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ARE SYNTACTIC PROCESSES IN LANGUAGE AND MUSIC DOMAIN SPECIFIC?

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Abstract

In recent years, an increasing number of studies have adapted music as a domain of experimental research, focusing on basic processes that underlie everyday music production and perception. This growing body of evidence shows a large similarity between the syntactic processing of melodies and sentences. The current paper focuses on the nature of this relationship between syntactic processing in language and music. The paper starts with a theoretical review that discusses research concerning the specific mechanisms underlying syntactic processing in music and their relationship to language. Based on this body of research, the current paper aligns with the Shared Syntactic Integration Resource Hypothesis (Patel, 2003) in stating that the similarity in syntactic processing of language and music can be characterized by domain-general processes of structural integration that make use of domain-specific syntactic rule representations to structure both linguistic and musical sequences.

This theoretical review is followed by an empirical study that addresses several weaknesses in previous evidence concerning the SSIRH. In contribution to previous research, the findings reveal that syntactic re-analysis of sentences interferes with incongruent harmonic integration of accompanying melodies. Apart from this novel form of evidence for the idea of shared resources for structural integration in both domains, the empirical study also investigates simultaneous structure processing of naturalistic language and music, showing that previously found interference evidence is mainly limited to unexpectancy designs.

A further remark that can be made concerning the concept of shared structural processing between language and music is that this finding has rarely been linked to the psycholinguistic domain. Therefore, a second empirical study applies the reviewed concepts to recent findings of attachment priming (e.g. Scheepers, 2003; Desmet & Declercq, 2006), a form of syntactic priming that is related to the structural hierarchy of a sentence, rather than syntactic rule representations. Here, a theoretical framework for syntactic priming is presented that is strongly based on the account of SSIRH. This theoretical framework states that attachment priming relates to priming of domain-general structural integration processes, and can therefore be seen as distinct from earlier syntactic priming findings that are explained through activation of the domain-specific syntax rules. The study further describes two experiments that provide evidence for this framework. A first experiment shows that attachment priming can be found from the structural integration of music to sentence completion, suggesting that attachment priming cannot be related to domain-specific syntactic representations. A second experiment provides evidence against a prosodic priming account for sentence priming, using modern sound-changing software, thereby confirming the explanation of sentence priming through implicit syntactic processing.

Korte Samenvatting

In de voorbije decennia is muziek een groeiend domein van experimenteel onderzoek geworden, waarbij voornamelijk gefocust wordt op basale processen van alledaagse muziekproductie en -perceptie. Dit heeft geleid tot een groeiend bestand van bevindingen die duidelijke patronen van gelijkenis vertonen in de manier waarop melodieën en zinnen syntactisch verwerkt worden. Deze scriptie gaat van start met een theoretisch overzicht van verscheidene studies die zich reeds gericht hebben op de specifieke mechanismen die aan de basis liggen van muzikale syntaxverwerking, en hun relatie tot taal. Uit dit overzicht wordt gealigneerd met de Shared Syntactic Integration Resource Hypothesis (Patel, 2003), die stelt dat de overlap in syntactische verwerking van taal en muziek gekarakteriseerd kan worden door domeinoverschijdende processen van structurele integratie, die gebruik maken van domein-specifieke syntaxrepresentaties.

Uit dit theoretisch overzicht volgt een empirische studie, die zich rich op beperkingen in eerder onderzoek betreffende de SSIRH. In overeenkomst met de SSIRH wordt in dit experiment de bevinding gemaakt dat syntactische heranalyse van zinnen direct interfereert met een incongruente harmonische integratie van begeleidende melodieën. Buiten deze nieuwe vorm van evidentie voor het idee van gedeelde resources voor structurele integratieprocessen in beide domeinen, richt de empirische studie zich ook op de manier waarop er gelijktijdige structurele verwerking van natuurlijke taal en muziek kan plaatsvinden. Hierbij wordt gevonden dat eerdere evidentie voor interferentie tussen de domeinen voornamelijk beperkt is tot experimentele opzetten.

Een laatste opmerking is dat het voorgestelde onderzoek omtrent de relatie tussen syntaxverwerking in taal en muziek weining ingang kent in psycholinguïstische studies. In een tweede empirische studie worden daarom de eerder besproken thema's toegepast op syntactisch priming-onderzoek. Deze empirische studie richt zich op de recente bevinding van "attachment priming" (e.g. Desmet & Declercq, 2006; Scheepers, 2003), waarin er een priming van abstracte hiërarchische zinsstructuur gevonden wordt. Gebaseerd op de SSIRH suggereert deze studie een theoretisch raamwerk dat stelt dat "attachment priming" gezien kan worden als priming van de domeinoverschijdende structurele integratieprocessen, en dus te onderscheiden is van syntactische priming door activatie van domein-specifieke syntaxregels. Er worden twee experimenten vermeld waarin evidentie aangebracht wordt voor deze stelling. In een eerste experiment wordt aangetoond dat "attachment priming" gevonden kan worden van de integrationele structuur van een melodie naar zinsaanvulling, en dat "attachment priming" dus niet gebaseerd is op domein-specifieke syntactische representaties. In een tweede experiment wordt er evidentie geboden tegen prosodische priming, waarbij gebruik gemaakt wordt van moderne geluidsmanipulaties, en op deze manier verdere evidentie geboden wordt voor de stelling dat zinspriming gebaseerd is op impliciete syntaxverwerking.

Preface

In everyday life, music is mainly regarded as a form of pastime; a skill for people to train themselves in, something that can be produced and listened to as a form of leisure and self-expression. Research has found it quite hard to state an uncontroversial function of music. Even though it is a characteristic of every known culture, society has therefore long regarded music as a by-product of human functioning. This perspective might shift attention away from the fact that, given the way we are exposed to music on a daily basis, people around the globe have very strong competences for musical processing. When regarding implicit musical capacities such as auditory understanding (listening) and production (singing), it becomes clear that the domain of music might entail some very basic and universal processes that are suited very well for experimental studies.

In recent years, an increasing number of studies has focused on music as a domain of mental functioning, addressing several processes such as rhythm comprehension (e.g. Boltz, 1993; Ibbotson & Morton, 1981; Jones, Boltz & Kidd, 1982; Narmour, 1990), emotional semantics (e.g. Krumhansl, 1997; Sherer & Zentner, 2001; Meyer, 1956) , acoustics (e.g. Juslin & Laukka, 2003) and memory (e.g. Radvansky, Flemming & Simmons, 1995). A recent review of such studies can be found in Zatorre and Peretz (2001). One important aspect that has been focused on quite intensively in recent years (e.g. Koelsch, Gunter, Friederici & Schröger, 2000; Maess, Koelsch, Gunter & Friederici, 2001; Patel, 2003) is the syntactic structuring of separate sounds into harmonically perceived melodies, and its strong similarity to syntax processing in the psycholinguistic domain.

In this thesis, the relationship between syntactic processes in language and music is further addressed in three separate chapters. A first chapter presents a theoretical review of previous studies concerning this particular relationship, thereby integrating contemporary evidence with the Shared Syntactic Integration Resource Hypothesis (SSIRH, Patel, 2003), which states that the syntactic relationship between language and music can be characterized through an overlap in structural integration processes that base themselves on domain-specific syntax representations.

A second chapter presents an empirical study concerning the SSIRH (Patel, 2003). Out of the theoretical review presented in the first chapter, it becomes clear that there are several

issues concerning previous SSIRH research that need to be addressed further (mainly involving the complex and indirect nature of linguistic syntax measures used thus far). Therefore, this study reports an experiment that contributes to the hypotheses of the SSIRH through a novel design using direct harmonic integration measures. Apart from confirming previously found effects of interference between structural integration in both domains, the study also provides evidence for the idea that aligned structural processing of both music and language is perfectly plausible for natural and unambiguously structured sequences.

Finally, a third chapter presents a second empirical study, in which the previously discussed overlap of structural integration processing in music and language is applied to a recent point of debate in syntactic priming research, namely the recent findings of attachment priming. In recent studies (e.g. Desmet & Declercq, 2006; Scheepers, 2003,2011) it has been found that sentential priming is possible on the basis of structural attachment hierarchy, thus not to be explained by activation of syntactic representations like earlier syntactic priming evidence. Therefore, there is a need for a new theory that positions this attachment priming evidence in the field of syntactic priming. In this second empirical study, a novel theoretical framework is presented separating these novel forms of attachment priming from theories of syntactic priming based on the previously discussed SSIRH. Specifically, the formed theory states that attachment priming can be seen as distinct from earlier findings of syntactic priming, since it is based on the priming of domain-general structural integration processes, rather than on domain-specific representational syntactic networks. Consecutively, two experiments are reported that provide evidence for the idea of attachment priming as a priming of the structural integration processes. In a first experiment, clear evidence is found for attachment priming from the domain of music to language, following structural integration processes that are stated to overlap between the two domains. A second account provides evidence against the alternative explanation of prosodic priming of the surface structure, again providing evidence for the idea of priming through syntactic processes.

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Theoretical Review: Are Syntactic Processes in Language and Music Domain Specific?

Recent studies have adapted music as a domain of experimental research, focusing on basic processes of everyday music production and perception. An important consequence of this recent focus on music as an experimental domain of study is that a lot of research on basic musical processes sketches a clear relation to linguistic processing (for a review, see Peretz & Coltheart, 2003). Both can (initially) be seen as the processing of structured sequences of sounds (Handel, 1989), reflecting human capacities that are unique to our species (Mc Dermott & Hauser, 2005). Both processes have also universally evolved in human culture, and people have been reported to acquire a strong, implicit competence in them through daily exposure.

A specific domain in which music shares a large amount of conceptual overlap with language is the processing of sounds into a syntactic structure. The structural processing in both domains consists out of the combining of smaller units (words or tones) using syntactic rules (linguistic or musical) to form an endless possibility of higher-order structures (sentences or melodies). Furthermore, research has shown that in both domains, this structural integration is strongly based on the processes of prediction and expectancy violations (e.g. Boltz, 1993; Jonaitis & Saffran, 2009; Slevc, Rosenberg & Patel, 2009). Based on this knowledge, it is intuitively understandable that the increased focus on music as a domain of research has lead to stimulation of theoretical comparisons between musical and linguistic syntax processing. This theoretical study provides an overview of recent studies that have focused on this specific relationship.

Syntactic Processing in Music: Similar to Language?

When regarding the concept of syntactic processing, one needs to acknowledge that the concept of syntax has traditionally been linked to the domain of language. A large body of research has already focused on the specific syntactic processes that are involved in sentence

comprehension and sentence production (see Pickering & Ferreira, 2008). However, language is not the only domain where syntax is present. When looking at a general level, syntax can be described as the principles and processes by which elements are structured. Therefore, the processes by which separate sound sequences are structured into harmonic melodies can also be referred to as processes of syntax. A first part of this review elaborates on the processes by which music is syntactically structured, and their similarity to linguistic syntax processing.

Harmonic Integration: Syntactic Processing of Music

An essential process in musical comprehension consists out of organizing the separately heard sounds into structured sequences. An important aspect in this processing is that sounds can be structured according to harmonic rules. These "rules", mostly termed as "musical syntax", can be defined as the set of harmonic relationships between pitches. Figure 1 shows the "Circle of Fifths", which is a rather simplified schema for the harmonic relationships between pitches in Western tonal harmony. An easy way to describe this circle is that tones that are placed close to each other on the circle are harmonically congruent.

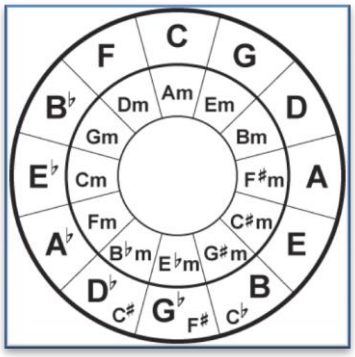


Figure 1: The "Circle of Fifths"

Recent studies have shown that the process of harmonically integrating separate tones into structured sequences mainly arises from the implicit learning of these harmonic relations underlying Western music (e.g. Bigand, Tillmann, Poulin, d'Adamo & Madurell, 2001; Koelsch et al., 2000; Tillmann, Bharucha & Bigand, 2000). With repeated exposure to a culture's music, listeners implicitly acquire expectations concerning what tones follow others,

based on this harmonic relationship between tones. If a tone is presented that is harmonically incongruent with the previous tones, people's expectation will be violated. The new tone will be perceived as unexpected/ "false" in the context of the previously heard tones, and therefore, a harmonic "boundary" will be constructed between this and the previous tones. Several studies (e.g. Bharucha & Stoeckig, 1986, 1987; Bigand & Pineau, 1997) have already been conducted to investigate this issue of harmonic "phrasing". In these studies, participants were provided with a musical context, which was supposed to activate the listeners' implicit knowledge of western harmony. This activation would lead listeners to anticipate events that are harmonically related to the previously heard elements. Throughout research, it was found that musically untrained listeners perceived musical tensions and relaxations when such anticipations were not met, in both melodies and harmonic chord progressions.

In summary, a person integrates sound sequences into "phrases" of harmonically congruent tones, based on his or her implicit knowledge concerning harmonic relations. This way, harmonic integration can be seen as a form of syntactic processing: combining smaller units (tones or chords) into structured "phrases" following syntactic rules (namely Western tonal harmony, cfr. Tan, Aiello & Bever, 1981). When relating this process of harmonic integration to syntactic processes in the domain of language, one could state that the structural segmentation of musical and linguistic sequences does indeed seem to happen through very similar mechanisms. In both domains, the structural integration of the sequence into meaningful "phrases" occurs by means of creating expectations for upcoming elements based on either linguistic or harmonic syntax rules.

The Nature of Harmonic Integration

Based on this strong theoretical relation between the process of harmonic integration and syntax processing in language, a growing body of research has investigated the nature and development of the processes underlying harmonic integration, thereby revealing further similarities with language processing. In the following segment, evidence will be reviewed proposing harmonic integration as a basic mechanism of auditory processing that - just like linguistic syntactic processing - can be largely seen as independent from formal knowledge, evolving very early in infancy through mere exposure in daily life.

Harmonic processing is largely independent from formal training.

A first topic of similarity between harmonic processing and syntactic processing in language is that the process of harmonic integration is found to be largely independent from formal knowledge, and rather seems to be based on implicit knowledge acquired through daily exposure. Several studies have shown that a wide variety of musical competences (and specifically harmonic integration) is strongly present with adults who have not received an official musical training (e.g. Cuddy & Badertscher, 1987). For example, the study of Koelsch et al. (2000) shows that also non-formally trained adults can clearly register violations in harmonic expectancy. This can be seen as evidence that, even without explicit knowledge, the human brain can create a harmonic context and expectancies based on auditory input. An extensive review concerning the musical abilities of adults with a lack of formal training can be found in the article of Bigand and Poulin-Charronnat (2006). Also when studying harmonic processing in children (Koelsch, Grossman, Gunter, Hahne, Schröger & Friederici, 2003), it is concluded that:

> *"The acquisition of (implicit) knowledge about musical regularities and the relatively fast and automatic processing of musical information according to this knowledge is a general ability of the human brain. "*
> (Koelsch et al., 2003, page 689)

Harmonic processing evolves very early in infancy.

A second topic of similarity between the process of harmonic integration and syntactic processing in language considers the finding that musical abilities such as harmonic processing are present very early in infancy. Several forms of research show strong musical competences in young infants (e.g. Safran, Aslin &Newport, 1996; Trainor & Trehub, 1994). A recent study conducted by Corrigal and Trainor (2010) has for example shown that harmonic sensitivity (i.e., registration of harmonic unexpectancies) can be found up until an age of 4 years. Also, the study of Koelsch et al. (2003) demonstrates that 5 year old children can already process music following a cognitive representation based on complex harmonic regularities. Neurological studies also provide strong evidence for the fast development of musical processing (e.g. Jentschke, Koelsch, Sallat & Friederici, 2008; Jentschke & Koelsch,

2009). Musical abilities like harmonic integration thus seem to be apparent very early in human development (see Wallin, Merker &Brown, 2000).

Harmonic processing has a universal basis.

A third similarity can be found in the universal nature of harmonic processing. In a study conducted by Trehub (2003), it was found that, where children detect harmonic alternations in simple Western or Javan melodies, adults will have a decreased performance on the unknown Javan melodies, towards chance level. In other words, harmonic integration seems to be based on quite universal processing, that can later be adapted following exposure to certain harmonic relations. This evidence supports the claim that there is a universal basis for music processing, and that cultural relativism at a musical domain can clearly be criticized (Mâche, 2000; Nettl, 2000). Contemporary evidence for the biological foundation and universality of several musical processes is further reviewed in Peretz (2006).

Overlap Between The Domains of Music and Language: The SSIRH

Due to the similarity that harmonic processing of music shares with syntactic processing in language on both the functioning and the nature of their mechanisms, it follows logically that there has already been quite extensive research directly investigating a possible overlap between both processes. This section of the review will focus on this direct comparison between syntactic processes in the domains of music and language.

Evidence for an Overlap in Syntactic Processing.

When reviewing studies that focus on this possibility of overlap, there does indeed seem to be evidence for shared syntactic processes. Neuro-imaging research has repeatedly investigated neuronal activity in both music and language processing, finding large domains of overlap. One example is the study of Patel, Gibson, Ratner, Besson and Holcomb (1998), in which was found that the P600 response elicited through a syntactic unexpectancy (as generally reported in language studies), could in fact not be distinguished from a similar P600 element elicited through a harmonic unexpectancy in music. Another example is the study of

Maess et al. (2001) in which was found that chords violating harmonic rules also elicited activation in areas that have repeatedly been shown to relate to syntactic processing in language, such as Broca's area. Furthermore, there is the study by Patel, Iversen and Hagoort (2004), investigating the effects of harmonic priming on people with a linguistic syntax comprehension deficit. They found that where normal participants have the effect that a target chord can be processed faster when it's harmonically close to its context (due to harmonic expectancies, cfr. "Circle of Fifths"), participants with deficits in linguistic syntax processing did not have such an effect. This can be taken as evidence that the harmonic knowledge of "musical syntax" is not activated or used in a normal way by Broca's aphasics. Finally, also developmental research (e.g. Jentschke et al., 2008; Jentschke &Koelsch, 2009), has shown that children with syntax processing difficulties in language also tend to have more problems in processing musical stimuli. All of this evidence strongly aligns with the idea of overlapping processes between harmonic integration of music and syntactic processing in language.

