) are careful to note. Reading times refer to the *on-line* processing *during* a task, whereas question accuracies measure *off-line* performance *post*-task. The distinction is important as both measures refer to different aspects of sentence comprehension. Pickering (1999) for example is careful to highlight the crucial difference between sentence *parsing* and *comprehension*; parsing refers to the processing of a sentence, which is the act of recognizing structure; whereas comprehension refers to structure recognition and assigning an *interpretation*. Therefore, the procedure involved in understanding a sentence is not the same procedure as reading a sentence. Hence, the typical use of reading times to assess the act of parsing, and comprehension questions to assess understanding. In the current study then, to avoid confusion, the terms *sentence comprehension* and *parsing* will be used interchangeably to refer to the extraction of syntactical structure. However, the distinction will be addressed in the discussion.

In studies of linguistic syntax researchers often employ a combination of ambiguous and non-ambiguous sentences. Sentence ambiguity is manipulated to increase comprehension difficulty, the dependent measures then provide evidence for a particular theory of syntactic processing (Clifton & Duffy, 2001). For an example, consider sentences 1(a) and (b):

1. (a) After the child had visited the doctor prescribed a course of injections.
   (b) After the child had sneezed the doctor prescribed a course of injections.

The sentences (taken from Mitchell, 1987) contain an example of two examples of ambiguity. In 1(a) the sentence is ambiguous and therefore, processed with greater difficulty than sentence 1(b), which is non-ambiguous. Responses to 1(a) are critical when investigating theories of sentence comprehension. Such theories may be classified into two types: Garden-path theory (Engelhardt & Ferreira, 2010, for example) and constraint based theories (Treuswell, Tanenhaus & Garnsey, 1994, for example). There is evidence for both accounts, although work by Ferreira and colleagues (2002; 2007) suggest that both theories are not sufficient in accounting for sentence comprehension. However, this will be discussed at an appropriate juncture. Now, it is necessary to describe these theories, with reference to empirical findings.

Garden path approaches are often serial models (Pickering, 1999), meaning that each new word is processed incrementally and a singular analysis is constructed until such a point in the sentence that a revision becomes necessary. Parallel models, in contrast, suggest that all possible analyses are considered until the correct one becomes apparent (Traxler & Pickering, 1996). Constraint-based theories are usually deemed parallel models because all possible analyses are subject to certain constraints, such as the plausibility or semantic information available (Clifton & Duffy, 2001; Ferreira & Patson, 2007). Consider again, the sentence 1(a). Early research suggested that participants initially read up to *the doctor*, before a revision was necessary (Frazier, 1987). This process, according to Frazier, has two components – *minimal attachment*, which refers to the attachment of new information into an existing phrase, so that as few nodes as necessary may be formed from a sentence; and *late closure*, which is tendency to keep open the initial phrase as long as possible. Together, these principles predict that in 1(a) the initial phrase is incorrectly parsed as far as *the doctor* because of the tendency to maintain the original phrase as long as possible whilst creating as few phrases (or nodes) as possible. Thus, readers are sent 'down the garden path'. Evidence since

Frazier has mounted; Traxler and Pickering (1996), Englehardt and Ferreira (2010), Frazier and Rayner (1982), and Katsika (2009) have found support for minimal attachment.

Constraint-based theories, by contrast, differ in that certain constraints are isolated in order to examine the effects on sentence comprehension (Pickering, 1999). For example Slevc *et al* (2009) manipulated ambiguity by omitting *that* in sentence 2(a):

2. (a) The scientist wearing thick glasses confirmed (that) the hypothesis was being studied in his lab.

Participants either read the sentence with *that* included (non-ambiguous) or omitting *that* (ambiguous). Response times were longer in the ambiguous condition due to the local manipulation of *that*. The effect of this omission results in a 'reduced relative clause'. In this example, *the hypothesis was being studied in his lab* is the relative clause (indicating a pause after *confirmed*). However, participants incorrectly parsed the sentence by pausing after *hypothesis*, thereby realizing the error and were forced to backtrack and revise the phrase. Thus, a reduced relative clause may be achieved by omitting key words (in the current example *that*), thereby resulting in a lack of information necessary to comprehend the sentence. This is supportive of earlier work by Trueswell *et al* (1994) who presented participants with sentences such as in 3(a):

3. (a) The defendant (that was) examined by the lawyer turned out to be unreliable.

In this example, the omission of *that was* resulted in a reduced relative clause, as in the Slevc *et al* (2009) example. Researchers interpret these findings as evidence for constraints on processing; rather than merely employ minimal attachment and late closure (which is a serial process), the parsing of a sentence requires multiple sources of information to be available (as in the parallel process of constraint theories). Such information includes disambiguating functions such as *that*, to parse the sentence with the correct phrase regions; and thematic material such as the object or subject of a sentence. Ferreira (2003) for example, had participants read the sentence *the dog was bitten by the man*. The task required naming the subject (recipient) of the action. A large proportion of students failed to correctly identify the agent of the action (the *man* bit the dog is the correct answer). Ferreira concluded that prior thematic information interferes with the correct interpretation, a finding supported by Kim and Sikos (2011) and Yamada and Neville (2006), both finding competition for syntactical and semantic integration in interpretation. Thus, it is possible that certain sentences favour a constraint approach to enable all possible factors be considered if a correct comprehension is to ensue.

However, a unique approach by Ferreira and colleagues has led to the 'good enough' theory. Ferreira, Bailey and Ferraro (2002) and Ferreira and Patson (2007) review evidence to suggest that sentence comprehension theories are incapable of fully accounting for the process of sentence parsing due to certain key features that are overlooked. A noteworthy feature is illustrated by the Moses illusion (Erickson & Mattson, 1981; cited in Ferreira *et al*, 2002), which simply asks 'How many animals of each sort did Moses put on the ark?' Participants usually respond with the answer of 'two types', seemingly unaware of the incorrect presumption inherent in the question – Moses did not own an ark, yet *Noah* did. This example, together with other issues such as disfluencies (speech related facets – 'oh', 'um', 'ah') illustrate

that people often misinterpret sentences. Indeed, as the Moses illusion dramatically illustrate, people may claim to understand yet clearly have not comprehended the sentence correctly.

A further factor relates to the reduced relative clauses. Although Slevc *et al* (2009) obtained significant results, ambiguity as a result of reduced relatives may not by ubiquitous. For example, reduced relatives are fairly common, as the word that was omitted in 33% of reduced relative clause sentences in the Wall Street Journal (Elsness, 1984; Garnsey, Pearlmutter, Myers & Lotocky, 1997). This further illustrates the fallibility of garden path and constraint models to fully account for the process of sentence parsing. Hence, all theories of syntactic comprehension are only 'good enough', until all compounding factors have been addressed.

For the present study therefore, the evidence reviewed above poses a problem; if minimal attachment/late closure is not sensitive to particular contextual factors (as illustrated by constraint approaches), and neither is particularly effective at fully demonstrating the parsing strategies used by readers (as illustrated by the 'good enough' approach), then what may be used as an exemplar of linguistic syntactical processing?

The answer is predicated on two principles: firstly, the current study is not a pure psycholinguistic investigation, it is a study of a shared syntactical resource for music and language and consequently, the compounding factors highlighted above are not of paramount importance; secondly, there is overwhelming evidence to implicate minimal attachment as a foundation for constructing stimuli. The first point requires a brief explanation. The objective of the current study is to compare music and linguistic syntax, therefore the type of example is not of paramount important, only that it is consistent in all conditions. This will enable a fair comparison. Consequently, *an* example is of greater importance than *which* example. However, the choice of linguistic stimuli is not merely random, there does exist a rationale for selecting an exemplar. The following section shall clarify this, in relation to the second point previously stated.

The current section has introduced the two main approaches to syntactical study yet also highlighted the weakness of both. It is necessary to provide awareness of these issues before returning full-circle to briefly state the merits of minimal attachment/late closure. Despite the criticism noted above, Ferreira and Patson (2007) conclude by stating that people have a heuristic bias to interpret the initial phrase as the noun phrase (the foremost part of a sentence that includes the agent and recipient of the action). This is in accordance with Frazier's (1979) minimal attachment principle to garden path sentences. Indeed, Ferreira, Christianson and Hollingworth (2001) find that people have such a profound bias for the initial noun phrase that even when reanalysis is necessary, the original interpretation lingers. Such a bias was supported by a recent study by Engelhardt and Ferreira (2010) who found a preference for the noun phrase over constraint approaches.