Evidence for Separated Syntactic Processing.

However, in contrast to the studies that were discussed earlier, there is also strong evidence in favor of domain-specific neuronal correlates of syntactic processing. Brain damage can turn people into musical "savants", meaning that even though there are general cognitive deficits, the harmonic processing of music is intact or even strongly improved (Beatty et al., 1988). At the other side of the dissociation, there are also known cases of "amusia", describing a specific deficit in music processing as a consequence of brain damage (Marin,1983). However, this finding of "amusia" in patients still seems to allow good verbal functioning (e.g. Luria ,Tsvetkova & Futer, 1965; Peretz & Coltheart, 2003). For a review, see Pearce (2005), and more recently, Alossa and Castelli (2009). Out of this dissociation in neurological correlates, there is strong evidence that at least when investigating on a certain level, there must be a clear distinction between harmonic processing in music and syntactic processing in language. Therefore, a comprehensive model is required that can account for the great similarities and overlap, as well as for the functional distinction found when comparing syntactic processing in music and language. Such an account can be found in the Shared

Syntactic Integration Resource Hypothesis (SSIRH, Patel, 2003), a theory that has recently gained a lot of attention in its research field.

The Shared Syntactic Resource Integration Hypothesis.

The Shared Syntactic Integration Resource Hypothesis (Patel, 2003) integrates all the above findings in an intuitively understandable way. It states that a distinction must be made between the specific syntactic rule representations of music and language on one hand, and on the other hand the structural resources and processes that make use of these representations. Of course, the representational networks underlying the syntactic or harmonic rules are clearly separated between the two domains. Therefore, a deficit in these domain-specific rule representations might cause a domain-specific problem. However, both domains depend on overlapping integration processes that base themselves on these domain-specific rule representations. In this way, there is indeed an overlap in the processes of "structural integration" (integrating a sequence into structurally relevant components). Thereby, the SSIRH accounts for both the neurological results of overlap, as well as the case studies showing clinical dissociation. For a schematic overview of this theory, see Figure 2.

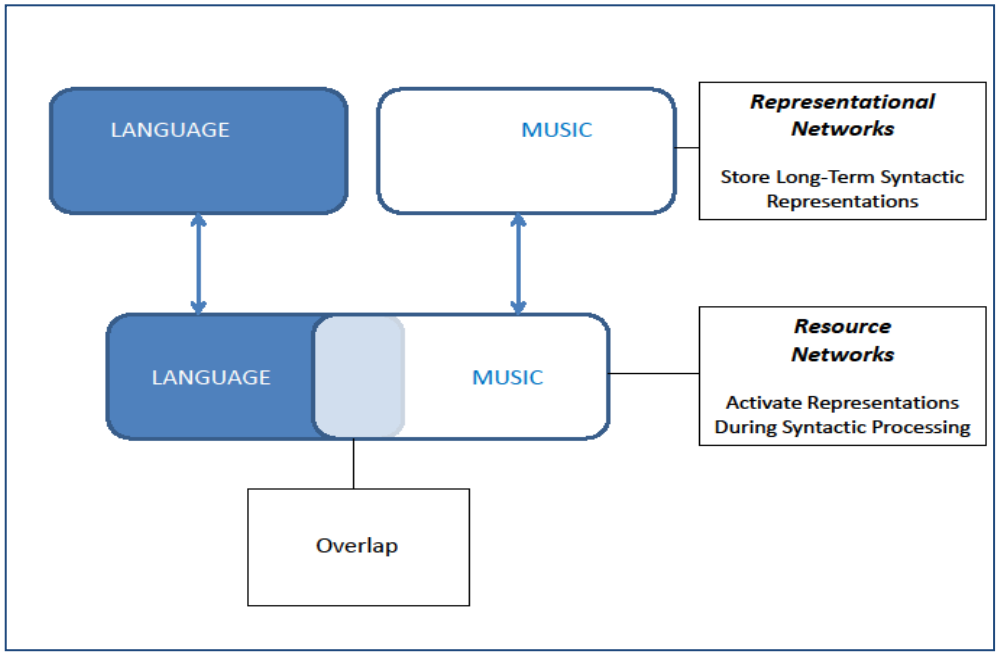


Figure 2: schematic overview of the SSIRH (adapted from Patel, 2003)

Evidence for the SSIRH

The theory behind the SSIRH (Patel, 2003) has important empirical implications. It assumes that an interaction between integration processes in language and music can be found, given that both depend on overlapping resources. Indeed, different forms of research have found evidence for an interaction between structural integration in music and language.

First, double-task designs in neuro-imaging research have revealed clear evidence for a neurological interaction between the domains of language and music. For example, a study conducted by Koelsch, Gunter, Wittfoth & Sammler (2005) showed what was called a "left anterior negativity" (LAN) when administering syntactically incorrect verbs in a sentence. However, the researchers also provided the participants with auditory melodies during the presentation of the sentences, and it was found that when there was a harmonically unexpected chord provided simultaneously with the syntactic error, there was a significant decrease in this LAN. Importantly, such a drop in linguistic processing effects upon hearing an unexpected chord was not found at the N400 with semantically unexpected words. This specific interference of harmonic violations with neurological measures of syntactic violation processing in language is viewed as evidence for limited and shared resources in the structural integration of both language and music.

Second, also behavioral studies have begun to show strong evidence for the SSIRH. Slevc et al. (2009) provided participants with self-paced reading tasks, in which they found similar results to the neurological studies. The experimenters instructed people to read sentences containing syntactic (“garden path”) and semantic unexpectancies whilst listening to melodies. Reading time was measured, showing a longer reading time for sentence segments that contained unexpectancies. Results showed that providing a harmonically unexpected chord in the melody increased the time that was needed to process the syntactic, but not the semantic unexpectancies. Furthermore, this specific interference between harmonic and linguistic processing of syntactic violations was strongest when both the linguistic and the musical unexpectancy were simultaneously provided. This kind of evidence again suggests an overlap in structural (re-)integration processes between language and music.

Third, research in the field of child development has also focused on the interaction between structural processing of music and language, specifically focusing on the “transfer” of

skills from early musical processing to later processing in language. In a recent study considering the effects of music on child development, Jentschke and Koelsch (2009) have found that musically taught children do not only show an increased ERAN amplitude ("early right anterior negativity") which is related to a greater sensitivity for violations of the musical harmony), but also that there was a clear ELAN("early left anterior negativity", related to violations of linguistic syntax) at an earlier age than non-musically taught children. Indeed, recent studies do seem to provide evidence for a stimulation of linguistic syntax processing through music. Another example is the study of Anvari, Trainor, Woodside and Levy (2002). In this study, the researchers found that musical capacities are strongly related to phonological awareness and early reading skills in children. However, the most important finding here was that even after controlling for several other cognitive mechanisms, pure musical experience did still have an influence, suggesting that structural processing of auditory sequences based on music-specific harmonic rules might have a direct influence on the syntactic processes involved in the structural integration of sentences.

Discussion

This theoretical review discussed evidence concerning the relationship between harmonic processing in music and syntactic processing in language. In general, it can be concluded that the process of harmonic integration in music is very similar to the way in which sentences are structurally processed, both in the underlying mechanisms (integration of sequences through violations of expectancies) and in the implicit and universal nature in which these processes evolve. However, it is important to note that even though the process of structural integration in both domains might be very similar, the actual syntactic representations on which they are based (linguistic and harmonic rule representations) are domain specific. This leads to the distinction that has been reported in the Shared Syntactic Integration Resource Hypothesis (Patel, 2003). By providing the claim of domain-general structural integration based on domain-specific syntax representation networks, this recent theoretical framework incorporates both the evidence for a neuronal overlap in syntactic processing, and on the other hand for the clear clinical dissociation that has been found between syntax processing in language and music. Recent behavioral and neuro-imaging

studies have indeed provided evidence in alignment with this claim, showing that though syntactic representations in the domains of language and music are different, there is still evidence for interference during simultaneous structural processing in both domains. In conclusion, an expanding body of research suggests that the question concerning overlap between syntax processing in language and music can be brought back to domain-general processes of structural integration through (violations of) expectancies. These expectancies themselves are based on domain-specific syntax rules.

At the end of this review, a few remarks should be made concerning the discussed topics. A first remark is that to address the domain specificity of structural processing in language and music, the current review has solely focused on integration of sequences through the use of (linguistic and musical) syntax. However, it is important to acknowledge that the integration of sequences is also in an important way guided by other aspects of both domains. As suggested in the introduction, expectancies concerning rhythm (e.g. Boltz, 1993) and semantics (e.g. Meyer, 1965) are also formed in the perception of both musical and linguistic sequences, and also these aspects contribute in an important way to music and language perception. Therefore, it should be clearly stated that by focusing on the domain generality of *syntactic* structure processing, this review only focuses on one of the many fields in which the relationship between language and music can (and should) be further studied.

A second important remark is that this review aligns with the SSIRH (Patel, 2003) as a theoretical framework concerning the domain specificity of syntactic structure processing: a theory that is still relatively new. The body of evidence that was reviewed is still quite small, and should be elaborated upon further to provide consistent evidence for the claims that are stated in this review. As a contribution to this domain of study, the following chapter will therefore present an empirical study that addresses several aspects of the SSIRH that are still relatively unexplored. However, this empirical study is only a single contribution, and further research concerning the SSIRH is definitely required.

A third and final remark is that the studies that were discussed in this review mostly originate from the field of music cognition. Even though a large body of research is available concerning the relation between music and language processing, this evidence has not yet truly found its way into theoretical and methodological contributions to the domain of psycholinguistics. Specifically in the domain of linguistic syntax processing, theories such as

the SSIRH could provide new insights and perspectives on current points of debate. Therefore, the third chapter of this paper will present an empirical study using the reviewed concept of domain-general structural integration to address the recent finding of "attachment priming" in linguistic syntax research, a form of syntactic priming that is suggested to be based on hierarchical structure priming (e.g. Scheepers, 2003, 2011; Desmet & Declercq, 2006). Again however, this study only focuses on one of many aspects that can be studied, and should be regarded as a mere aspiration to increase exchangeability between theories in the domains of language and music.

Structural Integration in Language and Music: Evidence for Shared Resources.

Based on a growing body of evidence concerning the relationship between syntactic processing in language and music, the Shared Syntactic Integration Resource Hypothesis (Patel,2003) states that processing of both melodic and linguistic sequences is based on domain-general resources for structural integration that rely on domain-specific syntax representations. Recent studies (e.g. Koelsch et al., 2005; Slevc et al., 2009) have provided evidence for this idea of domain-general structural integration resources through effects of interference between harmonic and syntactic processing of unexpectancies. In this study, issues concerning this previous form of evidence are discussed, and a further empirical contribution is made to the theory of the SSIRH.

Issues in Contemporary SSIRH Research

This section shortly discusses three important issues concerning previous SSIRH research. First, it is important to acknowledge that the SSIRH states to provide a theoretical framework for *mutual* influences between syntactic processing in language and music. However, where there is clear evidence for the effects that structural integration in music can have on measures of linguistic syntax processing (e.g. Koelsch et al., 2005; Slevc et al., 2009), no study has (to my knowledge) investigated the effects that linguistic syntax processing can have on measures of structural integration in music. Before one can speak of mutual influences, studies thus also need to provide evidence for this other direction of structural processing interference.

A second issue is the measure of linguistic structural processing. It is quite hard to distinguish syntactic processing in language from semantic and prosodic biases. This generally leads to the fact that most studies so far have focused on very indirect measures of the structural processing that is to be investigated (for example, reading speed in Slevc et al., 2009, or electrophysiological responses to violations in Koelsch et al., 2005). Regarding the

SSIRH, it might therefore prove worthwhile to measure other forms of structural integration, such as harmonic processing in music (which is based on clear harmonic relationships and thus much easier to directly manipulate and measure).

This leads to a third issue, being that (in using indirect measures of syntax processing) studies until now have mainly used designs of syntactic or harmonic violations, thus looking for enlargements or decreases in syntactic re-evaluation processes and so on. In other words, previous evidence supporting the SSIRH has been collected on an experimentally manipulated subset of sentences. Therefore, it is important to keep in mind that this sort of research still leaves open the question in what way such interference between structural processing in both domains can be found on more natural and unambiguous stimuli.

Summarizing, the fact that previous studies have solely focused on linguistic processing of syntactic unexpectancies causes several issues concerning (a) the theoretical interpretation (*mutuality)*, (b) the measures (*indirect measures*) and (c) the design (*unexpectancies*) used to provide the previous findings.

Current Study

In this empirical study, the above mentioned issues were addressed following a new research design. A way to address all three of these remarks would be to investigate (a) the influence of linguistic syntax processing on harmonic integration in music, by (b) using a dependent measure that directly relates to this harmonic integration, which also allows (c) the use of natural sentences and melodies. In other words, all the issues can be directly acted upon by constructing a direct dependent measure for the amount in which a tone sequence is harmonically integrated. First, using a dependent measure relative to the amount of harmonic integration allows this study to investigate structural processing effects from language on music. Second, given the fact that musical structure is much more equivocal and simple compared to linguistic syntax, the dependent measure can be constructed in such a way that it directly relates to harmonic structuring. Therefore, the experiment allows deriving simple and specific conclusions out of the data. Third, a dependent measure for harmonic processing can be constructed naturally and measured at a baseline level, whereas (to investigate effects on linguistic syntax processing) studies thus far needed to include manipulations such as

structural violations in the linguistic or the musical sequences. Therefore, measuring harmonic processing allows studying the simultaneous processing of unambiguous, naturalistic melodic and linguistic sequences. The main question that arises from this short discussion is: what kind of dependent measure would be able to accurately and directly measure the amount of harmonic integration in the perception of sound sequences?

Harmonic Integration as a Dependent Measure

To provide the needed dependent measure, this study has based itself on an experiment conducted by Tan et al. (1981). In this experiment, a recognition task was provided to measure whether or not a melodic sequence of tones was harmonically integrated. In the next part, this idea of measuring harmonic integration trough recognition will be further discussed.

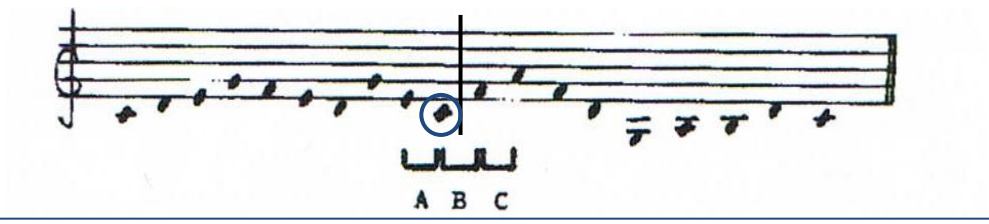
Harmonic Integration Through Recognition

The idea behind the task of Tan et al. (1981) was based on earlier research by Gregory (1978), in which was found that when people heard clicking during auditory presentations of melodies, they tended to report the time of this clicking as between two harmonic "phrases". Referring to harmonic integration, this means that the clicks were erroneously perceived at times when the harmonic expectancy was broken and people detected a harmonic boundary in the melody. This is very similar to the domain of language, in which it has also been shown that people are faster at responding to a word when this word was presented after (as opposed to before) a syntactic boundary in the sentence (e.g. Townsend, Ottaviano & Bever, 1979). Later studies have also consistently found effects of harmonic boundaries on perception and memory (e.g. Chiappe & Schmuckler, 1997).

Based on this early evidence, Tan and colleagues argued that if perception of clicks between tones could be influenced by harmonic integration, it was probably true that the perception of the tones themselves could also be influenced by harmonic integration. To test this, Tan et al. (1891) created a recognition task. In this task, participants had to first listen to a simple tone sequence. After the presentation of this tone sequence, participants heard a small

"target probe" of two consecutive tones. The task was simply to judge whether these two consecutive tones were presented in the previous sequence (in that specific order) or not.

The main manipulation of the task was that the experimenters provided harmonic boundaries (i.e., violations of the harmonic expectancy) at certain moments in the presented tone sequence. Tan et al. (1981) stated that, if the tone sequence would be harmonically integrated, the listener would thus perceive several harmonic "phrases" in the tone sequence. The dependent variable of the task was relatively simple. When the "target probes" that needed to be judged were correct, they could either be (a) two consecutive tones that were harmonically congruent (which would place them within the same harmonic "phrase" after harmonic integration), or they could be (b) two consecutive tones that were harmonically incongruent (i.e., a harmonic boundary would be created between the two tones, splitting them up in two separate harmonic "phrases" after harmonic integration). The expectancy of Tan et al. (1981) was that, if the melody was indeed harmonically integrated, one would expect that a "probe" of harmonically congruent tones ("within phrase"-probes) would be perceived more as a consecutive "chunk" of melody compared to the tones separated by a harmonic boundary ("between phrase"-probes). Therefore, it was expected that "between phrase"-probes would be recognized less well compared to "within phrase"-probes due to processes of harmonic integration. This is exactly what Tan et al. (1981) found (represented in Figure 3).



Remarks: The line in the melody represents the position of the harmonic boundary. Following the tone in the circle (just like any other tone), participants form harmonic expectations concerning the pitches that might follow. If these expectations are violated, the person will register a separation between this and the following tone, creating two separated segments in the melody. Because of this harmonical "boundary", the sequence of tones tagged as B ("between phrase"-probes) will be recognized less well as compared to the A and C tone sequences ("within phrase"-probes).

Figure 3: Schema of the harmonic integration measure, adapted from Tan et al. (1981)

This finding that "within phrase"-probes are recognized better than "between phrase"-probes as an effect of harmonic integration processes, has also been used in the current study. The more a melody is harmonically integrated, the more the harmonic boundaries are registered, which would lead to a bigger effect of perceiving the "between phrase"-probe as two separate tones. Since the size of this effect can thus be directly linked to the amount of harmonic processing of the tone sequence, it is well-suited as a dependent variable to measure harmonic integration. Therefore, the difference in recognition of the "between phrase" versus the "within phrase" probes was taken as a direct measure of the amount of harmonic integration in the current study.

Effects of Training on the Dependent Measure

An important remark that needs to be made concerning the measure of harmonic integration, is that studies on the automaticity of syntax processing in both language and music (e.g. Maidhof & Koelsch, 2011) on non-musicians have shown that the ELAN ("early left anterior negativity") and other effects related to syntax processing in language can be found at a more automatic level than ERAN ("early right anterior negativity") activation and other measures related to syntactic processing in music. The researchers have already stated that this might be due to the fact that language is a stimulus that is more common than music, and that therefore the tested non-musicians are more used to actively process sentences, but less so to actively process musical stimuli.

When relating this to the measure of harmonic processing, it is important to acknowledge that the automaticity and fluency by which this recognition effect of harmonic integration emerges, might be related to the amount to which participants have been actively been exposed to processing music. Especially given the task at hand, in which participants are merely exposed to the melodic structure of the tone sequence, and afterwards recognize separate "target probes", there might be an important difference regarding the experience the participants have had with actively processing music. One could state that non-musicians might regard the task more as a sequence recall task, and have a less natural tendency to automatically process (and harmonically integrate) the tone sequence as a melody. Indeed, the study of Tan et al. (1981) has also shown that people who were more experienced musicians

tended to show a stronger effect on measures of harmonic processing. Therefore, it is important to acknowledge that - even though this paper proposes that harmonic integration in itself is a basic, implicit capacity that is largely unrelated to formally trained skills - a participant who is actively involved with music might have higher tendency to apply harmonic processing to the recognition task, thus influencing the found effects.

Experiment

In this section, the current study reports an experiment in which the effects of simultaneous syntactic processing in the domains of language and music are investigated by means of the discussed recognition task. Through this novel measure of harmonic integration, the experiment focuses on the influences of both congruent and incongruent structural processing of sentences on the structural processing of tone sequences, for both ambiguous and unambiguous sentences. Thereby, this experiment addresses the issues concerning the mutuality, direct interpretation and generalization of earlier found interference evidence (e.g. Slevc et al., 2009).

Research questions

Out of previous research, a number of research questions can be proposed. First, given the fact that the current task is strongly based on Tan et al. (1981), a replication of the harmonic integration effect on recognition should be found. Second, the remark should be made that participants do not receive instructions to regard the tone sequence as a melody. Therefore, and given the knowledge that the automaticity of harmonic integration depends on experience with actively processing music (e.g. Tan et al., 1981), there might be an important influence of the musical training of a participant on the emergence of the general harmonic integration effect. A third research question regards the mutuality of the previously found interference effects. In accordance with previous studies (e.g. Slevc et al., 2009) and supporting the theory of SSIRH (Patel, 2003), interference is expected between the harmonic processing of the melody and a syntactic re-analysis of an incongruent sentential structure. In other words, the effect of harmonic processing of the tone sequence might significantly be

decreased due to a syntactic restructuration at the linguistic domain. Forth, given that the current design allows testing the amount of harmonic processing of the tone sequence when simultaneously presented with unambiguous or congruent sentence structures, the question is raised in which way the previously found interference effects can be replicated in naturalistic, simultaneous processing of music and language.

Participants

14 participants were invited by means of the online experiment platform of the University of Ghent. They were paid 4 euro in exchange for their participation to the experiment, which took 30 minutes. They were required to speak Dutch as their native language, and to have normal listening and reading skills. Participants were not required to have any musical experience, but at the beginning of the experiment, they were asked to report the number of years they had received formal musical training.

Materials

Sentences.

Throughout the experiment, relative clause sentences were used (all sentences can be found in Attachment A). The reason why such sentences were used, is that the required sentential categories (congruent | incongruent)* (ambiguous | unambiguous) can be formed with minimal changes in the sentential structure.

A first manipulation concerning the sentential structure (thereby manipulating congruency with the tone sequences) is the attachment of the relative clause. As can be seen in Figure 4, the relative clause (e.g. “that are wide” / “that is spacious”) can be attached to either the noun phrase (“the chairs”) or the pronominal phrase (“of the room”). If the relative clause attaches to the pronominal phrase, this is called a low attachment (“LA”), since the attachment is low in the Tree Adjoining Grammar (cfr. Joshi & Schabes, 1997). The sentence thus can be seen as two general phrases, the standard verb phrase (e.g. “the man sees the chairs”) with a pronominal phrase attached to the object (“of the room that is spacious”).

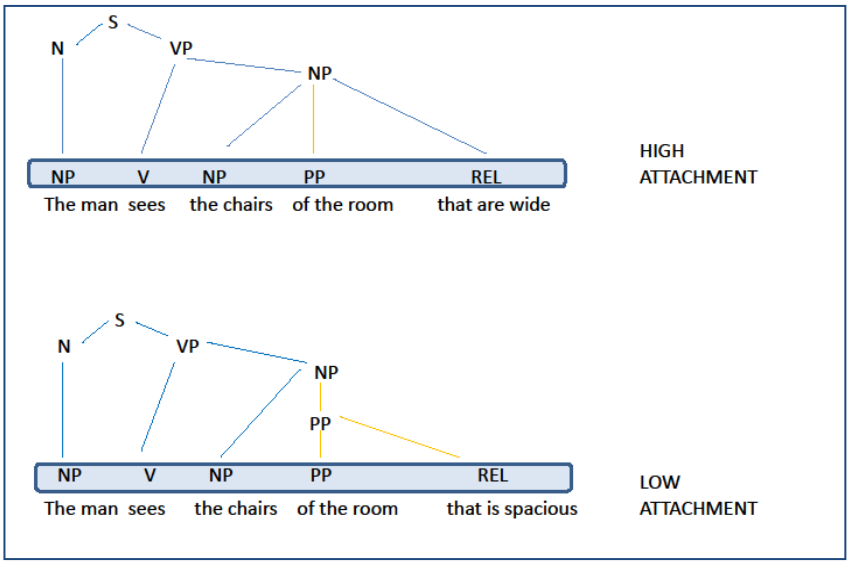


Figure 4: schematic presentation of the relative clause sentences used in the experiment

However, if the relative clause attaches to the noun phrase, this is called a high attachment, ("HA"), since the attachment is high in the Tree Adjoining grammar, above the attachment of the pronominal clause. The sentence can thus be seen as three general phrases, the verb phrase (e.g. "the man sees the chairs"), which has a pronominal phrase attached to the object ("of the room") and a relative clause phrase attached to the object ("that are wide"). In conclusion, this manipulation of HA versus LA sentences changes the syntactic structure of the sentence (whether or not the relative pronoun "that" introduced a continuation or a boundary to the pronominal clause), without changing the surface structure of the sentence.

A second manipulation was the timing of the disambiguation in the sentence. The timing of the disambiguation is determined by the syntactic information that is incorporated in the relative pronoun. For example, in the sentence "I saw the spoons of the butcher WHO …." the relative pronoun "WHO" already disambiguates the sentential structure, clearly defining that a relative clause referring to the cook is following (being an LA attachment). However, in a sentence like "I saw the spoons of the kitchen THAT…" the relative pronoun "THAT" does not entail such information, and it is still ambiguous whether the relative clause will refer to the spoons (HA) or the kitchen (LA). This distinction in attachment disambiguation is made to measure both the effects of structural processing of an unambiguous sentence (not studied thus

far), and the effects of a structural reconstruction of an ambiguous sentence (similar to the syntactic unexpectancies used in previous research).

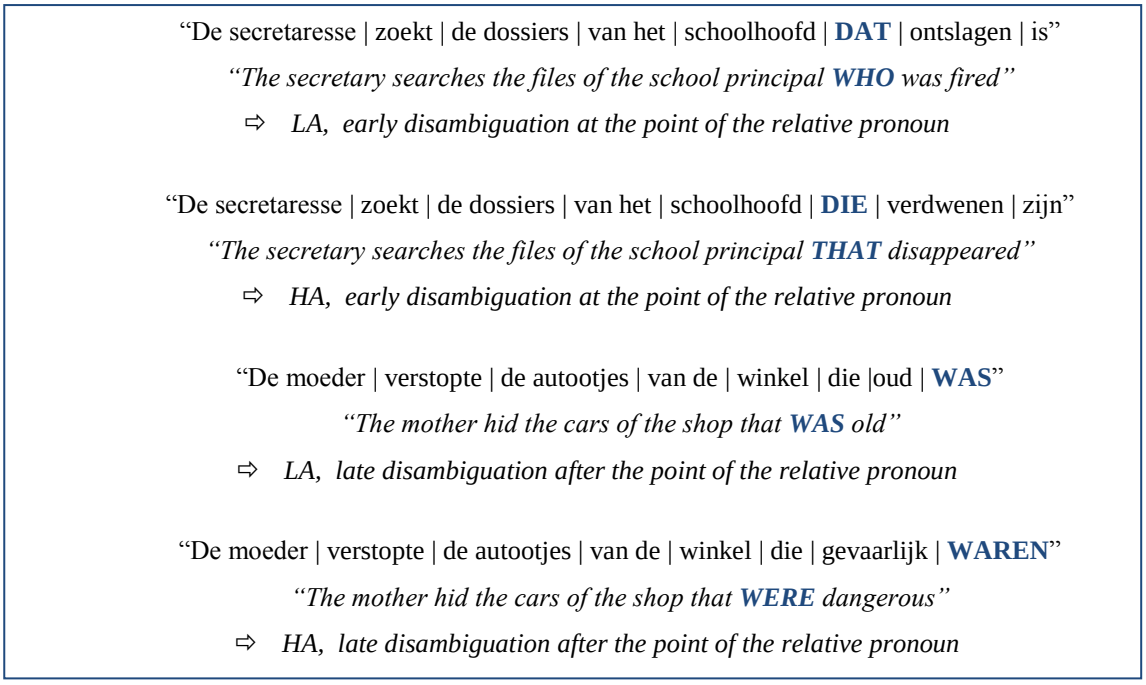


Figure 5: Example of the 4 conditions of sentences, bold indicating the point of disambiguation

Throughout the experiment, there were 120 relative clause sentences, that could be divided into 4 groups by sentence type (HA or LA sentences) and attachment ambiguity (solved early or late in the sentence), shown in Figure 5. All the sentences were split up into 8 segments (see the bars in the examples of Figure 5 for the segmentation). It is important to note that the relative pronoun was always presented at the 6th segment.

Melodies.

The melodies were composed in a random way, and consisted out of 8 separate tones (presented for 300 ms, with 270 ms of silence in between), that were to be presented simultaneously with the 8 sentence segments. The tones were generated by producing sine frequencies with a pitch range between 196 Hz and 440Hz.

All tones were selected out of two zones from the circle of fifths (see Figure 1): "E-B-A" and "F-C-G". These zones were chosen so that tones from different zones were

harmonically incongruent in the rules of Western tonal harmony. This way, harmonical boundaries could be created at a specific moment in the melody by instructing the program to select the following tone from the zone opposite to the previously selected zone. Apart from that, the program randomly chose a zone and first tone to start with and continuously produced random tones moving only one step in the selected zone, ensuring that consecutive tones were harmonically congruent and never a repetition of themselves.

Every tone sequence consisted out of 3 main regions: the first 3 segments, the middle part of 3 segments, and the final two segments (illustrated in Figure 6). Between these 3 melodic segments, harmonic boundaries could be made.

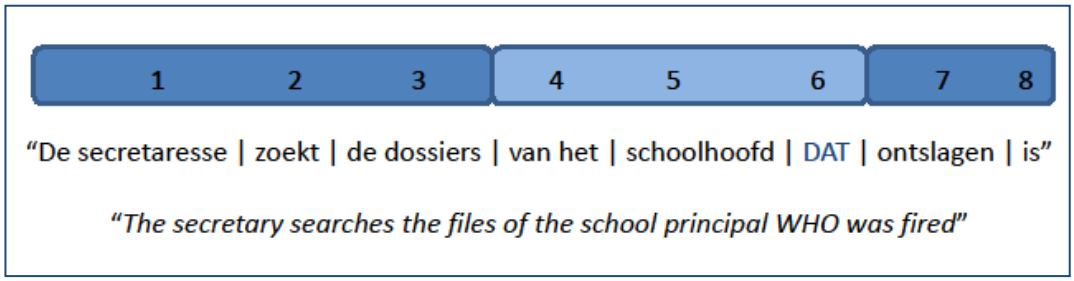


Figure 6: Illustration of the three regions of segments

For this experiment, the melodies either had an "AAB"-structure or an "ABB"-structure (for an overview, see Figure 7). In an "AAB"-structure, the harmonic boundary is presented between the first and the second part of the tone sequence (i.e., between the 3rd and 4th tone). In an "ABB"-structure, the harmonic boundary is presented between the second and third part of the tone sequence (i.e., between the 6th and 7th tone). Given the fact that the 8 tones of the tone sequence are presented together with the 8 segments of a relative clause sentence, these different melodic structures allow to investigate several forms of alignment and interaction between structural processing of language and music.

If a harmonic boundary is made between the first and the second part of segments, this harmonic boundary is congruent with all sentences, since in both LA and HA sentences, a distinction is made between the first and the second part of segments (e.g. "the secretary searches the files | of the school principal who was fired", see Figure 6). Therefore, in these "ABB"-structured tone sequences, there is a harmonic boundary constructed at the exact point

of a syntactic "phrasing" in all sentences. Therefore, the "ABB"-trials allow for an investigation of simultaneous and congruent structural processing (structural boundaries in both domains at exactly the same time).

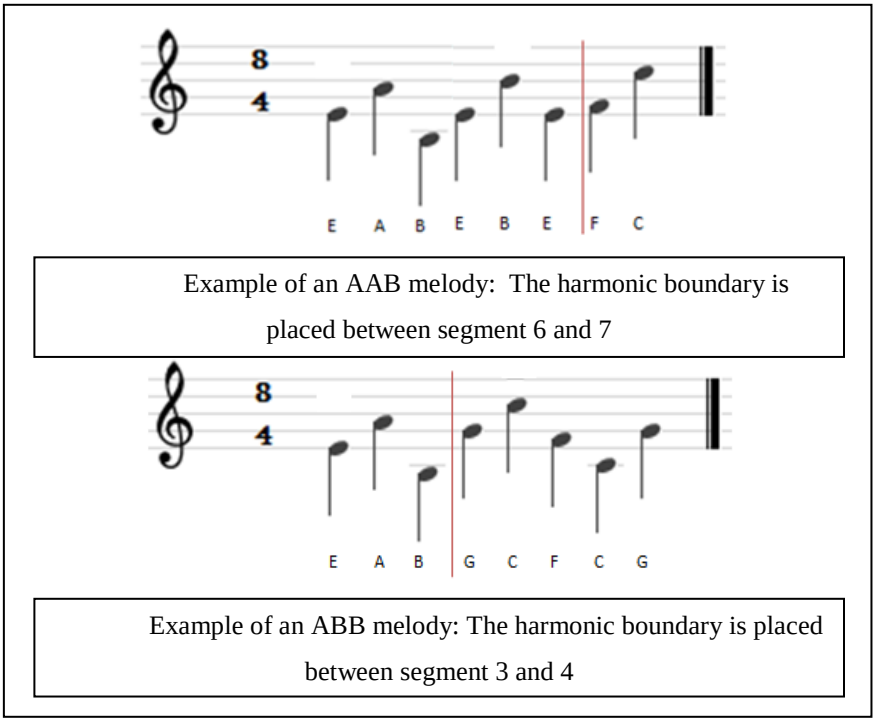


Figure 7: AAB and ABB melodies

However, if a harmonic boundary is created between the second and third part of the tone sequence ("AAB"-structured tone sequences), the harmonic boundary falls within the relative clause of each sentence (between the 6th and the 7th sentence segment). To fully register the harmonic boundary, participants thus need to process the harmonic difference between the 6th and 7th segment, even though this 6th segment also causes syntactic integration processes in the sentence. In other words, where the syntactic boundary is placed between the 5th and the 6th segment, the harmonic boundary is placed between the 6th and the 7th segment, and structural integration in both domains is expected to strongly interfere. It is here in these incongruent "AAB"-structured tone sequences that also the manipulations within the sentence concerning type (LA or HA attachment) and point of disambiguation (early or late) can shed further light on possible effects of interference.

Concerning the point of disambiguation of the sentences, it can be stated that when this point is early (i.e., when the syntactic information of the relative pronoun discriminates between a HA and LA relative clause), the syntactic integration of the sentence can be made at the 6th segment. Therefore, findings on these "AAB | early disambiguation"-trials can be seen as effects of interference between online structural processing in language and music. On the other hand, findings on these "AAB | late disambiguation"-trials can be seen as effects of interference concerning structural re-analysis, given that the syntactic structure of the sentence is (re-)processed after the presentation of the harmonic boundary.

Finally, within the conditions of ambiguity resolution, a distinction can also be made concerning whether the sentences are LA versus HA sentences. In LA sentences, there is no real syntactic "boundary" between the relative clause and the preceding pronominal clause ("the school principal WHO was fired"). Therefore, this incongruent syntactic boundary might interfere less with the harmonic integration of the melody as opposed to HA sentences, where there is a clear syntactic dissociation between the pronominal clause and the relative clause. Therefore, in comparing effects between "AAB | HA sentence"-trials and "AAB | LA sentence"-trials, the degree of structural interference can be investigated on the measures of harmonic integration.