Therefore, in answer to the question posed above, the minimal attachment/late closure principle will be used as material for assessing linguistic syntax processing. However, it is necessary to provide a little background on the syntax of musical processing.

Musical syntax

Processing syntax in musical structures largely stems from implicit learning (Masataka, 2009; Bigand & Poulin-Charronnat, 2006). Language, unlike music, is learned in an explicit fashion; children are first taught the phonemic sounds, before

combining phonemes to learn words. Then, sentences and phrase boundaries are learnt (Ziegler and Goswami, 2005). However, it is important to note that the above process relates to reading and not speech, which is held to be a predisposed human ability (Pinker, 1994). The distinction is important to note as Masataka (2009) suggests that music is also a predisposed ability. Masataka argues that both speech and music are learned in a similar manner, with vocal song-like ability developing at the same time as an infant first learns to 'coo'. Indeed, pitch detection is better in speakers of tone languages, where a word may have a different meaning dependant upon the pitch it is uttered (Krishnan, Xu, Gandour & Cariani, 2005). Undoubtedly, infants learning tonal languages develop an increased sensitivity to pitch, which aids in phonemic discrimination (Deutsch, Henthorn & Dolson, 2004). It is certainly no surprise then, that reading and musical awareness often correlate, as research suggests (Muter & Diethelm, 2001; Gervain & Werker, 2008; Strait, Kraus, Parbery-Clark & Ashley, 2010). Indeed, research has found that children with language learning deficits also have an impaired ability to discriminate musical pitches (Tallal & Gaab, 2006). Furthermore, Forgeard, Winner, Norton and Schlaug (2008) found musical practise enhances auditory discrimination (in a musical task) and improves a child's vocabulary and non-verbal reasoning. Bennet and Bennet (2008, p. 14) extend this by suggesting that "music clearly offers the potential to strengthen and increase the inter-connections across the hemispheres of our brain". It is suggested that increased connections improve the ability to learn and store information. Although, Bennet and Bennet postulate ideas that lie on the extreme pole of the continuum in comparison to merely facilitating reading skills, the evidence is clear: music and language share intimate connections, which develop at the same time in the life of an infant.

If music and language ability develop at the same time then there lies a suggestion of a similar learning process. Recall that music learning is largely an implicit process, acquired by all humans regardless of musical ability (to a certain degree, anyhow; Bigand & Poulin-Charronnat, 2006, Brattico, Tervaniemi, Näätänen & Peretz, 2006). It is the act of implicit learning that is often denoted in the literature as statistical learning (for example, Jonaitis & Saffran, 2009; Tillmann, 2008). This refers to the act of learning regularities with a given domain, thus developing an expectancy of upcoming items (Jonaitis & Saffran, 2009). An example will illustrate this point; Jonaitis and Saffran find that musical chord patterns help individuals learn the structure of a new musical key. Imagine therefore, the white keys of a piano: if certain groups of three notes are played concurrently (termed chords) then the musical key in use is known as C major. Imagine then, playing chords in another musical key, D major for example; this will involve a mixture of white and black keys. Participants will be aware of a change in musical key and have the ability to discriminate between musical keys; chords in D major will not sound dissimilar to G major or A major, however, participants will have transferred learning from chords in the initial C major example to identify the structure of D major. This example illustrates an important process of musical learning; it is not chords or notes specifically that is learned, it is the spatial relationship *between* the chords. McDermott and Oxenham (2008) and Matsunaga and Abe (2005) also note this in their studies of pitch discrimination; when presenting notes (pitches) from different musical keys, participants identified notes not based on the *actual* note sound, but on the distance *between* notes. In C major, the distance between the notes of *C* and *E* is a third; in G major, the distance between a *G* and *B* is also a third. Hence, learning the spatial distance in one musical key is transferable to any musical key.

Researchers predominantly argue that such statistical learning is culturally ingrained (Curtis & Bharucha, 2008; Koelsch & Jentschke, 2008; Wong, Roy & Margulis, 2009). Infants' perception of music is derived from the particular culture in which the child develops. Western music, for example, is different to Asian music, and research has demonstrated a cultural bias in perception of national styles (Wong *et al*, 2009; Koelsch & Jentschke, 2008). However, Wong *et al* (2009) found that sensitivity to music of a different culture could be developed. The chief point of note is that a musical sense may be acquired by all humans, due to the structural aspects of music. It is to the structure that attention is now directed.

The structure of Western music consists of 12 possible musical keys. Each key has 7 diatonic notes and 5 non-diatonic notes (diatonic meaning *within* key and *familiar*; non-diatonic meaning *outside* key and *unfamiliar*). Diatonic notes may be structured in groups of three to produce triads (*triads* refer to the explicit patterning of three notes, whereas *chords* refer to a combination of numerous notes – in theory a chord may have as many notes as the composer deems necessary). When the notes of a key are combined in this manner the process is known as harmonization (see figure 1):

I	ii	iii	IV	V	vi	vii
C	Dm	Em	F	G	Am	B°

Figure 1: Harmonized chords in C major. Capital letter refer to major chords and an m following a letter refers to minor chords, e.g. Am is A minor (the final chord symbol of ° denotes diminished but this is not important for the current study)

The structure shown in figure 1 is constant across all major keys; the third chord of a key is minor, whereas the fourth chord is major. Hence, in D major the second chord is E minor and the fifth chord is A major. It is this structure, research finds, that is implicitly learnt (Tillman, 2008, for example). Research into music tonality typically uses a priming paradigm (Tillmann & Bigand, 2002), whereby a sequence of chords is presented and followed by a target chord; participants then judge if the target chord corresponds to the chord sequence. The advantage of this approach is that the target chord can manipulated to investigate an aspect of musical processing. Bigand and Poulin-Charronnat (2006) report on a series of studies by Bigand and colleagues that tested both musically trained and untrained musicians. Their studies revealed several important findings; first, both trained and untrained participants quickly discriminated between consonant and dissonant chords (*consonant* chords refer to familiar-diatonic chords, whereas *dissonant* chords do not conform to a primed musical key and are thus non-diatonic); second, both groups of participants were influenced by the function of certain chords, as opposed to the frequency of occurrence in the primed sequence; third, participants were influenced by the local and global effect in the prime sequence. This latter finding is of particular interest to the current study. Tillmann and Bigand (2002), Tillmann, Janata, Birk and Bharucha (2003) and Tillmann (2008) find evidence that local and global cues influence musical perception differentially. *Global* effects are regarded as the key that a given sequence is presented (such as C major), whereas the *local* cues relate to the

individual chords and tonal relation between these (such as the prominent effect of chord 1 or 5 in C major). Tillman (2008) states that certain chords influence the perception of musical structure to a greater degree than other chords. For example, chords 1, 4 and 5 in a key are of particular importance (these are termed *primary* chords and symbolized by higher case Roman numerals, in figure 1). Therefore, in a musical sequence the use of such primary chords will act as spatial 'anchors' to facilitate the identification of a musical key.

Research into musical perception, as described above, has highlighted that untrained and trained musicians possess an ability to spatially navigate the musical world. Humans have a predisposed ability to identify chords that belong to a key or correspond to a nearby key; and the ability to identify certain primary chords whilst allowing the function of such chords to identify the perception of a musical structure. Indeed, the ability to detect musical grammar is sufficient that studies presenting novel musical structures have found that people still maintain the ability to learn the new syntactical structure (Loui, Wessel & Kam, 2010). In this study, the researchers use a Bohlen-Pierce scale, which differs to a standard scale due to the division of the notes – instead of 12 possible notes in a key, a Bohlen-Pierce contain 13. The notes are therefore, of a different frequency to standard Western notes. Yet, despite such a novel structure, participants were still able to learn the new musical structure; notes were combined to create novel chords and after 25 minutes, participants learned the new grammar. This is further evidence that music is statistically learnt, with people able to identify the musical structure inherent in any musical idiom.

However, certain researchers are not in agreement regarding trained an untrained musical abilities. Although no research seemingly disputes the ubiquitous human ability to spatially navigate through music, research does find that musicians' perception is quantitatively different to non-musicians. The following section shall briefly highlight such differences.

Musicians and non-musicians

The effect of musical training is putatively beneficial. Strait *et al* (2010) find music impairments lead to language and literacy deficits, suggesting that music training enhances auditory skills. Jentschke, Koelsch, Sallat and Friederici (2008) found that children with specific language impairments had difficulty perceiving musical structure. Accordingly, music training might alleviate such language impairments. Indeed, Jentschke and Koelsch (2009) found musically trained had better developed neural mechanisms for syntax processing in both music and language. These examples suggest that music might modulate auditory mechanisms in the brain, thus altering the neural plasticity.

However, literary sources are not in harmony regarding the particular stage of alteration. Certain research finds a pre-attentive difference (Rüsseler, Altenmüller, Nager, Kohlmetz & Münte, 2001; Van Zuijen, Sussman, Winkler, Näätänen & Tervaniemi, 2005) while many researchers find an attentive difference (Seppänen, Brattico & Tervaniemi, 2007; Loui and Wessel, 2007). Rüsseler *et al* (2001) investigated the temporal integration of musicians, using a mismatch negativity component (MMN) of the event-related brain potential (ERP). Results indicate a greater temporal sensitivity in musicians, compared to non-musicians. Importantly, the MMN detects automatic sound change, thereby leading the authors to conclude that music shapes the neural activity in musicians. Van Zuijen *et al* (2005) also investigated temporal processing in musicians and non-musicians using the MMN. The study found both groups were sensitive to the time of music, yet only musicians

perceived the numerical construction of the stimuli. This reflects non-musicians' ability to perceive the global temporal structure of music, but only musicians' were sensitive to the 'beat' structure of music. Furthermore, this study found the musicians' perceptive skills were pre-attentive.
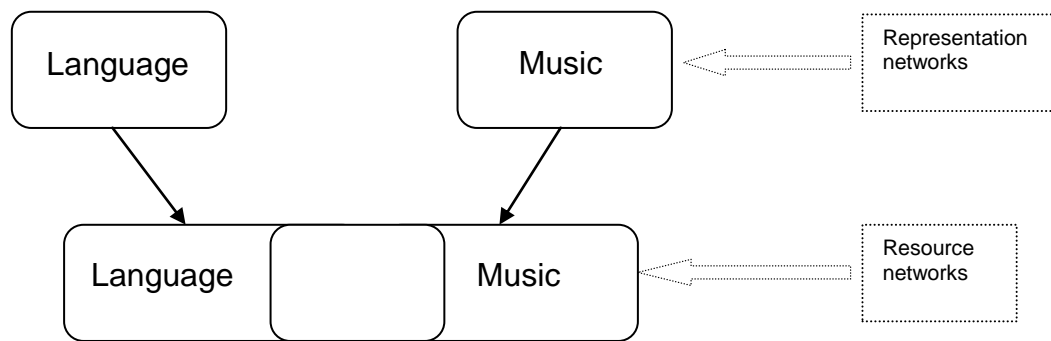
In contrast to this pattern of findings, Seppänen *et al* (2007) found the ability of musicians to perceive the contour and interval pattern of a melody was solely attributable to musical training. The researchers conducted the study using the MMN and found no evidence of a pre-attentive stage of processing. A further study by Loui and Wessel (2007) also found musicians were affected by a change in harmony of musical stimuli only with attentive focus. Accordingly, Levitin and Rodgers (2005), on reviewing the perception of absolute pitch, found the development of such a skill attributable to musical training (*absolute* pitch is the ability to accurately perceive the pitch of a note with no reference to previous notes. *Relative* pitch, by contrast, is the ability to perceive the pitch of a note only with reference to surrounding notes). Finally, the perceptual span of a musician is improved only with musical training (Burman and Booth, 2008). Although this latter finding lies in the domain of memory, it nevertheless indicates that musicians' differential skill is attributable to a focused, *attentive* stage of processing.

The latter argument stands in contrast to the former argument, which claims that musicians' perception is a product of pre-attentive processes; the latter states that musicians achieve higher attentive skills. For the present study it is unimportant which (if any) may be correct. The arguments are merely to alert the reader to the differential perceptual skills of musicians and non-musicians. Such a distinction is pertinent to the current study. If language and music share a relationship, yet musicians develop a refined degree of perceptual skill, then such a difference may be found in the current study. In particular, the current study may place demands on a pre-attentive stage of processing. However, it is now necessary to briefly describe the few studies that have investigated a shared music and linguistic syntactical relationship. Following this, the rationale of the current study will be stated.

A shared syntactical integration of music and language

Studies of investigating a shared resource integration of music and language are somewhat paradoxical. Many studies (both neural and behavioural) find an overlap in musical and linguistic resources (Sammler, Koelsch, Ball, Brandt & Elger *et al*, 2009; Fedorenko, Patel, Casasanto, Winawer & Gibson, 2009; Patel, Gibson, Ratner, Besson & Holcomb, 1998; Koelsch, Gunter, Wittfoth & Sammler, 2005; Patel, 2003; Slevc, Rosenberg & Patel, 2009); yet studies of amusia (a deficit of music perception) indicate such musical deficits are domain specific (Peretz, Gagnon & Bouchard, 1998; Dalla Bella & Peretz, 1999; Peretz, Gosselin, Tillmann, Cuddy & Gagnon *et al*, 2008; Patel, 2003). Thus, musical deficits are usually confined to the domain of music, leaving preserved language abilities. This appears in contrast to studies positing a syntactic relationship – one might expect deficits of syntactic processing unconfined to either domain specifically. However, Patel's (2003; 2008) Shared Syntactic Integration Resource Hypothesis (SSIRH) reconciles such a paradox.

The SSIRH posits functional distinction between *resource* and *representation* networks. According to the hypothesis, the basic premise states that *resource* networks activate items in *representation* networks. Such activation brings items up to the required threshold for integration (Patel, 2008). A diagram may be seen in figure 2:

Figure 2: **Schematic illustration of the SSIRH. Arrows denote the connections between network areas (adapted from Patel, 2008).**

The SSIRH offers reconciliation to the paradox with its dual network approach; in instances of musical impairment, the deficit relates to the representation of musical knowledge, thus preserving the language representation. The ability to integrate syntactical information from both domains is therefore intact.

The studies (cited above) that have investigated this relationship have employed a neural approach (EEG) or behavioural – employing the self-paced paradigm common to psycholinguistics. Patel et al (1998) used the P600 event-related potential to compare linguistic and musical syntax. The P600 responds to linguistic ambiguities (see section 1.1), yet in the study there were elicited P600 responses indistinguishable between language and music. In a similar study, Steinbeis and Koelsch (2008) used the N400 event-related potential to study music harmony and its priming effect on language. The N400 is elicited in response to musical tonal ambiguities, yet in this study it was found to prime affective words. Koelsh *et al* (2005) also found a similar result with the N400 regarding syntax processing.

Behavioural studies also found an overlap in syntax processing. Slevc *et al* (2009) presented syntactically ambiguous sentences concurrently with musical ambiguities. It was found that reading times were greater in the combined music/language task than the language-only task. Fedorenko *et al* (2009) also found a similar result with the same paradigm; although, there were only significant results for comprehension question accuracies, as opposed to reading times. It is important to note however, that participants in both behavioural studies were instructed to pay attention to the sentences and not overly attend to the music. Therefore, the effect of concurrent music/language presentation can be interpreted as an automatic process, as participants were dedicating attention to the linguistic stimuli. However, the researchers did also control for attention but found no significant effect. Thus, it seems music and languages indeed share a syntactical relationship, one that precludes a dual, focused attention.

Rational for the current study

The current study aims to test Patel's (2003; 2008) shared syntactic integration resource hypothesis. As the literature is not substantial, particularly with regard to behavioural studies, the study seeks first to replicate existing findings. The study also contributes to existing literature by including musicians and non-musicians, and

by manipulating the processing cues that predicate the SSIRH. The following are predictions of the study:

1. Ambiguous stimuli will not be processed as efficiently as non-ambiguous stimuli.
Following previous research (for example, Engelhardt & Ferreira, 2010; Ferreira & Patson, 2011; Fedorenko et al, 2009; Slevc et al 2009) it is predicted that ambiguous stimuli will cause processing difficulty and result in increased response times.

2. Tasks involving concurrent presentation of music and language will be processed inefficiently, in comparison to language-only tasks.
Research on Patel's SSIRH framework finds increased response times as a result of resource limitations. Findings from Slevc et al (2009), Fedorenko et al (2009) and Koelsch et al (2005) support this finding, explaining that as a result of a shared system, there will be limited processing resources. Therefore the response times are predicted to increase and question accuracies are predicted to decrease.