For each participant, the amount of "ABB" versus "AAB" structures in every condition of the sentences was balanced. Whether the melodic structure was "AAB" or "ABB" for a certain sentence was counterbalanced between participants.

Recognition probes.

The sequences that were offered after the presentation of the melody were 25% "within phrase"-probes, meaning tones that occurred within the same harmonic "phrase", 25% "between phrase"-probes, meaning the tones that were separated by a harmonic boundary after harmonic structuring (even though they are also presented consecutively in the tone sequence) and finally 50% false probes, consisting out of tones that were presented in the melody, but not in that consecutive order.

Procedure

At the beginning of the experiment, participants filled in the informed consent and a small survey concerning their musical training. After this, they received instructions concerning the recognition task. Participants were explicitly instructed to attend to both the melodies and the sentences. Participants started out with 4 practice trials to familiarize them with the set-up and way of responding, and then started the experiment, consisting out of 120 trials with 3 breaks of 2 minutes after every 30 trials. On every trial, a fixation cross was presented for 500 ms, followed by a black screen of 500 ms. After this, the first sentence segment , together with the first tone, was presented (respectively, visually and auditory) for 370ms. This was followed by a silence for 200 ms, and the next sentence segment. This was repeated until all 8 sentence segments (and respectively, notes) were presented. After the presentation of all 8 segments, the screen turned blue and there was a break of 1000 ms. The words "fout" and "juist" (Dutch for "right" and "wrong") appeared on the screen, respectively left and right, centered, and the two tones of the recognition probe were presented (both for 370 ms, with a gap of 200 ms). The participants were asked to press "j" or "f", for respectively correct and wrong probes. After this, the next trial started. There were 10 random trials on which a button appeared after the trial presentation. Participants had to write down the sentence that was presented in that trial, before clicking the button to continue to the next trial. This measure was taken to ensure that participants paid attention to the sentences.

Hypotheses

Relating to the research questions that have been described earlier, the following hypotheses can be stated. First, a replication of the harmonic integration effect of Tan et al. (1981) is expected, meaning a lower amount of recognition of "between phrase"-probes, presented at the point of a harmonic boundary in the melody, compared to "within phrase"-probes, presented at another point in the melody. Second, this effect might interact with the amount of musical experience or musical training that participants reported in the small survey. Specifically, a larger experience with actively processing musical stimuli (expressed

through years of formal musical training) might stimulate a participant to regard and process the tone sequence as a coherent melody, thereby boosting the harmonic integration effect.

Apart from these general hypotheses, specific hypotheses can be stated concerning the influence of syntactic processing of the relative clause sentences on the harmonic processing effects in the different melodic structures. When regarding "ABB"-structured tone sequences, A third hypothesis can be stated, namely that the effect of harmonic integration is expected not to be influenced by the presentation of the several forms of relative clauses, since the structural integration processing of the sentence and the tone sequence, that is stated to be based on shared resources, is completely aligned between the harmonic boundary and the syntactic distinction of verb phrase and propositional phrase in every sentence. When regarding "AAB"-structured sequences, which have a harmonic boundary that does not align with the syntactic structure of the sentences, a fourth hypothesis can be formed, stating that the harmonic processing of this boundary can be decreased by a syntactic re-analysis (late disambiguation) of a highly incongruent syntactic structure (HA sentences). This would provide evidence similar to earlier studies (e.g Slevc et al., 2009) finding an interference between harmonic unexpectancies and syntactic re-analysis processes. However, this claim leaves open the question to which extent such an interference can be found when (a) the sentences are LA sentences, thus not having a strong syntactic boundary conflicting with the harmonic boundary of the "AAB"-melody, or when (b) the syntactic structure has an early disambiguation at the point of the relative pronoun, and can thus be processed online.

Analysis

A LMER analysis was conducted (within-subjects, family is binomial), regressing the correctness of the recognition task to the probe type (between | within), the position of the harmonic boundary (ABB | AAB), the type of sentence (HA | LA), and the ambiguity timing (early | late).

Results

In alignment with the first hypothesis, the analysis clearly revealed a replication of a significant harmonic integration effect on probe type (z= 2.712, Pr(>|z|) = 0.007), in showing that there was a rise of 14% in the amount of correct responses on “within phrase”-probes as compared to “between phrase”-probes. Specifically, the amount of correct responses on the “between phrase”-probes was generally reduced to chance level. This replication of the harmonic integration effect is presented in Figure 8.

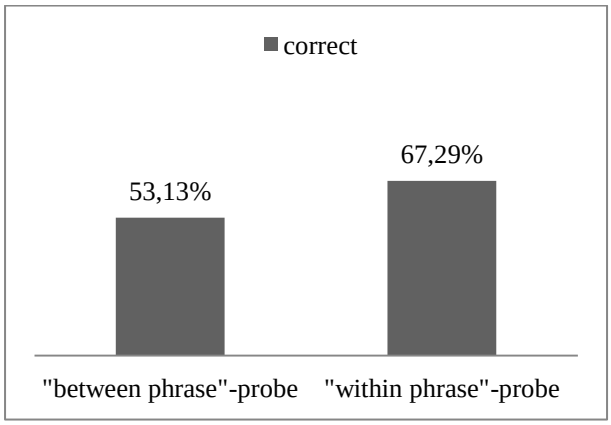


Figure 8: Percentage of correct responses by Probe Type

However, in alignment with the second research hypothesis, there was a significant interaction between the harmonic integration effect discussed above and the amount of years of formal training that participants reported on the survey. Specifically, the harmonic integration effects was significantly higher with participants who reported 9 years (z= 2.474, Pr(>|z|) = 0.0134) and 11 years (z= 2.055, Pr(>|z|) = 0.0399) of formal training, as opposed to participants who reported no formal training. Where the harmonic processing effect only entailed a 5% difference in participants with no formal musical training, the effect was 29 % and 24% for respectively participants with 9 and 11 years of formal musical training. As Figure 9 shows, participants who have had more formal training in music thus showed a stronger tendency to regard the tone sequence as a melody, thereby showing stronger effects of harmonic integration. A final remark that can be made is that, largely due to the fact that the there is a large decrease in the recognition of the “between phrase”-probes, there was also a

significantly lower overall performance on the recognition task in participants with 9 years (z= -2.390, Pr(>|z|) = 0.0169) and 11 years (z= -1.833, Pr(>|z|) = 0.0669) of formal training, as opposed to participants who reported no formal training. Where participants with a no formal training had a 65% correct recognition, the percentage of correct recognition is 48% and 53 % for respectively participants with 9 and 11 years of formal musical training. Important to note is that with participants that have a strong tendency to harmonically integrate the melody, the performance on "between phrase"-probes drops strongly below chance level, showing that the participants seem to recognize the probe, but make the decision that the probe was not presented as a consecutive chunk in the melody.

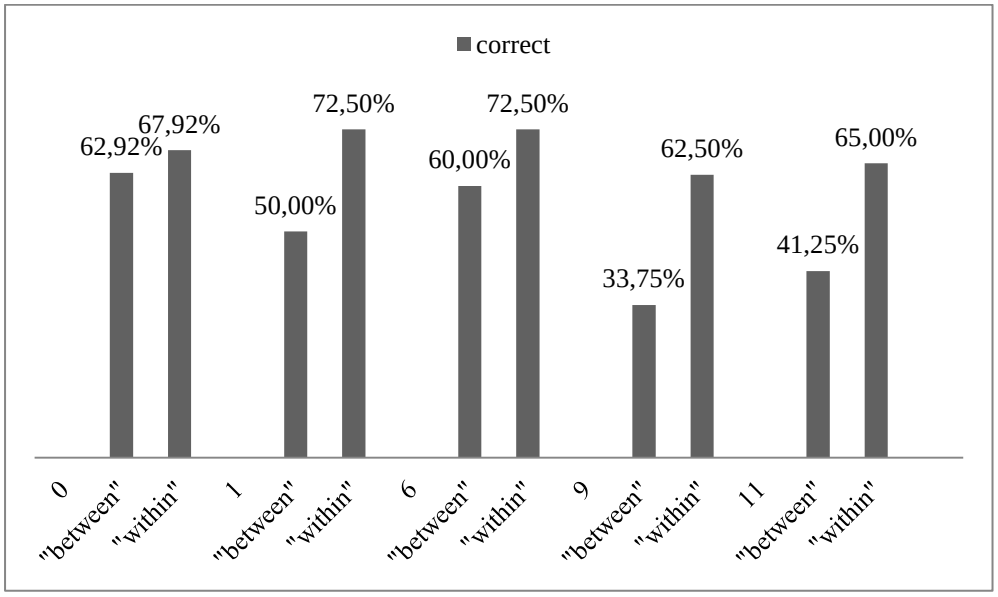


Figure 9: the percentage of correct responses by Probe Type and Years of formal training

To address the third hypothesis, it should be stated that there was no significant interaction with between the harmonic effect and any of the melody (AAB | ABB) or sentence (HA | LA and early | late disambiguation) conditions. The only effect of sentence manipulations that could be found was a marginally significant (z= 1.824, Pr(>|z|)= 0.068) effect that the general recognition performance of the correct probes is higher for LA sentences. This can be related to the fact that this type of sentence structure has a relatively easy syntactic structure as compared to HA sentences. Random slopes fitting did not improve the model.

Even though the general analysis did not reveal significant interactions between the sentence and melodic structure manipulation, it is important to acknowledge that there is only the expectation of an interference effect (e.g. Slevc et al. , 2009) in one specific condition, namely when a tone sequence is provided with a harmonic boundary that is incongruent with the structural analysis of the sentence (AAB), and the sentence structure makes a strong interfering syntactic boundary (HA attachment) through processes of syntactic re-integration processes (late disambiguation). Therefore, it might still prove worthwhile to contrast this specific "AAB | HA | late disambiguation"-condition with the other possible conditions of the experiment.

To address this specific issue, the data was subdivided into 4 smaller datasets, along the axes of "ABB" | "AAB"-structured tone sequences, and of "early" | "late" syntactic disambiguation. Within these four datasets, the interaction between type of attachment (HA|LA) and the harmonic integration effect could be investigated. When looking at the "AAB"/"late" dataset, the findings did indeed reveal a significant ($z= 2.157$, $Pr(>|z|) =0.031$) interaction, showing that where there was only a harmonic integration effect of 2% in the HA sentences, there was a harmonic integration effect of 27% in the LA sentences. There was no effect of formal musical training on this dataset. Therefore, there is indeed evidence for the third hypothesis, stating that when (similar to previous research, e.g. Slevc et al., 2009) an incongruent harmonic boundary is presented at a syntactic boundary point of syntactic re-analysis there is clear interference between the two processes. Furthermore, it is important to note that apart from the decrease of harmonic integration effect in this specific condition, there was also a general decrease in recognition performance (as shown by the fact that the "within phrase"-probes also have a decreased percentage of correct recognition as opposed to the other conditions). This can be very well explained by the fact that, as was stated above, only in this condition, a strong syntactic revision of the sentence structure can be found. Still, it is important to acknowledge that even though this syntactic re-analysis might have decreased the overall performance on the recognition task (as shown by the performance on the "within phrase"-probes), the perception of "between phrase"-probes as a non-consecutive chunk of the melody is strongly decreased. In other words, the findings reveal an effect of interference between syntactic re-analysis and the harmonic integration of the processed melody (see Figure 10).

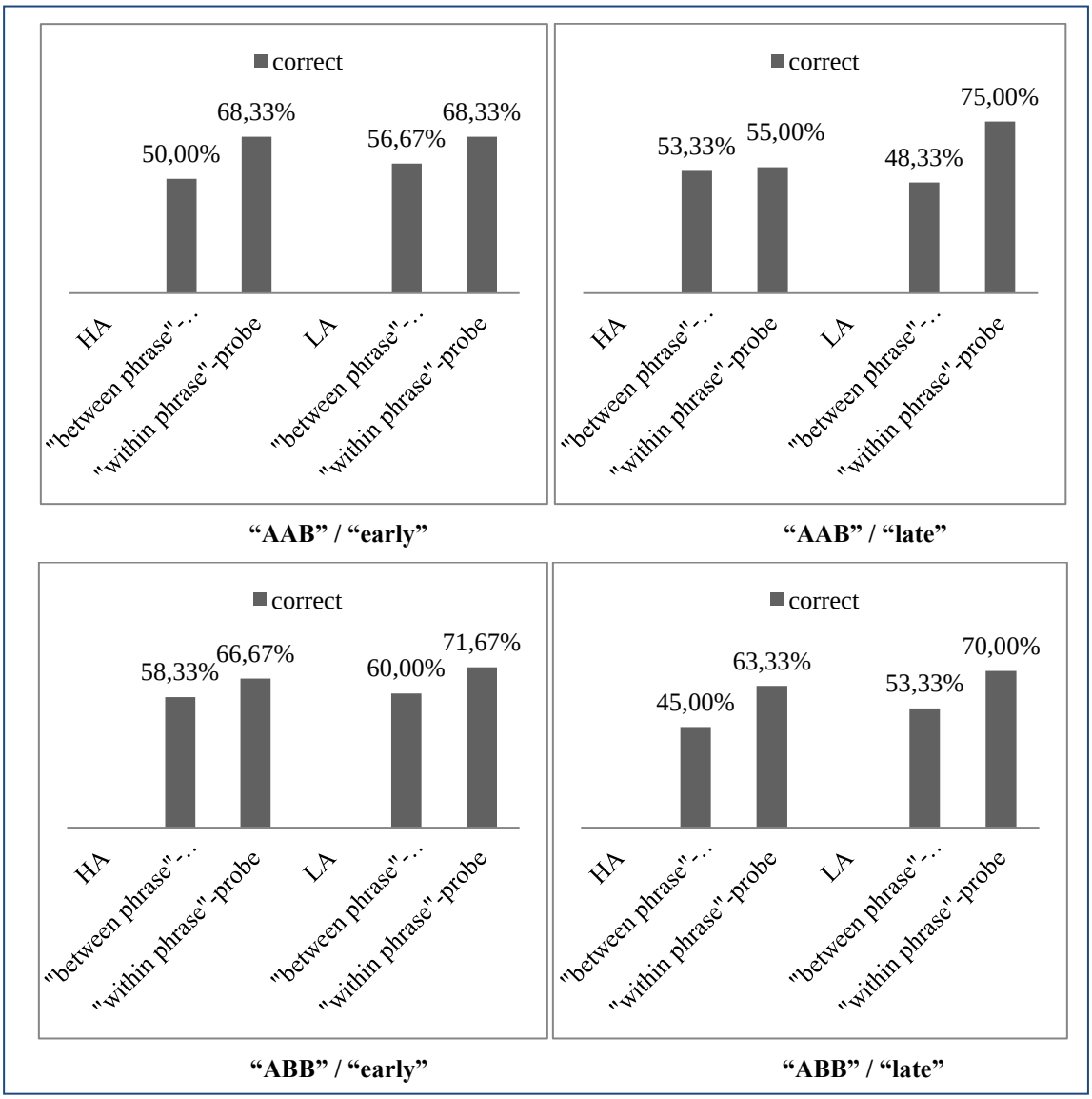


Figure 10: The interaction between the harmonic integration effect and attachment type, for all 4 datasets

Finally, when studying all other conditions, no significant effects emerged apart from a consistent harmonic integration effect in all conditions. For the "AAB"/ "early"- dataset, there was a marginally significant (z= 1.985, Pr(>|z|) =0.0471) interaction effect revealing a clear effect of harmonic integration for participants with more formal training. This also caused a general effect of lower performance (z= -2.002, Pr(>|z|) =0.0452) for participants with more formal training. In general, there was a difference of 15% more correct responses for "within phrase"-probes as compared to "between phrase"-probes. This dataset thus clearly shows the expected effects of harmonic processing when the sentences can be processed unambiguously.

For the "ABB"/ "late"- dataset, this significant (z= 2.921, Pr(>|z|) =0.003) harmonic integration effect consisted out of a difference of 18% more correct responses for "within phrase"-probes as compared to "between phrase"-probes. Also, there was a non-significant tendency for this harmonic integration-effect to be larger when the participant had received more formal musical training. For the "ABB"/ "early"- dataset, there was a marginally significant (z= 1.686, Pr(>|z|) =0.09173) effect of harmonic integration, revealing a difference of 10% more correct responses for "within phrase"-probes as compared to "between phrase"-probes. Also, this dataset revealed a significant (z= -2.279, Pr(>|z|) =0.02267) drop in recognition performance when the participants had more formal training, mainly guided by a stronger decrease in recognition of the "between phrase"-probes. The fact that only general effects of harmonic integration effect were found in all of these conditions provides evidence for the idea that previous findings of interference cannot be generalized to aligned structural integration processes in music and language, or to the simultaneous processing of unambiguous linguistic and melodic sequences.

Comment

In short, it can be concluded that the findings of this experiment align very well with the proposed hypotheses. First, the harmonic processing effect that was found in the study by Tan et al. (1981) has accurately been replicated. Results showed a lower recognition for "between phrase"-probes as compared to "within-phrase" probes.

Furthermore, there is also evidence aligning with the second hypothesis stating that this effect is related to musical experience. The findings did indeed reveal that participants with a larger amount of formal training had a stronger tendency to harmonically integrate the tone sequences into melodic structures. Another aspect of the findings that should be noted is that, at least in participants that have a strong tendency to harmonically integrate the tone sequence, the performance on the "between phrase"-probes drops strongly below chance level. In other words, these conditions show that the participants actually "recognize" the tone sequence, but make the decision that these two tones should not be seen as consecutive to each other.