3. Manipulation of local processing cues, in concurrent tasks, will significantly differ to non-manipulation of cues.
The manipulation of traditional tonal harmony is predicted to affect response times and question accuracies. Based on perceptual research by Tillmann (2008), Tillmann and Bigand (2002) and Loui et al (2010), the traditional approach to Western music necessitates in chord degrees serving as perceptual cues. Such cues function implicitly and guide the listener through 'musical space'. However, if such cues are manipulated then individuals are predicted to display impaired processing. Therefore, the current study will structure chords in a unique manner that removes local processing cues (chord degrees). However, global cues remain as the chords are still structured according to diatonic adherence. It is predicted that removal of local processing cues will affect performance. Specifically, that processing will be significantly different to traditional music/language conditions.

4. Attention will have no significant effects on processing of music and linguistic stimuli.
An obvious confounds regards attention. Performance of ambiguous stimuli might only be a facet of attention. It is necessary to then control for such a factor. However, no effect for attention is predicted.

5. Musician and non-musician difference will be investigated.
No prediction is made regarding the group effect of musicians and non-musicians. The literature is divided between implicit processes among musicians (Seppänen et al, 2007; Van Zuijen et al, 2005) and explicit, focused processes (Rüsseler et al, 2001). Music in the current study will function in an implicit manner, as participants are told to focus on the sentences. Therefore, it is possible for musicians to process music in an implicit manner, yet no firm evidence lends support to such a prediction. Therefore, musicians and non-musicians are included merely to investigate an effect.

Method

Design
The study employed an experimental method utilizing a mixed factorial design. Three factors were studied – two within-subjects factors and a within subjects factor. The

within-subject factors were ambiguity and condition: ambiguity consisted of two levels – ambiguous and non-ambiguous sentences; the condition factor consisted of three levels – language only, traditional music with language, and novel music and language. The between-subjects factor of group featured two levels – musicians and non-musicians. In order to control for possible confounding variables, memory and attention were measured. Memory, specifically short term memory, was measured with a digit span procedure (musicians mean score = 6.75, S.D. = 0.73; non-musicians mean = 6.06, S.D. = 1.39). Noteworthy is that no significant differences were found between groups (t(34) = 1.873, p = 0.07, two-tailed). Attention was included in the second condition (traditional music/language) to establish whether ambiguity could be attributed purely to attention. Also, this allowed comparison to Fedorenko *et al* (2009) and Slevc *et al* (2009), as the studies contained similar attentional controls. Demographic measures of age and gender were also taken, although these were not subject to analysis. Measures of instrument (among musicians) were taken; these revealed no significant difference when split into harmonic and non-harmonic categories[1]. Dependent measures included response times and accuracy to comprehension questions. Finally, a pilot session was conducted to investigate methodological issues, prior to main testing sessions.

Participants

Two groups of participants were used in the current study. Musicians from the Royal Welsh College of Music and Drama were recruited (N = 18), and non-musicians from University of Glamorgan (N = 18). Non-musicians were questioned about musical ability; only participants with no experience playing a musical instrument were included. Furthermore, only students were recruited in the present study (see table 1 for participant age and gender information).

Table 1: Mean age and standard deviation (*in parenthesis*), and gender (Male = M, Female = F)

	Musicians	Non-musicians
	M (S)	*M* (S)
Age	21.70 (5)	24.60 (7.60)
Gender	M = 9 F = 9	M = 5 F = 13

Participants were recruited by individually approaching each student. Each student that agreed to participate was provided with information and asked to sign a consent form before commencing the study. Due to the nature of the study, only participants with first language proficiency in English were recruited. Furthermore, students reporting reading impairments such as dyslexia were not recruited.

Regarding the pilot study, participants from the Royal Welsh College of Music and Drama were recruited (N = 14). The session was primarily to assess potential issues
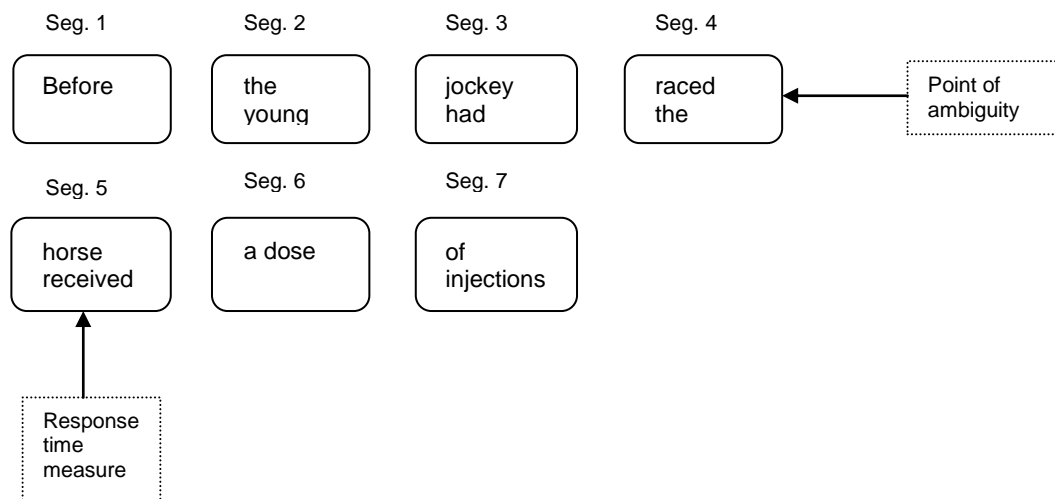
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[1] Harmonic instruments refer to both melody and supporting chords played on the one instrument such as piano or guitar; Non-harmonic instruments refer to melody only, such as the flute of clarinet. It may be predicted that piano players have an increased sense of harmony compared flautists. There was no difference however.

such as recruiting musicians and practical concerns, chiefly regarding unavoidable background noise. The participants in this session were *not* asked to repeat the study in the main testing session.

Materials

The language stimuli employed in the study consisted of 15 ambiguous sentences, 15 non-ambiguous sentences and 5 attention control sentences. The sentences were based on minimal attachment/late closure theory (Mitchell, 1987). According to the theory, when individuals parse sentences, the initial phrase is left open for as long as possible. Individuals aim to comprehend both the agent and recipient of an action in the initial phrase. This is partly achieved through the use of transitive verbs, which function by creating tension that demands resolution. In example 1, "raced" in segment 4 is ambiguous if a pause is inserted afterwards; this then demands resolution by attaching "raced" to an agent or recipient (subject or object in psycholinguistic terminology). Thus, it is likely that individuals pause after "horse", in segment 5, and are forced to backtrack to the source of ambiguity in segment 4.

The sentences were constructed by dividing into 7 segments, with each segment presented to the participant in serial order. Ambiguity was created by manipulating sentence structure in segment 4 (non-ambiguous sentences did not feature such a manipulation). Response times were measured in segment 5, a point of integration for sentence parsing; participants became aware of the ambiguity (or lack of ambiguity) at this section of sentence. Figure 3 is a schematic diagram of an ambiguous sentence construction:

Seg. 1	Seg. 2	Seg. 3	Seg. 4	
Before	the young	jockey had	raced the	← Point of ambiguity

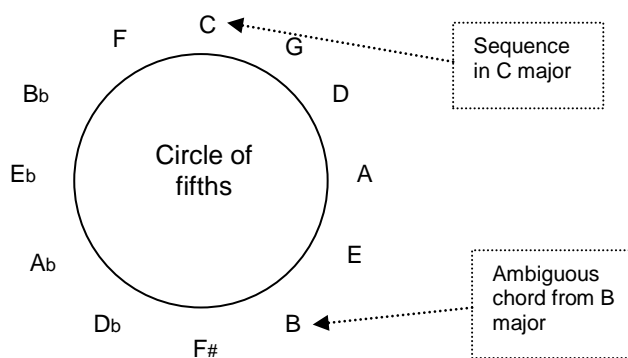| Seg. 5	Seg. 6	Seg. 7
horse received	a dose	of injections

↑ Response time measure

Figure 3: Ambiguous sentence featuring point of ambiguity and location of response time measure

Non-ambiguous sentences were constructed in a similar manner, but with no inherent ambiguity; Response times were also measures in the same location, however, to maintain reliability (see appendix for stimuli).

The music files were created using Cubase SX midi software. All chords were manually entered into a musical score format, before realistic sound effects were added. This was achieved using Reason (version 3) software, which is designed to add sound effects to midi information. This process consisted of adding reverb and

chorus effects to create a non-artificial sound; also, a combination of grand piano and soft organ sounds were generated to create a realistic yet non-distinctive sound[2]. Finally, the midi files were transformed into recognizable sound file (wav. format) using Melodyne software.
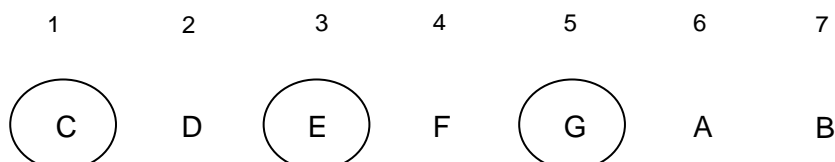
The chords were composed in order to generate ambiguity and non-ambiguity. To generate ambiguity, chords from the same musical key were employed, yet one chord was placed at the point of ambiguity; this chord did not conform to the key and thus, ambiguity was created my manipulating expectancy. This sequence is referred to as non-diatonic (meaning the sequence does *not* conform to a particular key). The chord used to generate musical ambiguity was selected from the circle of fifths (see diagram 2.1), which is a musical representation of relations among keys. Keys that are adjacent share tonal relations, whereas keys represented at distant points do not bear a tonal similarity. A sequence in C major, for example, contained a B major chord at the point of ambiguity; this is separated by 5 steps, as may be seen in figure 4:

Figure 4: Circle of fifths demonstrating relationship between major keys

This figure illustrates a substantial distance between C major and B major. Therefore, there the choice of key was predicated on psychological and musical theory[3].

A musical condition also manipulated local expectancy. To achieve this, all chords were created in the manner described above, yet were not constructed according to traditional musical theory. For example, traditional chords serve as local cues for processing musical stimuli; certain chords may act as spatial cues that orientate the listener towards a particular key. Figure 5 illustrates the construction of traditional chords:

---

[2] In order to avoid a possible attention confound with a grand piano, for example, a combination of sounds were used to generate a non-attentional, yet realistic sound.

[3] Note also that studies by Krumhansl and Kessler (1982) led to the creation of a geometric diagram illustrating the spatial relation of musical keys. A reference to this diagram finds C and B major to be distant relations.

Figure 5: Construction of traditional chords from the key of C major. Circled notes are played concurrently to create a chord (referred to as a triad)

When notes 1, 3 and 5 are combined, the result is a C major chord. Further chords are also created according to the same pattern, which results in a combination of major and minor chords that act as local cues to spatial analysis. Accordingly, certain chords play more prominent roles than others. For example, the chords I, IV and V are highly important chords that aid musical navigation (note that chord degrees are referred to in Roman Numerals). Figure 6 illustrates the chords in a typical major key:

I	ii	iii	IV	V	vi	vii
C	Dm	Em	F	G	Am	B°

Figure 6: Chord degrees in C major; m refers to a minor chord (for example, Dm is D minor) and ° refers to a diminished triad (this is not important for the current example however, and will not be discussed)

Chords can also be constructed to exclude local processing cues, such as the chords C, F and G in the above example. The result of this approach is that no particular chord acts as a perceptual cue. However, all notes will be derived from the same key (C major, for example), therefore the global perceptual cue remains. As an example of this approach, consider the following chords in relation to figure 6:
1. Notes 1,2,5 yield the notes C, D, G.
2. Notes 1,4,7 yield the notes C, F, B.

Both examples are within the key of C major yet are not traditional chords. Therefore, local processing cues are absent but a global cue remains. Also, as a further note on chord construction, note that ambiguity was created in the same manner as traditional chords; a distance of 5 steps on the circle of fifths to manipulate expectancy (see figure 4). Note that in the study, chords were constructed of 4 notes (3 notes are used here for example purposes only). Finally, chords were selected from five keys, in order to avoid effects of habituation[4] (see appendix for musical stimuli). Figure 7 illustrates both a traditional and novel musical sequence with sentences:

(a)

| After | they | finally | paid the | bill left | a mark on | their wallet |

(b)

---

[4] The keys of C, D, G, F and A major were used.

Figure 7: Example of music and language as presented in the study. (a) Traditional music/language condition. (b) Novel music/language condition

In order to facilitate participant concentration, a comprehension question was asked after each sentence. The response accuracy (yes or no) was measured. Also, response times to answer each question were taken, yet only as a means of excluding responses above 8000 milliseconds and below 1000 milliseconds.

The experiment was created using E-Prime version 2.0 software. Sentences were programmed to display each segment individually, with a musical chord presented concurrently (in the musical conditions). E-prime was programmed to collect response times and measure question accuracies. A practice session was also provided prior to commencing the main task. All tasks were presented on a laptop with 17.3 inch screen size, with headphones in all conditions (headphones facilitated background noise reduction in language only tasks whilst providing clarity of sound in concurrent tasks).

Further materials included the use of controlling measures such as attention and short term memory. Attention was included in the traditional music/language task and featured an ambiguous chord played 10 decibels louder (db). As noted in Patel (2008), this is sufficient to distract attention[5]. This chord was placed on the point of ambiguity to enable a distinction to be made between syntactical ambiguity processing and mere attentional processes. Short term memory was assessed with a numerical digit span test. Each numerical string consisted of three examples; if participants failed to answer two correctly then a third opportunity was provided. Measures were also taken of age, gender and instrument.

Procedure

The groups were approached with an offer of participating in the study. Participants who agreed to undertake the study were first provided with an information sheet and consent form. Participants were informed verbally and in writing that no pressure was being placed upon them and the freedom to leave remained. After signing the consent to participate, demographic details were collected before a digit span test was administered. This was administered verbally and responses collected by the researcher.

Following the memory test, participants were told to focus on the computer screen and follow the instructions. A practice session introduced the participants to the procedure; a welcome screen was read, followed by instructions to press *space bar* to move to the nest screen/segment, and *Y* for a yes answer, *N* for no. Two practice sentences were presented before the main tasks commenced. Response times were *not* collected for the practise sentences.

The main study consisted of three tasks: (1) a language only task, (2) traditional music and language, and (3) novel music and language. All tasks were performed successively, with an information screen between each task. All tasks also adhered to a self-paced paradigm, whereby participants were in control of the presentation. The language task featured 5 ambiguous and 5 non-ambiguous tasks, in random order. Participants were required to answer a comprehension question after each

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[5] Note that increasing volume to 10db is substantial and may result in the sound being clipped. A visual display revealed a clipped sound but it did not affect the auditory quality. Future researchers should nevertheless be aware of this issue.

sentence. The second tasks featured traditional chords presented concurrently with sentence segments; 5 sentences of ambiguity, 5 of non-ambiguity and 5 of attention were presented in random order. Participants were again required to respond to a comprehension question. Finally, the third task featured novel musical chords and sentences presented randomly, and comprehension questions once again.

Participants were advised to use the headphones throughout the tasks, regardless of whether music was presented. This ensured background noise was suppressed in the language only task, and music/language tasks required less attentional resources to distinguish musical stimuli from background noise.

Participant response times were recorded at segment 5 and question accuracy responses were also measured. A final noteworthy point regards background noise; for non-musicians the environment was free of distractions, both auditory and visual; yet for the musicians, the environment was moderately distracting, with both visual distractions and auditory distractions. However, the pilot study session highlighted the importance of noise-reducing headphones, which eliminated a great deal of auditory noise.

Results

A brief outline

To maintain clarity in the current section, the results will be reported in the following manner: firstly, the pilot data will be briefly reported; secondly, the results of response times; and thirdly, the question accuracy findings. The dependent measure of response time will be regarded as the chief representation of the dataset; question accuracy findings are merely reported to add support to the former measure, whilst also illustrating certain divergent findings so that a thoroughly objective account may be drawn.