In line with the third hypothesis, the findings also revealed that the harmonic integration of the "ABB"-structured tone sequences was not influenced by the sentence

manipulations. This provides evidence for the claim that aligned structural integration in both the domains of language and music is possible, which confers with the idea of overlapping resources for structural processing in both domains. This finding is relatively new, given the fact that previous studies have mainly used structural violations and unexpectancies. Considering the "AAB"-structured melodies, there is also evidence for the fourth hypothesis that was stated. The results do indeed show a clear interaction between the harmonic processing of a harmonic boundary, and the incongruent syntactic re-analysis of a relative clause sentence. Specifically, when a HA sentence with a late disambiguation is presented that interferes with the harmonic integration of the melody, the re-analysis of this syntactic structure strongly interferes with the registration of the harmonic boundary. Finally, when comparing the processing of the "AAB"-structured melody in the condition with a HA and late disambiguation sentences to harmonic processing of the "AAB"-structured melody in the other types of sentences, there is no decrease found in the harmonic processing of an interfering harmonic boundary when the syntactic point with which it interferes is (a) registered less strong (LA-sentences), or (b) processed online (early disambiguation).

Discussion

A first remark on the reported findings is that previously discussed effects of interference between incongruent harmonic structure and a syntactic reanalysis of sentences could be replicated. Therefore, this study aligns with earlier studies concerning the SSIRH (Patel, 2003) in stating that there is a clear interaction between structural processing in language and music. Furthermore, there are some novel aspects to this replication, which allow a further interpretation of such findings of interference. The study is novel in showing that this effect can be found not only through a reduction in syntactic re-analysis processes, but also through a reduction of harmonic integration processes. Thereby, it directly addresses several previously mentioned issues: the effect can be found (a) from language to music, on (b) direct measures of structural integration (namely harmonic integration), reflecting (c) harmonic processing of natural melodic tone sequences. Therefore, this replication provides an important contribution to earlier studies investigating the relatively novel theory of SSIRH (Patel, 2003).

A second remark is that the experiment also included several conditions that were not available in previous research concerning influences in shared processing of language and music. First, there was a condition in which the harmonic integration of the tone sequences was perfectly aligned with the syntactical structure processing of the sentence ("ABB"-structured sequences). This condition clearly showed that simultaneous processing of aligning structure across the two domains did not inflict any form of interference. Second, the previously discussed effect of incongruent syntactic processing on the perception of harmonic boundaries was also studies in condition where (a) this processing did not result in the construction of strong syntactic boundaries, or (b) this processing did not incorporate syntactic re-analysis, but rather an unambiguous and direct processing of the sentence structure. It was found that in both of these conditions, no interference could be found. The finding that (a) harmonic processing happens in a generally effortless manner without specific instructions and (b) this harmonic processing can be performed simultaneously with the syntactic processing of natural unambiguous sentences, thus is a very important contribution towards the question of generalization of earlier findings. This new evidence strongly suggests that previous findings of interference between structural processing in the two domains only occur under very specific conditions, and that musical and linguistic structure can generally be efficiently processed simultaneously. This is an important remark towards further investigation and application of the SSIRH theory.

A third remark that can be made concerning this empirical study is that this study presents a direct measure for structural integration in melodies. Given that this measure provides consistent effects of structural integration, this study aspires to stimulate the use of such measures further research concerning the SSIRH (Patel, 2003).

Furthermore, the concept of measuring structural integration through perceptual effects in recognition could also be investigated further in the domain of language. As has been shortly addressed, research in the domain of language has also revealed perceptual effects generated though the creation of syntactic boundaries (Townsend et al., 1979). Therefore, it might be worthwhile for further research to address the idea of measuring syntactic integration through recognition or response tasks, especially since the current study revealed a distinction between measuring effects of syntactic re-analysis (such as is often used through methods of "garden path" manipulations) and unambiguous sentence processing.

Structural Integration Priming: A Theoretical Framework for Syntactic Priming

Up to this point, the paper has mainly focused on the relationship between syntax processing in language and music, thereby focusing on the SSIRH and the statement of domain-general integration processes in both domains. However, an important remark that could be made is that the review of this research mainly stems from the domain of music cognition, and that there is a relatively low application of these findings in the psycholinguistic domain. In an aspiration to promote theoretical interchangeability between theories in the domains of music and language, this empirical study focuses on a recent point of debate in linguistic syntax research that could be addressed through the discussed theory of SSIRH, namely the recent finding of attachment priming (e.g. Desmet & Declercq, 2006; Loncke, Van Laere & Desmet, 2011; Scheepers, 2003, 2011) that provides an account for syntactic priming not explainable through domain-specific syntax representations.

Attachment Priming and Syntactic Priming Research

Syntactic Priming

The term "syntactic priming" mainly originates from the early research of Bock (1986, 1989). In these experiments, Bock studied the often reported finding that people tend to produce sentences in a syntactic structure that has previously been uttered or heard. Bock (1989) found that the way people describe transitive pictures (either a "prepositional object" or "PO"-dative like "the man gives a book to the girl", or on the other hand a "double object" or "DO"-dative like "the man gives the girl a book") could be primed through PO or DO sentences. Bock used this finding of structural priming to provide further insight in the kind of processes that could be influenced by such priming, and in that regard the syntactic representations and processes of language.

Syntactic priming has been a popular research design up until recent research, especially to investigate the nature of syntactic representations and processes this day. Apart from its apparent use as an experimental tool, research has also related this mechanism for structural priming to coordination and fluency in dialogue (especially concerning the idea of shared representation accounts in language, as is discussed in Pickering & Garrod, 2004). Furthermore, several studies have also shown persistent effects of syntactic priming, congruent with the idea that syntactic priming might also represent a mechanism for implicit long term learning through experience (e.g., Bock & Griffin, 2000; Chang, Dell & Bock, 2006).

Syntax Priming as priming of Syntactic Representations

On the basis of earlier research concerning the effects of syntactic priming (Bock & Loebell, 1990; Pickering & Ferreira, 2008), it has been generally accepted that sentential priming is based on syntactic representations in the brain. Through different designs in research, studies have been able to exclude lexical, semantic and prosodic explanations of syntactic priming. Even though these levels can contribute to syntactic priming effects, empirical studies have shown that they cannot be the basis of syntactic priming. This evidence has been adapted in a recent revision by Branigan, Pickering, Mclean and Stewart (2011). The article concludes that syntactic priming is based on representations that code specifically for the hierarchical syntactic partitioning of a certain sentence (Pickering, Branigan, Cleland, & Stewart, 2000). A schema that relates to this theory is the lemma-model of Pickering and Branigan (1998), presented in Figure 11.

This lemma-model is an adaption of the model of Levelt, Roelofs and Meyer (1999), stating that syntactic priming is based on representations of the local syntactic structure, presented as "knots" in the lemma level of the lexical access. These "knots" represent syntactic representations that lie between the basic representations of words, and that aid in linking words in a way structurally similar to the local hierarchy of the sentence (for example, the word "give" activates a syntactic rule knot specifying that it is a verb, and that an object and a patient are expected to follow shortly). When relating this to for example the original finding by Bock (1986), one can state that, when a verb is used in a DO (double object)

structure (e.g. “the man gives the girl a book”), the NP-NP node (double noun phrase, “the girl” and “the book”) is activated through the verb. However, with a PO (person object) structure (e.g. “the man gives a book to the girl”), the NP-PP (the noun phrase “a book” followed by a prepositional phrase “to the girl”) node is activated. This way, syntactic priming is possible through the activation of these nodes. This theory is further explained in detail by Branigan and Pickering (2004).

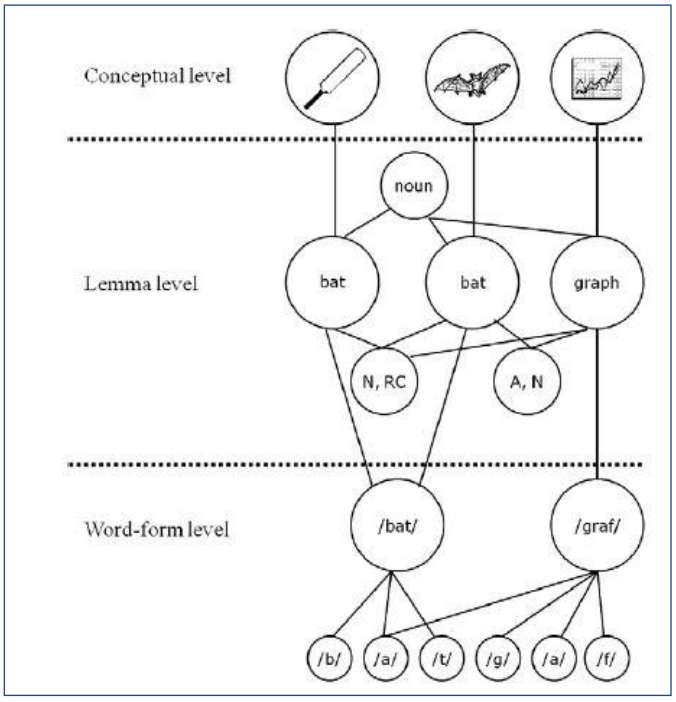


Figure 11: the Lemma-model, adapted from Pickering & Branigan (1998)

It should be noted that this idea of syntactic priming through rest activation in these nodes has been criticized by some theories. For example, in the view of Chang et al. (2006), syntactic priming is mainly regarded as an effect of implicit learning. However, in general, the conclusion can be made that the current research domain seems to largely link syntactic priming to the activation of a representational network (through rest activations or implicit learning). If we relate this to the SSIRH, one might say that language research has for long had the idea that syntactic priming effects were related to the domain-specific, linguistic representational network (and therefore to be separated from other domains like music).

Attachment Priming: a Larger Basis of Syntactic Priming?

In recent language research, the question has been raised to what extent there can also be syntactic priming on the basis of more general structural aspects of the sentence. This question has largely surfaced because of the consistent finding of what has been called "attachment priming" (e.g. Desmet & Declercq, 2006; Loncke et al., 2011; Scheepers, 2003). This concept entails that the attachment of a subordinate clause to a main sentence is also prone to priming conditions. The way this effect of priming is mostly tested, is through complex noun phrases. For example, in the unfinished sentence "I see the lights of the room that ….", the relative clause completing this sentence might relate to "the room" (which we would call a low attachment), but it might also refer to "the lights" (which we would call a high attachment). It has indeed been found that the way people complete such unfinished sentences can be primed by previously heard or produced HA or LA sentences. However, this poses a problem for an explanation through syntactic representations, since the surface structure between a HA and a LA sentence is exactly the same (see Figure 12).

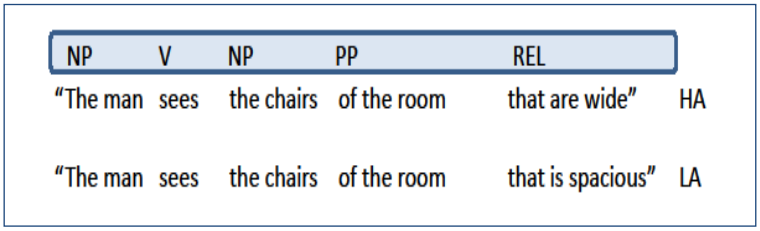


Figure 12: examples of "attachment primes": both LA and HA sentences have the same surface structure

Such evidence strongly suggests that syntactic priming must also be possible on a level that surpasses the specific syntactic rule representations. Furthermore, the recent study by Loncke et al. (2011) found that it was possible to prime not only the attachment height between relative clause sentences, but also the attachment height of a different structure (from the attachment of a relative clause to the attachment of a propositional phrase), thus stating that the effect is cross-structural. Even further , Scheepers et al. (2011) have found that this priming of attachment height can be extended to a priming of general hierarchical structure, in

showing that relative clause priming is also possible across domains (from arithmetic problem solving to relative clause attachment). Since it is generally agreed upon that these forms of priming can only be accounted for by the abstract hierarchical configuration of the sentence, recent studies (e.g. Desmet & Declercq, 2006) generally refer to the Tree Adjoining Grammar of Joshi & Schabes (1997), and state that the hierarchical structure of the sequence (as it was presented in Figure 4), and not only the specific syntactic representations, can be a basis for priming.

In the general review of syntactic priming of Pickering and Ferreira (2008), the conclusion is made that it appears that syntactic rule representations do indeed form an important basis for syntactic priming, but that recent research shows that this explanation is not sufficient for more recently found syntactic priming effects (e.g. Desmet & Declercq, 2006; Loncke et al., 2011). Therefore, there is a need for further evidence concerning the several different levels of syntactic priming, and also a theoretical framework that incorporates these novel findings.

Attachment Priming and the SSIRH: Structural Integration Priming

In this section, the mentioned concepts of harmonic integration and the SSIRH (Patel, 2003) shall be applied to provide such a theoretical contribution. When looking at the discussion concerning the levels of syntactic priming, one might remark that this discussion consists out of priming of syntactic representations on one hand, and priming of the hierarchical structuring of the sentence on the other hand. This distinction made in recent syntactic priming research relates closely to the distinction that the SSIRH makes between representational networks and the structural integration processes that are based on them. Regarding the models (e.g. Branigan & Pickering, 2004) considering the priming of "syntactic nodes" from the SSIRH, one could state that this generally discussed form of syntactic priming is based on the domain-specific representations acknowledged by the SSIRH. Regarding the recently found priming of a more general hierarchical processing of the linguistic sequence, one could state that this can be compared to priming on the level of the structural integration processes. Therefore, using the theoretical framework presented in the

SSIRH (Patel, 2003), the following levels of syntactic priming can be distinguished (presented in Figure 13).

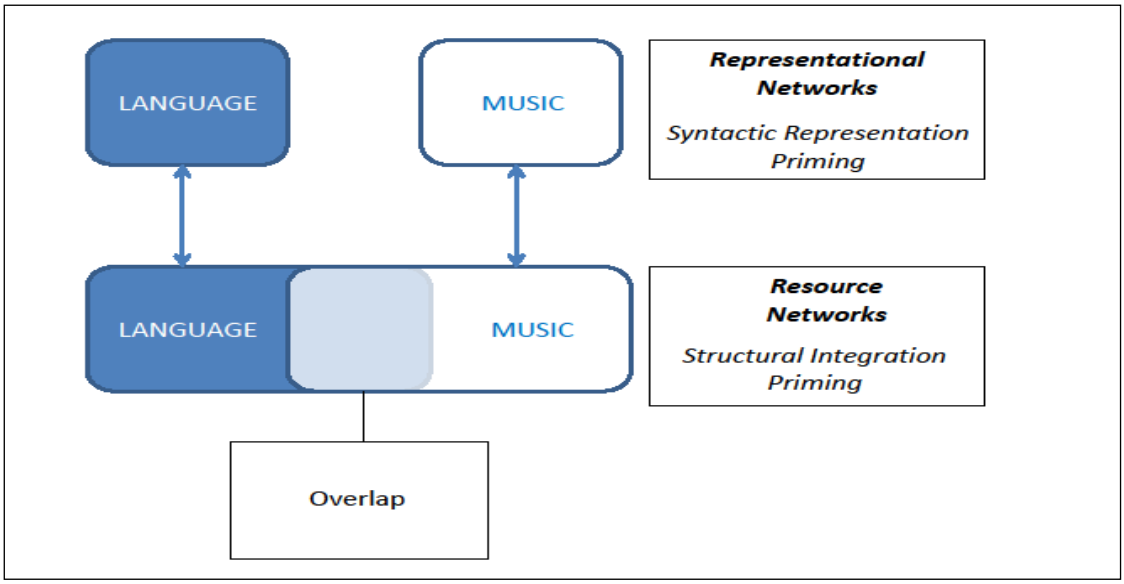


Figure 13: Presentation of the proposed theoretical integration

At one level there is Syntactic Representation Priming, referring to priming of the local syntactic representations in the representational network. This relates to the cases of syntactic priming that have mainly been studied, and the commonly accepted theories behind syntactic priming. In general, one can state that these syntactic priming effects are based on specific syntactic rule representations that are activated. Therefore, this level of syntactic priming is domain-specific to language.

The other level of priming can be called Structural Integration Priming. This form of priming is not based on the syntactic rule representations, but rather on the general integration processes that make use of these syntactic representations to form a hierarchical structure. These syntactic integration mechanisms are cognitive processes that have limited and shared resources across several domains, including music and language. The recently found effects of "attachment priming" are to be categorized in this category of priming evidence. Importantly, on this level of priming, cross-structural and cross-domain priming is plausible.

Experiment 1

Research question

The model stated above predicts that the recent findings of attachment priming (Scheepers, 2003) , cross-structural priming (Loncke et al.,2011) and cross-domain priming (Scheepers et al., 2011) can be clearly separated from classic studies of syntactic priming, given that they are examples of structural integration priming, and not the more commonly studied priming of syntactic representations. A logical way to provide evidence for the distinction that is proposed in this picture is to test whether structural priming effects like attachment priming can be found between domains that have overlapping structural integration resources. The SSIRH clearly states that music and language have separate syntactic rule representations, but shared resources for structural integration. Given that (a) SSIRH states that language and music have overlapping integration processes, and (b) attachment priming is assumed to be a priming of these integration processes, attachment priming is expected to be found between the domains of language and music.

Participants

30 participants were invited by means of the online experiment platform of the University of Ghent. They were paid 4 euro in exchange for their participation to the experiment, which took 30 minutes. Participants were required to speak Dutch as their native language, and normal listening and reading skills. Participants were not required to have any musical experience.

Materials

Sentences.

In total, 80 sentence beginnings were presented (presented in Attachment B). 60 of these were ambiguous, 20 were non-ambiguous. In ambiguous sentences, sentence beginnings could be completed using both an HA and an LA structure. For example, an ambiguous

sentence beginning like “ik zag de vriend van de vrouw DIE” (*/”I saw the friend of the woman WHO”)*, could be completed referring to the friend (HA) or the woman (LA). In unambiguous sentences, the syntactic construction only allowed for one attachment structure. For example, “de kok DIE” *(/ “the cook WHO”)* has a different relative pronoun compared to “het mes DAT” *(/” the knife THAT”)*, so a sentence beginning like “ik zag het mes van de kok DIE” *(/“I saw the knife of the cook WHO”)* can only be responded to using an LA structure, referring to the cook.