Pilot session

Results from the pilot session will be reported briefly in order that comparisons may be made with the main data findings. Two 3*2 ANOVA with condition and ambiguity as within-subjects factors were performed with response times (measured at segment 5) and question accuracies. Initial findings indicate the effect of condition violated ANOVA assumptions ($p = < .0005$ for response times and $p = < .05$ for question accuracies). Results are therefore reported from multivariate tests, which found no significant effect for condition on response times ($F(2,12) = 3.533$, $p = .062$) and question accuracies ($F(2,12) = .927$, $p = .422$). Regarding ambiguity, no significant effect was found on response times ($F(1,13) = .591$, $p = .456$), yet a main effect was found on question accuracy ($F(1,13) = 65.945$, $p = < .0005$).

The disparity of findings from both dependent measures necessitated adjustment to the study, prior to the main data gathering. The obvious factor influencing the heterogeneity of results was likely the background noise. This was largely unavoidable, although a change of location marginally reduced the noise. However, it was necessary to utilize noise-reduction headphones in the main testing sessions. This ensured background noise was barely audible and therefore, unlikely to affect participants' attention. The inclusion of headphones vastly improved the significance of the results, as the following data report.

Response times

Response times were measured in milliseconds on segment 5 of each sentence. The mean response times may be seen in table 3.1. Condition 1 refers to task 1 (language only), condition 2 refers to task 2 (traditional music/language) and condition 3 refers to task 3 (novel music/language).

Table 2
Mean response times for musicians and non-musicians in each condition in milliseconds (ms). All responses measured on segment 5 of each sentence *(standard deviation in parenthesis)*
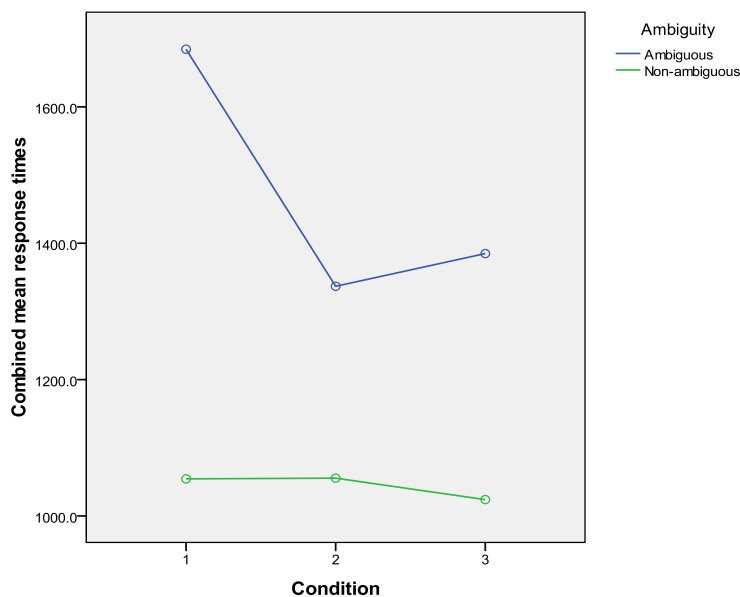
	Musicians		Non - musicians	
Condition	Ambiguous	Non-ambiguous	Ambiguous	Non-ambiguous
1	1820.53 (*768.71*)	1071.02 (*389.39*)	1548.58 (*525.16*)	1037.73 (*308.10*)
2	1502.81 (*868.06*)	1135.39 (*794.39*)	1170.83 (*395.37*)	975.46 (*268.56*)
3	1485.58 (*855.93*)	1082.31 (*500.63*)	1284.10 (*384.94*)	965.61 (*284.31*)

Responses differed according to ambiguity in all conditions for both groups; longer response times indicate ambiguous sentences took longer to process. Mean responses also highlight a difference between condition for both groups; however, contrary to Patel's SSIRH the results indicate reduced response times in both music conditions compared to the language only condition. Interestingly, the table indicates differential responses to conditions 2 and 3 between groups (ambiguous sentences); musicians response times slightly improved in condition 3 (as indicated by faster responses), whereas non-musicians response times slightly worsened (as indicated by a slower response time). However, the combined group responses indicate an increase in syntactical processing in music conditions, particularly condition 2. (see figure 8 for the ambiguity*condition interaction).

These results are supported by statistical analysis. A 3 factor (3*2*2) mixed ANOVA was conducted where condition and ambiguity were within-subjects factors and group was a between-subjects factor. Results of the ANOVA reveal a significant effect for condition ($F(2,68) = 4.504$, $p = < .05$, partial $n^2 = .12$). Tests of within-subjects contrasts also reveal a significant linear trend ($F(1,34) = 6.327$, $p = .017$, partial $n^2 = .16$). This supports the descriptive statistics for differences among condition. However, to further analyze this effect, two 2*2 ANOVA were conducted for conditions 1 and 2, and 2 and 3. The results reveal a significant effect when conditions 1 and 2 are included ($F(1,34) = 5.741$, $p = .022$ partial $n^2 = .14$), but no significant effect for conditions 2 and 3 ($F(1,34) = .021$, $p = .884$). This indicates a

significant difference between condition 1 (language only) and condition 2 (traditional music/language), but no significant difference between conditions 2 and 3 (novel music/language). This might be partially explained by the differential group responses to conditions 2 and 3 (see table 2). Furthermore, this might also explain the low effect sizes.

The expected result for ambiguous sentences was also supported ($F(1,34) = 64.566$, $p = < .0005$, partial $n^2 = .66$); Ambiguous sentences were longer to process than non-ambiguous sentences. A significant effect was also found for condition*ambiguity interaction ($F(2,68) = 17.610$, $p = < .0005$, partial $n^2 = .34$; see figure 3.1 overleaf). This interaction also produced a linear ($F(1,34) = 23.866$, $p = < .0005$, partial $n^2 = .41$) and quadratic relationship ($F(1,34) = 13.432$, $p = .001$, partial $n^2 = .28$).

Figure 8: Combined group responses for ambiguity across conditions (ms)

Despite a mean difference in group (musicians mean = 1349.61; non-musicians mean = 1163.72), no significant effect was found ($F(1,34) = 1.291$, $p = .264$). Similarly, there were no interaction effects for group*condition ($F(2,68) = .320$, $p = .727$), group*ambiguity ($F(1,34) = 2.448$, $p = .127$) and group*condition*ambiguity ($F(2,68) = .785$, $p = .460$).

A final analysis of response time concerns the effect of attention in condition 2. Attention was measured to test if ambiguity could be differentiated from mere attention. A 3*2 ANOVA was conducted with attention, ambiguousness and non-ambiguousness as levels of condition 2, and musicians and non-musicians as levels of group. Combined group means indicate that attention affected processing times above that of ambiguity (see table 3.2). Inferential statistics reveal no group difference ($F(1,34) = 1.718$, $p = .199$) but indicate a significant effect for condition 2 variables ($F(2,33) = 17.290$, $p = <.0005$, partial $n^2 = .51$). Note that F values from multivariate tests are reported due to significant sphericity effects.

Table 3
Combined mean response times for condition 2 levels (ms)

Variable	Combined mean responses
Ambiguous	1336.82
Non-ambiguous	1055.42
Attention	1540.36

To further examine this effect, three t-tests were conducted to examine the exact difference between variables (significance level was adjusted to .017). Results indicate significant difference between attention and ambiguous sentences (t(35) = 3.079, P = .004), between non-ambiguous and ambiguous sentences (t(35) = 4.775, p = < .0005) and between attention and non-ambiguous sentences (t(35) = 5.738, p = <.0005). These results suggest that contrary to previous findings, attention played a significant role in sentence processing. However, given the significance of ambiguity, it is not likely that attention is a sole factor; the coupling of attention and ambiguity might have had dual effects on ambiguous sentence parsing.

Question accuracy
Data from question accuracies were also analyzed. Although questions were primarily included to encourage focus among participants, the significant effects found in the analyses highlight the necessary inclusion of this data. The initial results may are displayed in table 4, illustrating the mean differences of each group across conditions:
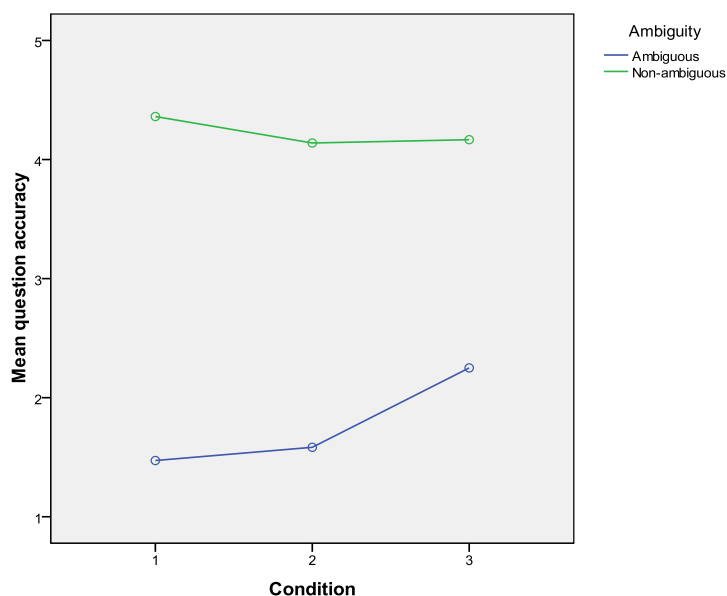
Table 4
Mean question accuracies for musicians and non-musicians in each condition (maximum possible score was 5 correct responses)

Condition	Musicians		Non – musicians	
	Ambiguous	Non-ambiguous	Ambiguous	Non-ambiguous
1	1.94 (1.55)	4.33 (0.59)	1.00 (0.84)	4.39 (0.85)
2	1.56 (0.78)	4.11 (0.96)	1.61 (0.85)	4.17 (0.92)
3	2.11 (1.13)	4.22 (0.73)	2.39 (1.34)	4.11 (0.68)

The figures indicate a difference in processing ambiguous sentences compared to non-ambiguous sentences; in each condition data from both groups indicate increased accuracy in non-ambiguous sentences, whereas accuracy is lower for ambiguous sentences. However, the results for conditional differences are not congruent with the previously reported response times. Musicians' responses for ambiguous sentences decreased in accuracy in condition 2 but increased above baseline in condition 3. Non-musicians, however, displayed a constant increase in each condition. However, the condition*ambiguity interaction reveals a linear increase in accuracy (see figure 3.2 overleaf). This result is congruent with response time results, suggesting that overall, the music facilitated the processing of linguistic syntax.

The statistical analyses support the mean results. A 3*2*2 ANOVA was conducted with condition and ambiguity as within-subjects factors and group as the between-subjects factor. Results suggest a significant effect for condition (F(2,68) = 3.205, p = < .05, partial n² = .09), ambiguity (F(1,34) = 351.022, p = < .0005, partial n² = .91) and interaction effect of condition*ambiguity (F(2,68) = 4.985, p = .01, partial n² = .13; see figure 9 overleaf). These results support the previous analyses on response times, with significant effects for condition and ambiguity in particular. Furthermore, the results of within-subjects contrasts reveal a linear relationship for the interaction of condition*ambiguity (F(1, 34) = 12.629, p = . 001, partial n² = .27), and condition*ambiguity*group (F(1,34) = 6.443, p = < .05, partial n² = .16).

Figure 9: Combined group accuracy means for ambiguity in each condition

The results of the ANOVA did not support a group difference (F(1,34) = .392, p = .54), further confirming the response time results. Also, all interaction effects involving group were not supported.

To explore the exact difference among conditions, two 2*2 ANOVA were conducted with ambiguity as a factor and condition as a factor (conditions 1 and 2 were included first, then conditions 2 and 3). The object of these analyses was to determine whether condition differed between conditions 1 and 2 only (as in

response time analyses) or if conditions 2 and 3 also displayed a significant difference. Results reveal no significant difference of conditions 1 and 2 (F(1,34) = .156, p = .70) but indicate a significant difference between conditions 2 and 3 (F(1,34) = 5.645, p = < .05, partial n² = .14). Contrary to response time results, the analyses of question accuracies reveal the direction for significance lies between conditions 2 and 3, not conditions 1 and 2 (as found in response time results). This presents a somewhat perplexing finding, yet it is important to note that response time reflect measures of greater validity, whereas question accuracies were not validated by standard means (for example, Cronbach's alpha). Therefore, question accuracy data should not be wholly relied upon; the data represents a general direction to be referred to as support of response time measures, not as an independent and solid measure of reliability.

Given the previous consideration, the data was subject to a final analysis for the role of attention; this data was then compared to that for response times. To analyze the data, a 3*2 ANOVA was performed with condition 2 variables (ambiguous, non-ambiguous and attention) as within-subject variables and group as a between-subjects factor. Descriptive results are displayed in table 3.4, highlighting a combined group difference:

Table 5
Combined group accuracy means

Variable	Combined mean responses
Ambiguous	1.58
Non-ambiguous	4.14
Attention	3.08

The figures suggest that attention certainly differed from ambiguous sentences, yet in a contrary direction to response times; rather than impede sentence comprehension, the data suggests that attention facilitated comprehension. Although, congruent with response time data, the current ANOVA finds no group difference (F(1,34) = .130, p = .72). However, to further explore the data and determine the exact direction of significance, a series of three t-tests were performed (significance adjusted to .017). The results reveal significant effect for all variables, although the variables of interest are attention and ambiguous sentences (t(35) = 7.052, p = < .0005). Therefore, the effect of attention is indeed significant, yet in a converse manner to the response times. It is necessary to reiterate the significance of interpreting question accuracies, however. The questions were not validated according to general statistical methods and any incongruence may be reflected in this fact. Further to the point, correlations between response time and question accuracy data for ambiguous sentences in each condition yield the following: condition 1 (r = .43, p = < .01), condition 2 (r = .08, P = > .05) and condition 3 (r = .10, p = > .05). A significant yet moderate correlation is found for response time and question accuracy in condition 1 ambiguous sentences, yet no worthy results for

conditions 2 and 3. The weakness of the correlations may therefore, reflect the inconsistency between both measures. Consequently, it is necessary to reaffirm the importance of interpreting *response times* as a reflection of the data, whilst interpreting question accuracy data as additional *support* for response times.

Discussion

The current study contributes to the literature on music and language relationships. Specifically it adds to the small but expanding literature regarding a shared syntactical relationship for music and language processing. The hypotheses of the study were as follows: (1) Ambiguous sentences would require longer processing times than non-ambiguous stimuli; (2) Music and language presented concurrently would result in longer processing times than language only; (3) Novel music/language would differ from traditional music/language due to the removal of local processing cues; (4) Attention would not significantly effect sentence processing; and (5) Musician and non-musicians were recruited to investigate any performance differences. Many effects were significant and predictions either fulfilled or partially fulfilled. Indeed, main effects were found for both measures – response times and question accuracies. However, it is important to note that reference is made to response times mainly, with additional support for question accuracies when noted. The reason for this distinction regards on-line and off-line processing and will be discussed below.

Fedorenko *et al* (2006) distinguish between response times, which are a measure of on-line processing and question accuracies, which are a measure of off-line processing. Ferreira *et al* (2001) states that off-line measures do not accurately reflect what participants have understood. Off-line measures only reflect what people *believe* has been understood (see Erickson & Mattson, 1981, for the Moses Illusion). Caplan and Waters (1999) add to this by stating that off-line measures reflect *post*-interpretive processing, which involves various cognitive processes, such as the semantic integration with previously held knowledge. Such post-interpretive processing does not accurately reflect on-line processing during tasks. It is for these reasons that response times will be referred to unless specific mention is made of question accuracies. However, it is now necessary to discuss the main findings.

Results of the ANOVA revealed a significant effect for ambiguity. Mean response times indicate that ambiguous sentences were longer to process than non-ambiguous sentences. This is not a surprising result as an overwhelming amount of psycholinguistic research has found ambiguous sentences difficult to process (see Clifton and Duffy, 2001; and Pickering, 1999 for reviews). In particular it reflects the tendency of human parsing to attribute the initial phrase of a sentence to both the subject and the object of the action. This is in line with minimal attachment theory (Frazier, 1987; Frazier & Rayner, 1982).

Furthermore, the findings also support the arguments forwarded by Ferreira *et al* (2002) for factors that might affect sentence processing. Such factors, such as semantic extraction and disfluencies render any parsing theory as incomplete. However, it is also noteworthy that despite such confounds, the human parser maintains the tendency to comprehend sentences as per Frazier's (1987) minimal attachment theory. Note that responses from question accuracies also reflected this finding. Although, as noted in the previous paragraph, it is necessary to include this as supporting date yet it is not sufficient as an individual dependant measure, despite such a large effect size ($n^2 = .91$).