For the analysis of the experiment, only the ambiguous sentence beginnings were used. However, there is an important reason for adding some non-ambiguous sentences, namely to have forced responses of both structures (10 HA, 10 LA). This way, participants were aware of both response options, thereby creating a bigger chance for an even distribution in completion types. This was an important measure, given that most Dutch speakers have a very strong tendency to use LA completions. All the sentences that were presented were chosen to be fluent natural sentences with a strong semantic bias towards a certain structure completion. This was done for two reasons, being again to acquire a more even distribution of both completion types, and also to drive attention away from the syntactic structures of the sentences, making the completions more fluent and natural. Given this information, it is important to note that the matching of melody structures and ambiguous sentence beginnings was counterbalanced between participants, as to cancel out semantic effects of the sentence beginnings.

Melodies.

The melodies that were to prime the verbal completion were constructed in a very similar format to the melodies used in Experiment 1. They again consisted out of 8 tones, recruited randomly from the same 2 zones of the circle of fifths. The notes were paced in the same fashion as the first experiment. The only difference is that this time, the harmonic structures were made to resemble a sentence with an LA versus an HA attachment (as presented in Figure 14).

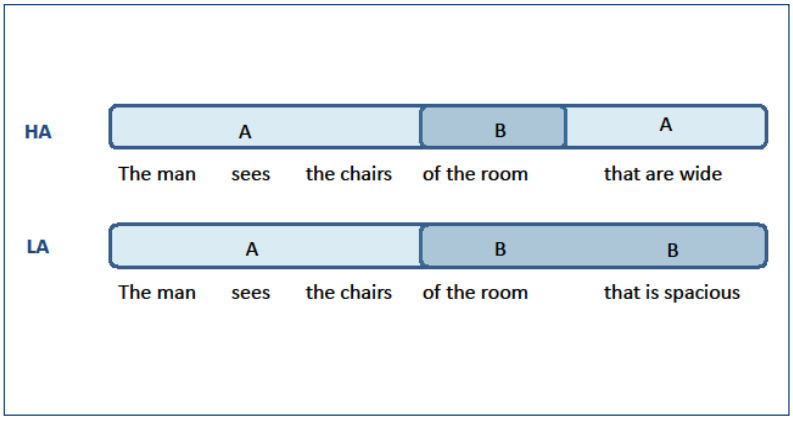


Figure 14: structures of HA and LA sentences

For the HA melodies, the first 3 tones and the last 2 tones of the melody were selected from the same zone, but the middle 3 tones were selected from the different region. This resulted in an "ABA" sequence. Therefore, the HA-constructed melodies had two harmonic boundaries. This closely resembles the structure of an HA relative clause sentence (verb phrase, followed by a propositional phrase attaching to the verb phrase, followed by a relative clause that attaches back to the verb phrase).

For the LA melodies, the second and last parts of the melody were selected from a different zone compared to the first 3 tones. This resulted in an "ABB" structure, meaning that only one harmonic boundary was presented in the LA-constructed melodies, and that the second and final part of the tone sequence were played in the same harmonic context. This is similar to the narrative of a LA sentence (verb phrase, followed by a propositional phrase structure that consists out of a propositional phrase and a relative clause). Figure 15 presents an example of what an HA and an LA melody could look like.

It is important to note that every tone in the melody is presented at the same rhythm, and that there are no large differences in tonal height (every tone was selected in a range of two octaves), as was done the first experiment. This makes sure that there is a distinction between the two priming melodies only at the level of implicit structure, and not tonal height or rhythm. Auditory examples can be found in the online attachments (see Attachments section).

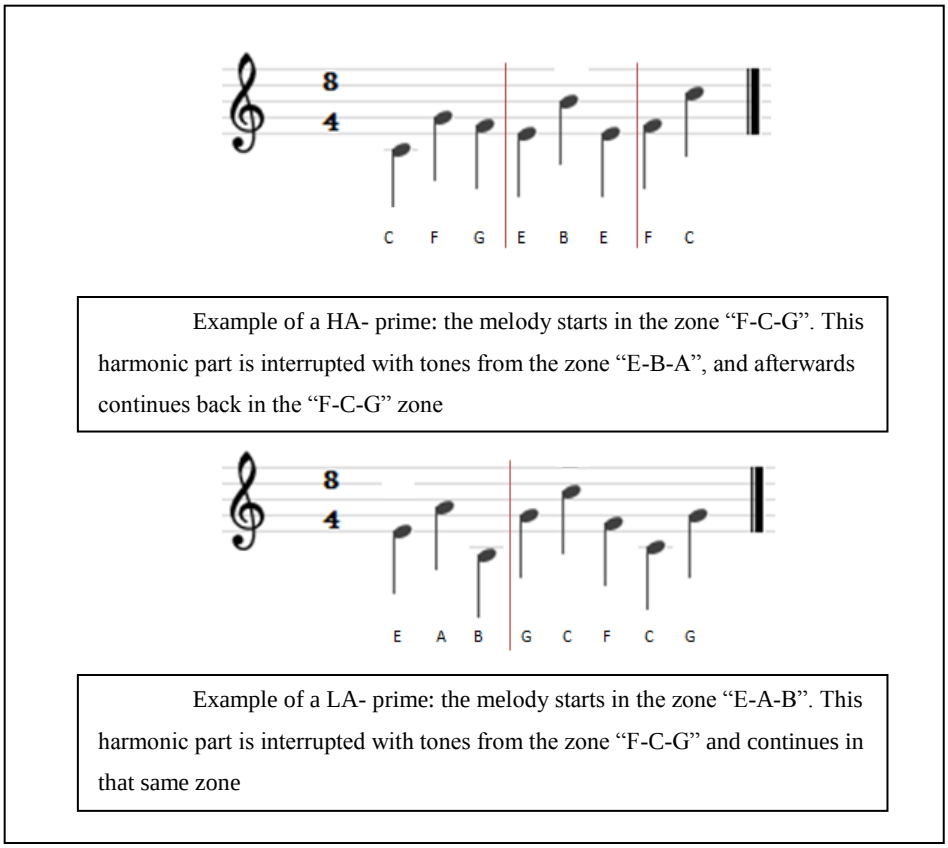


*Figure 15***:** examples of possible HA and LA melodies

Probe task.

To make sure that participants attended to the presented melodies, there was a small recognition task at the end of each melody, based on the task presented in the previous study. Apart from requiring the participants to actively listen to the melodies, the presentation of this task before the sentence completion task allowed for the experimenter to instruct participants to look at both tasks (tone sequences and sentences) as being independent, thereby improving the implicit priming design of the experiment. To create such recognition task, participants again heard a recognition probe of two tones after each tone sequence. They had to judge whether these two tones were a sequential segment taken from the previously heard melody, or a combination of two tones in the previous melody that were not presented in that sequence.

As in the previous study, there were 50 % correct (25% "within phrase", 25% "between phrase") and 50% false probes. "within phrase"-probes consisted out of two tones

that were consecutively presented in the previous tone sequence and were harmonically congruent, "between phrase"-probes consisted out of two tones that were consecutively presented in the previous tone sequence, but were harmonically incongruent, thus separated by a harmonic boundary after harmonic integration. False probes consisted out of two tones that were presented in the previous tone sequence in non-sequential order.

Procedure

First, the participants filled in their informed consents and received instructions concerning the experiment. In the instructions, participants were told that the main research question was the automaticity of musical processing, which was tested by a recognition task. They were instructed in the nature of the recognition task. After this, the participants were told that they would have to produce short sentence endings (recorded verbally) of some sentence beginnings, a task that was supposedly done to shift attention away from the melodies and reduce confusion between the previous and earlier presented melodies. After this, the participant received an example of a trial, and further question could be asked. This was followed by the experimental part. On each trial, a melody was provided to the participants, consisting out of 8 tones (duration 370 ms with silences in between of 200 ms). After the presentation of this melody, the screen turned blue, and 1 second later the probe was produced, consisting out of two tones presented at the same pace as the melody. The words "juist" and "fout" (Dutch for respectively "right" and "wrong") were presented left and right on the screen, and people pressed the corresponding keys "f" and "j" (again, left and right on the keyboard) to respond. When a response was registered, the screen turned black, and the sentence beginning was presented (e.g. " I saw the lights of the room that…" in Dutch). Participants were asked to read the sentence beginning out loud and fluently complete with a sentence ending in a syntactically correct fashion. After this, the participants clicked a button to start the next trial. The verbally produced sentence endings were recorded using a clip-on microphone, and judged into HA and LA structures after the experiment was done. The 60 ambiguous sentences were retained for analysis. A schematic overview of the procedure can be found in Figure 16.

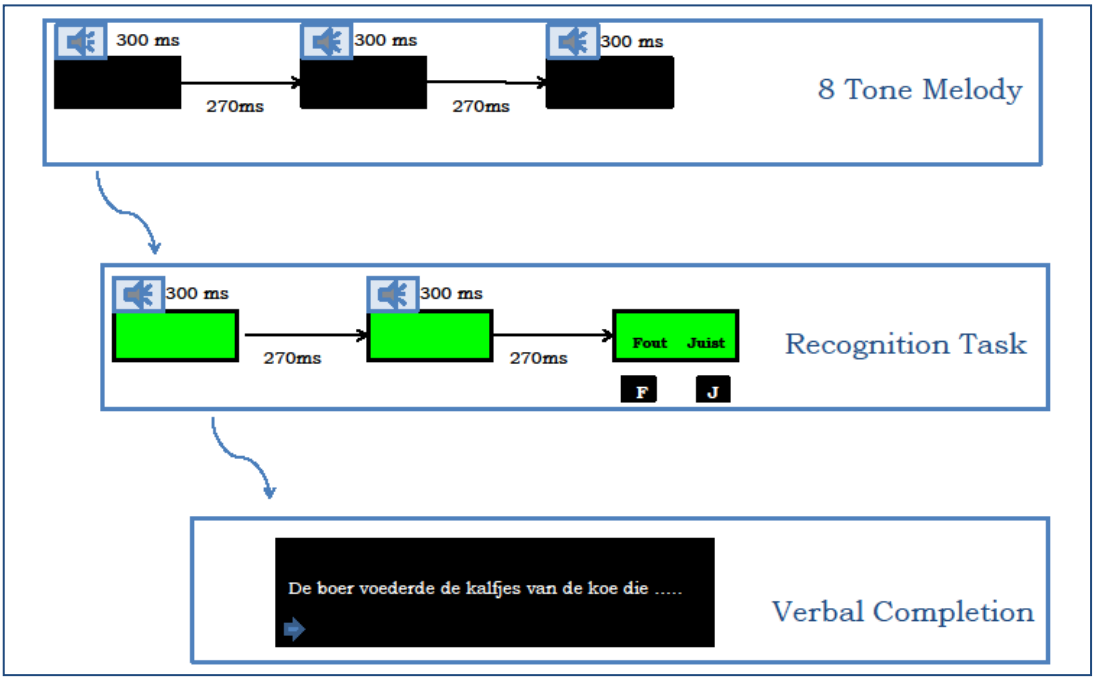


Figure 16: Procedure of the first experiment

Hypothesis

The main hypothesis of the second experiment was that the processing of hierarchical structure could be primed from music to language. In the experiment, the dependent measure was the type of sentential endings (HA or LA) that participants produced following ambiguous sentence beginnings (e.g.: "I see the lights in the room that…"). Following the idea of structural priming, the findings were expected to display an enhanced occurrence of a type of sentence ending (e.g. HA) when the sentence beginning was preceded by a congruent (e.g. HA) versus an incongruent (e.g. LA) melodic structure. Also, the probe recognition task was expected to display a harmonic integration effect ("between phrase"-probes recognized less well as compared to "within phrase"-probes), similar to the previous study.

Analysis

We conducted and LMER (within participants, family is binomial) for the completion type (HA | LA) and the recognition performance over prime type and recognition probe type.

Results

The priming condition (HA or LA) was a significant (z= 3.062, Pr (>|z|) =0.002) predictor for the type of sentence completion. Specifically where there were 31% more LA-responses after an LA-structured melody, whereas this number was reduced to 17% more LA-responses after a HA -structured melody. In other words, there was a 14 % priming effect (see Figure 17). Slope model fitting did not improve the model.

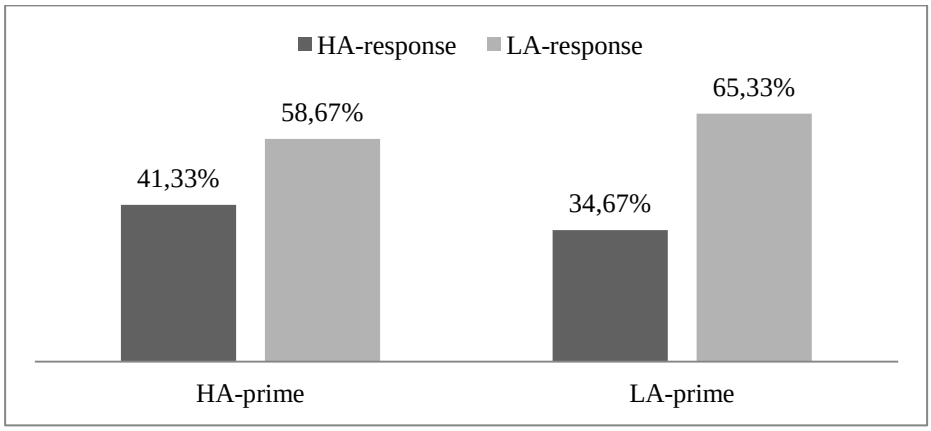


Figure 17: Overview of the percentage of HA versus LA completions by priming

As expected, there was also a harmonic processing effect on the probe recognition task. The amount of correct recognition for "within phrase"-probes was significantly higher (z=4.240, Pr(>|z|) <0.001), as compared to the recognition of "between phrase"-probes. Figure 18 clearly shows an increase of 15% in performance. The general performance is also higher compared to the previous study, due to change from double to single task performance.

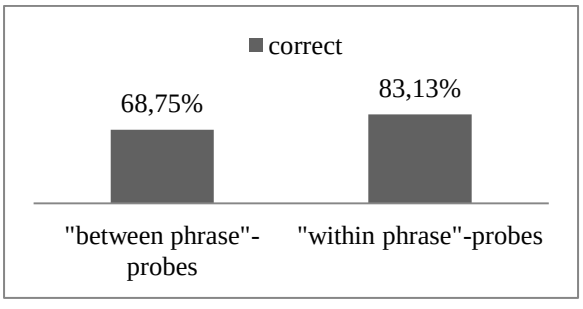


Figure 18: Presentation of the harmonic integration effect found in the recognition task

Comment

The findings reveal a strong effect of priming for the melody structure onto the preferred attachment structure in unrelated sentence productions. This supports the previously stated claim that "relative clause"-attachment is indeed to be regarded as a priming of structural integration processes, independent from domain-specific syntactic rule representtations.

The Issue of Prosodic Priming

A second point of discussion in the research of syntactic priming is the possibility of prosodic priming. This alternative explanation to the syntactic priming effects, being that people only aspire superficial similarity between sentences and not underlying syntactic similarity, has been falsified by the early studies of Bock (1986, 1989). In these studies, Bock found that superficial similarities without underlying syntactic congruency ("I give a book to Stella" versus "I give a book to study") were not suited for priming. This has been seen as clear evidence to exclude prosody. Even though this study has been referred to by a large body of later studies, this finding has very rarely been replicated. Especially when looking at sound manipulation software that is available now (frequency filters, amplitude changes), the prosodic explanation could be studied in far more detail.

In the recent studies considering attachment priming (Scheepers, 2003; Desmet & Declercq, 2006; Scheepers et al., 2011), the linguistic level on which syntactic priming is based is questioned again. Even though in these studies specific syntax rule representations do not seem to be able to account for the effects, it is again uttered that the effects must be based on an underlying structural similarity. Therefore, it has become important to more thoroughly examine the possibility of the prosodic priming account through modern designs using a more detailed manipulation. In a second experiment, this study has attempted to replicate the falsification of the prosodic explanation found in Bock (1986), using prosodic primes that were direct sound-altered versions of the syntactic primes, in that way providing evidence that is clearly interpretable.

Experiment 2

This experiment was based on a syntactic priming design. In this basic design, the participants first have to match auditory presented descriptions with pictures, and then describe a transitive picture themselves (e.g. “the boy gives the ball to the girl”). Following the theory of syntactic priming, the descriptions heard in the matching task should only be able to prime the structure of the later produced descriptions if there is an underlying syntactic overlap.

Research questions

Based on earlier syntactic priming evidence (e.g. Bock, 1986), priming effects on the transitive descriptions that participants produce would be expected if the heard prime descriptions are transitive as well. This is generally done by either providing the prime in a “propositional object” (PO, “de jongen geeft de bal aan het meisje” / *“the boy gives the ball to the girl”*) or “double object” (DO, “de jongen geeft het meisje de bal” /*”the boy gives the girl the ball”*) structure, and measuring the structure that is being produced in the participants own description.

Of course, such syntactic priming effect is not expected when the priming descriptions cannot syntactically match the description produced by the participant. For this experiment, the priming descriptions in the control condition were intransitive (e.g. “de jongen kust het meisje”/ *the boy kisses the girl”*). Therefore, no priming is possible, and the baseline distribution of PO versus DO responses can be investigated for the same target set.

Finally, the experiment also included a new set of priming description, namely the prosodic descriptions. These descriptions are sound-altered versions of the syntactic priming descriptions, so that they were stripped of semantics and syntax, but not of their prosody, rhythm and sound amplitude. Based on the statement that syntactic priming in solely based on syntactic representations, these altered descriptions should not be able to prime the target descriptions produced by the participant.

Participants

15 participants were invited by means of the online experiment platform of the University of Ghent. Participants did not take part in the first experiment. They were paid 4 euro in exchange for their participation to the experiment, which took 30 minutes. They were required to speak Dutch as their native language, and to have normal listening and reading skills. Participants were not required to have any musical experience.