Continuing with significant effects, a finding of considerable interest regards condition. A significant was obtained for response times (p < .05) but not for question accuracies (p = .70). The disparity might reflect the difference of on-line and off-line processing. As stated, post-interpretive methods involve a degree of integration with long-term semantic knowledge. Nevertheless, the prediction for response time was met. However, contrary to previous research (Slevc *et al*, 2009; Fedorenko *et al* 2009) the current findings revealed efficient processing in the music/language condition above that of the language only condition. Previous work on the SSIRH found processing to be significantly longer when both music and language were presented concurrently. The current findings stand in stark contrast and present a problem. In appealing for solutions, two possibilities present themselves. The first concerns practise effects and the second poses a new role for the SSIRH. Both solutions are discussed in the following two paragraphs.

Practise effects are an obvious culprit. Although the sentences were randomized, there were three conditions and it is possible that condition 1 laid the foundations for practise, while condition 2 presented an opportunity to display the skill. Indeed, practise effects are often unavoidable and in the current study it is likely to have exerted influence. However, given that response times and question accuracies were significant it also suggests another solution.

The second offering concerns the SSIRH and its role in a different manner. Indeed, although the results offer grounds for refuting the SSIRH it is nevertheless inappropriate as a solution may be possible that reconciles the current data and previous work. The solution concerns modularity (Fodor, 1983); while music and language may be conceived as independent modules, it is also possible to conceive of the SSIRH as a module. The shared syntactic relationship of music and language necessarily pose a problem then – are music and language independent modules or is auditory syntax a module? To offer a full exposition is beyond the scope of the current paper. However, if the following argument is predicated to the basis of music and language syntax as a module then progress and understanding may be made. Consider: if one module governs the processing of auditory syntax instead of two modules than require constant attention switching, then it logically follows that processing may well be efficient due to the reduced burden. In effect, a single module conducting the work that two modules would otherwise perform. Surely, the attentional demands of processing two modules would be less efficient than governing one? Such a solution would certainly account for the present data. However, it is realized that such an idea stands in opposition to previous data and the predictions of the SSIRH. There may however, be means of reconciliation. Consider sentence 4(a):

4(a) "The knight (that) the king helped sent a gift from the castle"

This example appears in Fedorenko *et al* (2009). It contains two examples of ambiguity – reduced complement and object extraction. If presented without *that*, the sentence is described as reduced complement. It is known in the literature that reduced complements causes processing difficulty (see Gibson, 2000; King & Just, 1991). However, there also exists the difficulty caused by object-extraction, which refers to the recipient of the action being parsed in the initial phrase. Gibson (2000) finds that this is harder to process than a subject-extracted sentence, such as sentence 4(b):

4(b) "The king that helped the knight sent a gift from the castle"

In this case the subject (the agent) of the action is parsed in the initial phrase. The stimuli are therefore difficult to process with two sources of ambiguity. In contrast, the stimuli employed in the current study, despite being ambiguous, contains only one source of ambiguity. It is therefore easier to process than the previous example. Therefore, the SSIRH might facilitate the processing of easier stimuli with concurrently presented music, and hinder the processing of difficult stimuli. It is a novel solution than can account for the current findings but further research is required to substantiate such a claim.

With regards to the novel music and language condition, closer analyses revealed no significant difference to the traditional music/language condition. However, this pertains to response times; for question accuracy data a significant difference was found (p = < .05). Given that these results reflect off-line processing, it is not considered a significant finding. Instead it merely reflects a finding of partial significance. The mean responses might account for the disparity; regarding response times, musicians' performance improved in condition 3 from condition 2; Non-musicians' performance became slightly impaired, however. For question accuracy data the findings are less disparate; both musicians and non-musicians improved in accuracy in condition 3, from condition 2. The latter finding further highlights the significance for question accuracies. However, such incongruity between dependent measures requires explanation. It is likely that participants became fatigued in condition 3, or that the novelty of the musical stimuli was not processed immediately; the novel chords may have elicited post-interpretive processing to comprehend the stimuli. A further explanation concerns the effects of harmonic manipulation. If traditional harmony facilitates implicit and explicit music perception then the absence of such cues might have triggered a perceptual obscurity. In other words, the absence of recognizable chords elicited a perceptual 'ignorance', with immediate (on-line) access to representations impossible because no representations exist for the novel stimuli. In this scenario, participants would need to reflect post-interpretively on the novel stimuli. This may therefore account for insignificant response time measures but significant question accuracies. However, further research is required to assess the important role of traditional harmonic sequences for music perception.

A noteworthy aspect of the study was the inclusion of both musicians and non-musicians. With no significant difference found for both dependent measures it is likely that musicians' ability to process music implicitly is questionable. Research using EEG finds musicians have a pre-attentive ability to detect music (Seppänen *et al*, 2007; Daltrozzo & Schön, 2009; Tillmann, Justus & Bigand, 2008), reflecting an implicit process. Yet, in the current behavioural study the evidence suggests that musicians did not process the musical stimuli implicitly. One explanation may be that musicians simply develop sophisticated attentional mechanisms. Another regards the nature of the study; all participants were told to focus on the linguistic stimuli. Therefore, musicians simply did not attend to the musical stimuli, further reflecting the trained attention required from musicians. A final note concerns the nature of the paradigm; Caplan and Waters (1999) state that presenting dual tasks, with one interrupting the other task is a matter of attention switching and does not accurately reflect a shared pool of resources. Although the current paradigm did not feature interruptive tasks, it still remains a possibility that attention is an inherent phenomenon of the paradigm. Therefore, the result may also reflect methodological

concerns. Indeed, attention featured as a significant factor for both measures. However, it is not plausible to suggest that attention is purely the dominant force. This is due to the significance of ambiguity in all conditions and for both measures. Despite previous research finding no effect for attention (Slevc *et al*, 2009; Fedorenko *et al* 2009) the current study suggests that attention is inherent to a degree, yet is not the only variable.

Limitations
An obvious limitation of the study concerns distraction. The pilot session highlighted the need for reduced noise, and consequently, noise-reduction headphones were employed in the main study. This did not help with visual distraction however. Non-musicians were studied in a quiet area free of distraction. Musicians, by contrast, were subject to varied amounts of visual distraction. Although, it is not the intention of the researcher to overstate this; distraction for the musicians did not play a huge role. It merely highlights the difference in testing conditions of both groups.
Although significant results were obtained, a larger sample would be advantageous to study. A substantial sample would further support the notion of a SSIRH.
A further limitation concerns the linguistic stimuli. Although, Ferreira and colleagues (2002) have argued that facets such as semantics are an inherent component of syntactical processing, the use of response times as the primary measure dilutes the effect of semantics. Such effects of semantic integration are observed in question accuracies, further emphasizing the importance of on-line measures.
A final limitation concerns the paradigm employed in the current study. Based on the self-paced reading paradigm used in psycholinguistic research (Pickering, 1999) it is modified to concurrently present music stimuli. A concern of the current author is the implicit presentation of music stimuli, whereas the linguistic stimuli demands explicit attention. If language is a product of focused attention, yet music is outside of focused attention then one wonders if it is the correct paradigm for fully researching the SSIRH. It is therefore important to view present behavioural evidence in conjunction with EEG and neuro-imaging studies. Taken together, both approaches present a more appropriate means of supporting the shared syntactical framework, in place of evaluating *one* approach.

Future Directions
Further research on Patel's (2008) SSIRH may be predicated on two approaches: the first concerns the pure, cognitive nature of the syntactical relationship; the second concerns the applied value. In the first instance, research into stimuli of varied difficulty levels would be advantageous. If easier sentences are facilitated by music then research is needed to determine *how* this may work. The second concerns the perceptual cues that guide music perception. Music stimuli require independent focus to determine if local cues function prominently in guiding individuals through musical 'space'. Such research would serve as a foundation for practical study, such as determining if certain harmonies attract attention, or if attention wanes as a result of certain harmonies. Furthermore, the applied value of the SSIRH may be directed toward music therapy. Research with music and dyslexia has returned positive outcomes (Huss, Verney, Fosker, Mead & Goswami, 2011), and research with specific language impairments strongly suggest music may foster syntactic understanding in language (Jentschke *et al*, 2008).

In conclusion then, evidence from the present study suggests that music and language share a unique syntactical relationship; this relationship may be advantageous if music does indeed facilitate certain skills involving language. However, research is needed to examine this issue, particularly in an applied setting where music and language bear the hallmark of conferring possible learning benefits.

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