Materials

Priming figures and descriptions.

In the control condition, 80 different intransitive pictures were created. Also, 80 taped auditory descriptions were made, congruent to these pictures. When the priming pictures were presented together with the auditory descriptions, participants had to match whether the description was congruent with the picture. To create non-matches, descriptions of one of the other 79 pictures within the intransitive set were chosen.

In the syntactic condition, 80 different transitive pictures were created. All of these pictures' descriptions were taped in both PO and DO structures. For every picture, the subject was always printed on the right side of the figure, the object was printed in the middle, and the receiver was presented at the left side of the figure. This was done since now in the reading direction (from left to right), the patient is viewed before the object (as to promote the less popular DO structure in Dutch). Again participants had to match the auditory descriptions to the transitive pictures. Half of these descriptions were PO structures, the other half were DO structures. Which pictures were coupled with which type of structure, was counterbalanced between participants. Important to note is that, to create nonmatches, other descriptions were chosen that always the same PO or DO structure as the correct description.

Finally, for the prosodic condition, the figures and the descriptions were very similar to the syntactic condition. To create the prosodic primes, the transitive PO and DO descriptions from the syntactic condition were used, and altered through what is mostly called a "whahwhah" effect. This effect uses a frequency change and can be made at high speed. In other words, the voice tone shifts very fast, so that the separate sounds are altered. After

repeated use of this method the voice pitch changes so fast that the voice sounds as if it is presented through a wall. Even though rhythm, amplitude, and even to some extend the vowel/consonants distinction is guessable, there is no word comprehension, and in that way also no implicit syntactic structure processing. Figure 19 presents an example of such a prosodic derivation. Important to note here is that, even though the semantic and syntactic meaning of the description is gone, the amplitude changes and prosody (for example, the rhythm caused by the extra word "the" in PO-primes) are still distinguishable. Since the prosodic descriptions were not understandable enough to match to a figure, participants needed to match two prosodic descriptions, to tell whether they were the same or different. This again ensured attention to the several aspects of the prosodic prime. Auditory examples of all sorts of priming descriptions can be found in the online attachments (see the Attachment section of the paper), examples of priming and target pictures can be found in Attachment C.

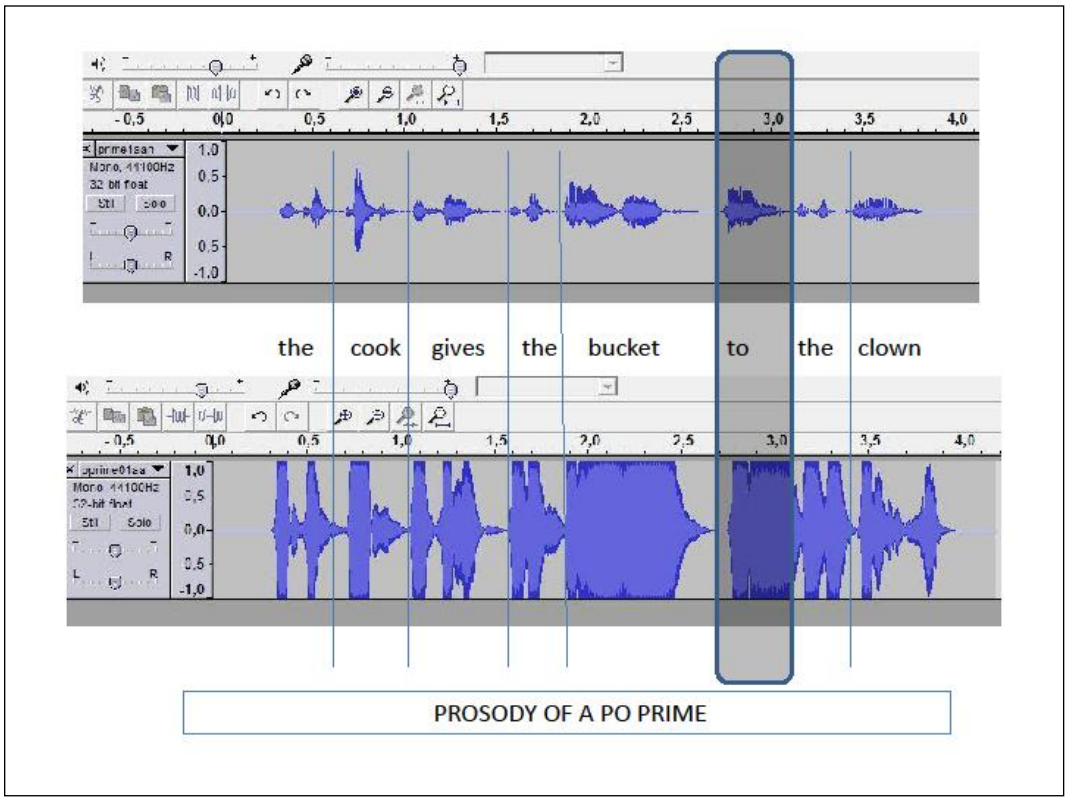


Figure 19: Example of a prosodic manipulation

Procedure

The procedure is depicted in Figure 20.

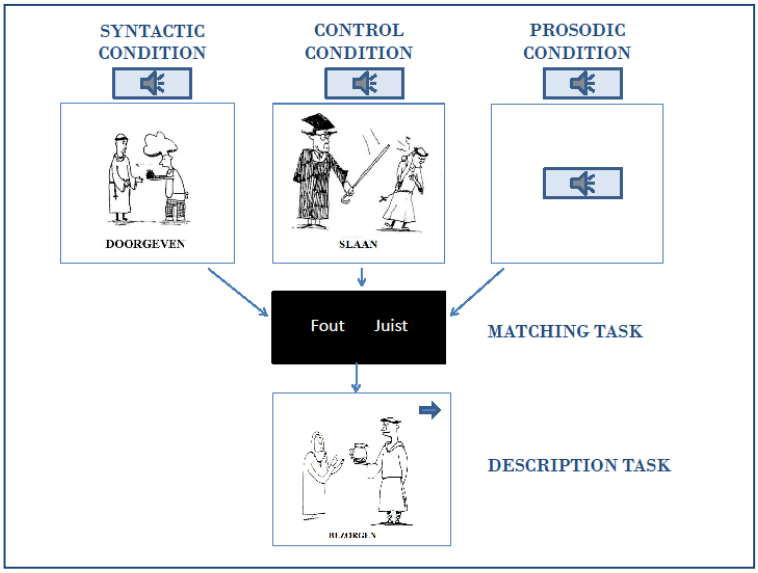


Figure 20: Presentation of the procedure of Experiment 2

After signing the informed consents, participants were randomly assigned to one of the three (syntactic priming | control | prosodic priming), and received instructions for the task they were to perform. After this, participants received all 80 trials in one block. Every trial started with a fixation cross that was presented for 1 second, followed by a black screen for 2 seconds. This was followed by the matching task. In the syntactic priming and control conditions, a picture was presented on the screen, while participants heard a verbal description through their headphones. After the auditory presentation of the description, the screen turned black, and the words "juist" or "fout" (Dutch for respectively right and wrong) were presented left and right on the screen. Participants needed to press "j" if the auditory description matched the presented picture and "f" for a mismatch. In the prosodic priming condition, participants needed to match two prosodic auditive descriptions that were presented consecutively, with a gap of 1 second between the two descriptions. Again, after the presentation of the last description, the screen turned black, and the words "juist" or "fout" (Dutch for respectively right and wrong) were presented left and right on the screen. Participants needed to press "j" if the two descriptions were the same and "f" if they were different. After responding to this

matching task, the participants (in every condition) were presented with a target picture, which participants needed to verbally describe into a clip-on microphone. When their description was finished, they clicked a button to start the next trial. The target picture was presented until the button was clicked.

Hypothesis

The hypothesis can be clearly defined. Where there should be a significant increase in the amount of PO descriptions participants make when they were primed with a PO-structure matching task (as opposed to a DO-structured) matching task in the syntactic priming condition, such a priming effect is not expected in the control condition, or in the prosodic condition.

Analysis

A lmer analysis was used (within subjects, family is binomial) to derive the amount of PO descriptions participants gave for each condition (syntactic, prosodic or control) and prime structure (PO or DO).

Results

The general analysis did not reveal a significant effect of syntactic priming, and furthermore also no significant interaction between priming and the condition. Given that there was a very low power (only 5 participants per condition) further analysis was done to reveal priming tendencies between conditions. There was a non-significant effect of priming in the control condition ($z = 0.214$, $Pr(>|z|) = 0.8306$). When comparing DO to PO priming, there was only a .05% increase in DO descriptions. However, there was a clear increase of priming effect in the syntactic condition compared to the control condition($z=1.530$, $Pr(>|z|) = 0.126$), showing a 11.5% change in descriptions. In the prosodic condition the priming effect was not at all different ($z=0.110$, $Pr(>|z|) =0.9126$) from the control condition, showing again

a 0.5 % change in descriptions. When comparing the syntactic condition with the prosodic condition, there was a significant increase in priming effect (z=2.129, Pr (>|z|) =0.0332). A presentation of the results can be found in Figure 21.

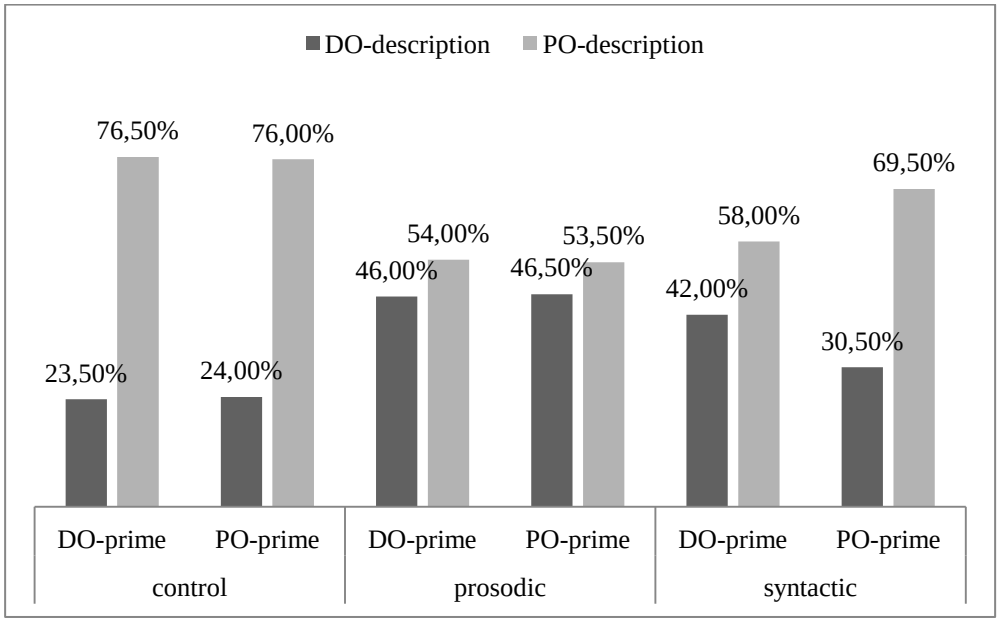


Figure 21: amount of DO and PO responses for every condition

There are two remarks to be made considering these findings. A first remark to be made is that even though the difference in syntactic priming between the syntactic and the control condition might not be up to significance level (p=0.12), it is important to acknowledge that the power of these tests is relatively low, given that only 5 participants could be tested in each condition. Therefore, it is argued that it is still possible to speak of a replication of the syntactic priming effect, though the data are only suggestive.

A second remark to make is that, even though there is no change in priming between the control condition and the prosodic condition, there is a very clear change in the distribution of DO versus PO target descriptions. Figure 20 shows that, where the control condition shows a strong tendency of participants to produce PO descriptions (as is commonly found in Dutch), such a tendency is no longer present in the prosodic condition. It seems, therefore, that even though the prosodic primes are not capable to prime DO versus PO descriptions within a specific trial, there is still some sort of "awareness" of the two options provided by the primes.

Comment

Using a novel paradigm for investigating prosodic priming, this third experiment has provided evidence against a prosodic explanation of syntactic priming research. The novel aspect of this replication is that rhythm and prosody could be kept exactly alike between syntactic and prosodic primes, thus only leaving semantics, and therefore syntactic analysis open. Therefore, this study suggests that priming of sentential structures is not due to rhythm or other surface structure, and that in the light of the newly found levels of structural priming, the prosodic priming account can still be falsified.

Discussion

This empirical study reviewed the recent discussion point of attachment priming, such as attachment priming that can be found cross-structural and cross-domain (e.g. Desmet & Declercq, 2006; Scheepers, 2003, 2011). The study provided a theoretical framework for these new findings, strongly based on the previously discussed SSIRH. In this framework, a distinction is made between two forms of syntactic priming. First, there is the classic form of syntactic priming, which can be related to the activation of syntactic representations, and therefore are based on domain-specific representational networks (following the SSIRH). Second, there is the new form of attachment priming, which can be related to the priming of the hierarchical structure of the sentence, and can therefore be related to the domain of integration processes (following the SSIRH).

Following the claim that attachment priming is to be seen as a priming of domain-general integration processes, it follows out of the SSIRH that attachment priming should be possible from music to language. The empirical study therefore discussed two experiments that provided evidence for the relation between attachment priming and structural integration processes. In a first experiment, it was shown that the attachment of a relative clause to a main sentence could be primed by tone sequences that had a similar structural integration. Specifically, the findings revealed that participants' tendency to complete the relative clause with a high or low attachment favored the attachment that was most similar to a preceding melodic structure. This experiment therefore provided novel evidence for attachment priming

from musical to linguistic structures, in line with the idea that attachment priming is based on domain-general integration processes. A second experiment shortly addressed the alternative explanation that sentential priming effects could be explained through prosodic similarities. After the initial study of Bock (1986), introducing syntactic priming by falsifying this prosodic account, there has been little to no empirical falsification of this account. Given that the idea of priming through surface structure again takes a large importance when regarding attachment priming that is not based on domain specific syntax representations, this falsification was re-examined by means of a basic syntactic priming study, and adding a condition with prosodic similar descriptions. The novel aspect of this study is that instead of a direct sound-altered version of the syntactic primes was used, thus reducing the difference from the syntactic priming condition to an absolute minimum, merely stripping away the ability for participants to distinguish the different vowels and consonants (and to that extent the semantics of the linguistic sequence).

A first remark that should be noted when discussing this empirical study is that the theoretical framework that is proposed needs to be further addressed and supported with further evidence. With the reported experiments, the study merely aspires to increase awareness for the concept of structural integration in music.

A second remark to make is that the proposed explanation of attachment priming through structural integration processes is not to be seen as a novel explanation. In essence, the concept of priming structural integration processes aligns very well with previously uttered explanations in attachment priming research. For example, the study of Desmet and Declerq (2006) refers to Tree Adjoining Grammar (Joshi & Schabes, 1997) as a theoretical framework behind the found effects of attachment priming. This account thus refers to attachment priming as a priming of the sentential tree structure, thereby referring to the hierarchical structure of the sentence, rather than the syntactic representations that make up this hierarchical structure. Also other explanations of attachment priming (e.g. Scheepers 2011) refer to the construction of hierarchy as a basis. Therefore, the remark should be made that regarding attachment priming as a priming of structural integration should be seen as a theoretical framework that is also in line with various similar explanations.

General Discussion

Are Syntactic Processes in Music and Language Domain Specific: Structural Integration

The first chapter provided a theoretical review concerning the domain specificity of syntactic processing in music and language. Syntactic processing in music can be generally related to a structural integration of sound sequences through (the violation of) expectancies based on harmonic rules. This process of harmonic integration closely resembles the way sentences are syntactically processed, both in its underlying mechanisms and its implicit and universal development in young infants. As a consequence of this similarity, a growing body of research has investigated the domain specificity of syntactic processing in both domains, finding evidence for large forms of overlap as well as dissociation. This body of evidence has been theoretically integrated in the Shared Syntactic Integration Resource Hypothesis (Patel, 2003), stating that syntactic priming in both domains is based on domain-general resources for structural integration though (violations of) expectancies that are based on domain-specific networks of syntactic rule representations. Based on this theoretical framework, there is a strong expectancy to find an interaction between the processes of structural integration in music and language. However, only a small number of studies have directly addressed the statements provided by the SSIRH (Patel, 2003), and furthermore, the application of this theoretical framework has mainly been limited to studies concerning music cognition.

Structural Integration in Language and Music: Novel Findings in SSIRH Research

A first empirical study addressed the existing evidence concerning the SSIRH. Specifically, it directly addressed several important issues with previous research concerning the SSIRH. Previous research mainly focused on the influence of music processing on simultaneous psycholinguistic tasks (such as syntactic re-analysis of "garden path"-sentences, e.g. Slevc et al.,2009), thereby largely neglecting the mutual influence of sentence processing

on structural processing in music, and also using unexpectancy manipulations in both melodies and sentences. Therefore, an experiment was designed that directly contributed to this body of research, studying the influence (a) of language on musical processing, (b) through direct measures of harmonic processing (c) in both normal structure processing and syntactic reanalysis. The results showed that harmonic processing of a melody could be influenced by syntactic reanalysis, thereby providing novel evidence for the mutuality and theoretical interpretation of previously found interference effects. Furthermore, the experiment also addressed aligned structural processing of language and music as well as online effects of simultaneous processing of unambiguous sentences and tone sequences, thereby clearly showing that the previously found interference evidence does not exclude the possibility and uses of aligned structural processing in both domains.

Structural Integration Priming: A Theoretical Framework for Syntactic Priming

A second empirical study addressed the use of the theoretical framework of the SSIRH on a recent point of debate in psycholinguistic research, namely the finding of attachment priming between sentences. This attachment priming can be brought back to a priming of the hierarchic structure of a sentence, independent form the specific syntactic rule representations on which this structure is constructed. In this empirical study, the finding of attachment priming was integrated with the model of the SSIRH, stating that syntactic priming could be subdivided in priming of the domain-specific syntactic representations (referring to the classic forms of syntactic priming), and a priming of the structural integration processes, that are shared between domains (and can thus explain the found cross-structural and even cross-domain priming). Two experiments were described that provided evidence for this claim that attachment priming was based on domain-general structural integration processes. A first experiment showed that relative attachment priming can indeed be found from music to language, two domains that have been shown to have overlapping structural integration resources. A second experiment replicated a modern falsification of the prosodic priming account, concluding that surface similarities between sentences are not able to cause sentential priming.

Further Research

A first aspect concerning further research is that this paper solely focuses on syntactic processing in language and music. However, syntax is but one of many ways by which melodic and linguistic sequences are processed. By discussing the relation between syntactic processes in language and music, this paper merely aspires to increase the interchangeability between the domains of music cognition and psycholinguistics. Large bodies of research have already addressed several different ways in which sequences are structured, such as prosody and rhythm (e.g. Boltz, 1993; Ibbotson & Morton, 1981; Jones et al., 1982). Given that processing on these levels is also very similar between language and music, there are still many levels on which the relationship between language and music processing can further be discussed. For further research for example, the process of structuring melodic sequences has also been related to the creation of rhythmic expectations (Boltz, 1993). This again suggests possible overlap with prosodic structuring of sentences. In short, there are many levels on which a comparison of musical and linguistic processing might prove worthwhile.

A second aspect concerning further research is the measure of harmonic integration used that has been brought up in the empirical studies. This recognition task, focusing on perceptual differences in the tone sequences though harmonic integration, has proven to be a consistent measure of structural processing. However, this method of measuring structural processing could also be applied to other domains like language. As was suggested earlier, studies have also found evidence concerning perceptual changes in sentences (e.g. Townsend et al., 1979) due to syntactic integration processes. Therefore, a similar dependent measure could also be created to measure structural integration in language. For example, an increased structural integration of a sentence into its syntactic "phrases" might reduce the performance or speed with which words presented in a sentence are recognized. Such a dependent measure might prove worthwhile, given that it would be possible to measure the syntactic processing of unambiguous sentences.

A third aspect concerning further research is the implementation of the reported findings concerning domain-general structural integration outside of experimental research. When relating this claim to developmental studies, it has indeed been shown (e.g. Anvari et

al., 2002; Jentschke & Koelsch, 2009) that experience to music processing at a young age does have effect on early syntactic competences in language. Furthermore, studies have put the integration of sequences into syntactic clauses at the basis of syntactic development in young infants (e.g. Hirsh-Pasek, Nelson, Jusczyk, Cassidy, Druss & Kennedy, 1987). Therefore, a further elaboration on the shared processes between language and music can be implemented in developmental practices. Apart from developmental studies, there are also clinical deficits that can be further explored in the light of domain-general structural integration processes. For example, a recent study by Lelekov, Franck, Dominey and Georgieff (2000) has linked the commonly found deficit of syntactic processing of sentences in schizophrenic patients to a dysfunction of cognitive sequence processing mechanisms that seem to be domain-general. Such studies provide a strong starting point for an application of the above mentioned concepts.

A final aspect concerning further research is the elaboration on the domain-generality of structural processing. Even though this paper has solely focused on the domains of music and language, it is important to be aware that also other domains of cognition incorporate structural processing. For example, the recent study of Scheepers et al. (2011) has found evidence for attachment priming from arithmetic equation structures to sentences. Other studies have generally related syntactic processing to the processes of analogical reasoning, which can be conceptualized as the mapping of relational structure across domains (e.g., Goldwater, Tomlinson, Echols & Love, 2010). Another example is the relationship that researchers (e.g. Allen, Ibara, Seymoun, Cordova & Botvinick, 2010) have made between the idea of abstract structural representations and goal-directed behavior. In short, there are many different domains and mental processes that have been linked to structural processing throughout the experimental domain, and that might be further addressed following the idea of domain-general structural integration processes.

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ATTACHMENTS: TABLE OF CONTENTS

Data files of the experiments can be found online at http://users.ugent.be/~rhartsui/SupMat.html under the section Van de Cavey (2012)

Data of the SSIRH Experiment (Expt 1) : ...……exp_1.dat

Data of the Attachment Priming Experiment (Expt 2) :……...exp_2.dat

Data of the Prosodic Priming Experiment (Expt 3) :……exp_3.dat

Example stimuli of the experiments can be found online at http://users.ugent.be/~rhartsui/SupMat.html under the section Van de Cavey (2012)

Data of the Attachment Priming Experiment (Expt 2) :

Sound example of a HA-structured tone sequence:…….High-attachment melody

Sound example of a LA-structured tone sequence:……...Low-attachment melody

Data of the Prosodic Priming Experiment (Expt 3) :

Sound example of a normal description PO prime:……PO-dative normal

Sound example of a normal description DO prime:…...DO-dative normal

Sound example of a prosodic description PO prime:….PO-dative modified

Sound example of a prosodic description DO prime:…DO-dative modified

Attachment A: Sentences used in the SSIRH Experiment

De secretaresse zoekt de dossiers van het schoolhoofd dat ontslagen is
De secretaresse zoekt de dossiers van het schoolhoofd die verdwenen zijn
De ober kuist de tafels van het restaurant dat oud is
De ober kuist de tafels van het restaurant die vuil zijn
De vrouw ziet de broers van het meisje dat mooi is
De vrouw ziet de broers van het meisje die oud zijn
De kapper knipt de vlechten van het meisje dat luid weent
De kapper knipt de vlechten van het meisje die lang zijn
De schoonmaker poetst de bedden van het ziekenhuis dat oud is
De schoonmaker poetst de bedden van het ziekenhuis die vuil zijn
De dief steelt de kisten van het huis dat beveiligd is
De dief steelt de kisten van het huis die zwaar zijn
De priester ziet de ramen van het klooster dat oud is
De priester ziet de ramen van het klooster die vuil zijn
De journalist leest de artikels van het tijdschrift dat dik is
De journalist leest de artikels van het tijdschrift die lang zijn
De leraar schildert de muren van het lokaal dat vervallen is
De leraar schildert de muren van het klaslokaal die stoffig zijn
De artiest bewondert de kleuren van het schilderij dat mooi is
De artiest bewondert de kleuren van het schilderij die fel zijn
De man plaatst het bureau van de secretaresses die nieuw zijn
De man plaatst het bureau van de secretaresses dat zwaar is
De dirigent straft het neefje van de muzikanten die moe zijn
De dirigent straft het neefje van de muzikanten dat stout is
De school organiseert het galabal van de verenigingen die morgen samenkomen
De school organiseert het galabal van de verenigingen dat morgen plaatsvindt
De politie vindt het zoontje van de ouders die kwaad waren
De politie vindt het zoontje van de ouders dat vermist was
De kunstenaar maakte het logo van de muzikanten die bekend waren
De kunstenaar maakte het logo van de muzikanten dat groot was
De secretaris schreef het verslag van de vergadering die lang duurde
De secretaris schreef het verslag van de vergadering dat gevraagd was
De apotheker vroeg het voorschrift van de medicijnen die drogerend zijn
De apotheker vroeg het voorschrift van de medicijnen dat gegeven was
De directeur leest het briefje van de studente die gespijbeld heeft
De directeur leest het briefje van de studente dat doorgegeven werd
De leraar straft het dochtertje van de dokter die gisteren werkte
De leraar straft het dochtertje van de dokter dat stout was
De secretaris wijzigt het schema van de afwezigheden die vaak voorkomen
De secretaris wijzigt het schema van de afwezigheden dat verouderd is

ATTACHMENT A

De man zag het zoontje van de buurvrouw die de was ophing
De man zag het zoontje van de buurvouw dat luid speelde
De architect tekende het plan van de school die gebouwd werd
De architect tekende het plan van de school dat gedetailleerd was
De piloot vernielde het vliegtuig van de miljardair die op reis was
De piloot vernielde het vliegtuig van de miljardair dat duur was
De leraar strafte het vriendinnetje van de jongen die buiten loopt
De leraar strafte het vriendinnetje van de jongen dat gisteren spijbelde
De toerist bezocht het hotel van de stad die druk was
De toerist bezocht het hotel van de stad dat volzet was
De dokter roept de verpleegster van het kindje dat ziek was
De dokter roept de verpleegster van het kindje die weg was
De matroos zocht de kapitein van het schip dat snel zonk
De matroos zocht de kapitein van het schip die aan wal stond
De architect ontwierp de attractie van het pretpark dat goedkoop is
De architect ontwierp de attractie van het pretpark die vernield werd
De schilder behandelde de muren van het huis dat gerenoveerd werd
De schilder behandelde de muren van het huis die vochtig waren
De manager ontsloeg de arbeiders van het magazijn dat verlaten was
De manager ontsloeg de arbeiders van het magazijn die gestolen hadden
De rechtbank veroordeelde de ontvoerders van de prins die gevat waren
De rechtbank veroordeelde de ontvoerders van de prins die jong was
De ontsnapte gek schoot op de kinderen van de buurman die angstig waren
De ontsnapte gek schoot op de kinderen van de buurman die binnen was
De moeder verstopte de speelgoedautootjes van de winkel die gevaarlijk waren
De moeder verstopte de speelgoedautootjes van de winkel die oud was
De detective volgde de minnaars van de vrouw die gevaar liepen
De detective volgde de minnaars van de vrouw die overspel pleegde
De overheid financiert de onderzoeken van de universiteit die duur zijn
De overheid financiert de onderzoeken van de universiteit die nieuw is
De meid kuiste de kamer van de broers die vuil was
De meid kuiste de kamer van de broers die lui waren
De agent beledigde de uitgeefster van de brochures die onbeleefd was
De agent beledigde de uitgeefster van de brochures die illegaal waren
De arts begroette de verpleegster van de bejaarden die stage liep
De arts begroette de verpleegster van de bejaarden die ziek waren
De meid staarde naar de juwelen van de gravin die duur waren
De meid staarde naar de juwelen van de gravin die kwaad werd
De leraar bekeek de huistaken van de studente die te kort waren
De leraar bekeek de huistaken van de studente die erg slim was
De presentator toonde de prijzen van de show die waardevol zijn

ATTACHMENT A

De presentator toonde de prijzen van de show die populair is
De verkoper opende de schuiven van de kast die lichtjes knelden
De verkoper opende de schuiven van de kast die goedkoop was
De baby keek naar de lichten van de auto die fel schenen
De baby keek naar de lichten van de auto die de oprit opreed
Het kind lachte met de opmerkingen van de clown die grappig waren
Het kind lachte met de opmerkingen van de clown die luid gilde
De manager bekeek de resultaten van de grote opening die afgeprint waren
De manager bekeek de resultaten van de grote opening die succesvol was
De tandarts onderzocht de tanden van de bejaarde vrouw die rot waren
De tandarts onderzocht de tanden van de bejaarde vrouw die tandpijn had
De boer voederde de kalfjes van de koe die juist rechtstonden
De boer voederde de kalfjes van de koe die verkocht werd
De manager wachtte op de muzikanten van de band die vertraging hadden
De manager wachtte op de muzikanten van de band die populair was
De docent adviseerde de leerlingen van de lerares die stil waren
De docent adviseerde de leerlingen van de lerares die ziek was
De priester sprak met de leidster van de scouts die deze dag trouwde
De priester sprak met de leidster van de scouts die op bezoek waren
De expert loofde de firma van de jonge ondernemers die snel groeide
De expert loofde de firma van de jonge ondernemers die net afstudeerden
De huisbaas herstelde de deurbel van de huurders die kapot was
De huisbaas herstelde de deurbel van de huurders die weg waren
De vorst vernielde de oogst van de fruitboeren die noodzakelijk was
De vorst vernielde de oogst van de fruitboeren die opstandig waren
De commisie verwees naar de bron van de donaties die gul was
De commisie verwees naar de bron van de donaties die de conventie financierden
De reisleider vernoemde de klokken van de kerk die erg luid waren
De reisleider vernoemde de klokken van de kerk die erg oud is
De geheime dienst legde beslag op de documenten van de overheid die geheim waren
De geheime dienst legde beslag op de documenten van de overheid die overgenomen werd
De geleerde bestudeerde de taal van de oerbewoners die erg ruw was
De geleerde bestudeerde de taal van de oerbewoners die vroeger leefden
De mecanicien controleerde de auto van de diplomaten die gedepanneerd werd
De mecanicien controleerde de auto van de diplomaten die in het land aankwamen
De chauffeur poetste de limousine van de staatsgasten die gehuurd was
De chauffeur poetste de limousine van de staatsgasten die belangrijk waren
De leraar verbeterde de huistaken van de student die slordig waren
De leraar verbeterde de huistaken van de student die slim was

Attachment B: Sentences used in the Attachment Priming Experiment

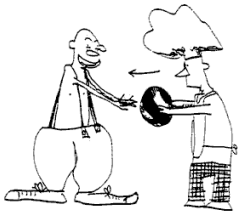
De rechtbank veroordeelde de ontvoerders van de prins die ...
De ontsnapte gek schoot op de kinderen van de buurman die ...
Mama verstopte de speelgoedautootjes van de winkel die ...
Iemand waarschuwde de familie van de kinderen die ...
De detective volgde al de minnaars van de vrouw die ...
De technicus herstelde de internetkabels van de computers die ...
De overheid financiert de onderzoeken van de universiteit die ...
De brandweer redde de twee katten van de oude vrouw die ...
Gisteren zag ik de manager van de muzikanten die ...
De architect tekende de plannen van de nieuwe school die ...
De arbeiders staken voor de poorten van de fabriek die ...
Ik dans graag op de muziek van de jaren negentig die ...
Bush negeert de nabestaanden van de soldaat die ...
Vandaag verjaren de zussen van de jongen die ...
De geleerde bestudeerde de architectuur van de oude gebouwen die ...
Isabelle ziet graag de standbeelden van de kathedraal die ...
Toeristen bezoeken de musea in de stad die ...
In de herfst vallen de bladeren van de boom die ...
Jan verwijderde de achterzetels van de auto die ...
De getuige is de beste vriend van de verloofden die ...
Er lag bloed op de vloer van de kamers die ...
De welzijnswerker begroette de verpleegster van de bejaarden die ...
Klaas ontmoette de bazin van de bediendes die ...
De meid kuiste de kamer van de twee broers die ...
De boer voederde de kalfjes van de koer die ...
De manager wachtte op de muzikanten van de band die ...
De docent adviseerde de leerlingen van de lerares die ...
Klara bezocht de studenten van de pianolerares die ...
De priester sprak met de leidster van de scouts die ...
Klaas ontmoette de bazin van de bediendes die ...
De gepensioneerde beledigde de uitgeefster van de brochures die ...
De welzijnswerker begroette de verpleegster van de bejaarden die ...
Kurt controleerde de uittreksels van de secretaresse die ...
We amuseerden ons met de artikels van de verslaggeefster die ...
Dieter glimlachte om de schetsen van de ontwerpster die ...
Franceska corrigeerde de manuscripten van de schrijfster die ...
De expert loofde de firma van de jonge ondernemers die ...
De huisbaas herstelde de deurbel van de huurders die ...
De vorst vernielde de oogst van de fruitboeren die ...

ATTACHMENT B

De commissie verwees naar de bron van de donaties die ...
De verhuizer verzekerde de meubels van de opdrachtgeefster die ...
De meid staarde naar de juwelen van de gravin die ...
De reisleider vernoemde de klokken van de kerk die ...
De geheime dienst legde beslag op de documenten van de overheid die ...
De geleerde bestudeerde de taal van de oerbewoners die ...
De mecanicien controleerde de auto van de diplomaten die ...
De chauffeur poetste de limousine van de staatsgasten die ...
Het sportnieuws prees de defensieformatie van de Rode Duivels die ...
De leraar schreef commentaar op de huistaken van Mieke die ...
De presentator toonde de prijzen van de show die ...
Mieke vroeg om de tekeningen van de kunstenaar die ...
De verkoper opende de schuiven van de kast die ...
Ik bekeek de afbeelding van de strijders die ...
De baby keek naar de lichten van de auto die ...
We gingen naar de openingsfuif van de studenten die ...
Het kind lachte met de opmerkingen van de clown die ...
De manager bekeek de resultaten van de grote opening die ...
De tandarts onderzocht de tanden van de bejaarde vrouw die ...
We gingen naar de plaatsen van de nieuwe zaal die ...
Hij vraagt naar de leden van de muziekgroep die ...
Martine streelde het huisdier van de schoolvriend die ...
Iemand schoot op het lief van de filmdiva die ...
De storm verwoestte de veranda van het huis dat ...
Frits klaagde bij het slagermeisje van de supermarkt die ...
Hans poetste het uitstalraam van de apotheek die ...
De tuinier maaide de weide van het park dat ...
De jongen plaagde de hamster van het meisje dat ...
De patiënt consulteerde de hoofdarts van het ziekenhuis dat ...
Francine herinnerde zich het broertje van de vriendin die ...
Leo wees naar het prentje van de oude man die ...
Jan ontmoette de vader van het meisje die ...
De piloot bestuurde het vliegtuig van de voetballers dat ...
De dokter onderzocht het vriendinnetje van de jongen dat ...
De conciërge bewaakte het hotel van de rijke vrouw dat ...
De arts complimenteert de verpleegster van het oude mannetje die ...
De schipper commandeert de matrozen van het schip die ...
De opvoedster verzorgt de kinderen van het dagverblijf die ...
De rechter beschuldigt de moeder van het gezin die ...
Mieke plaagt het vriendje van de verkoopster dat ...
Het kind houdt van de attracties van het pretpark die ...

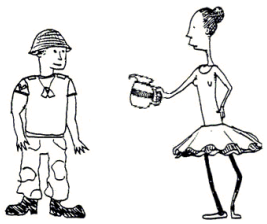
Attachment C: Stimuli used in the Prosodic Priming Experiment

Examples of Transitive Primes



DOORGEVEN

"the cook passes the ball to the clown"



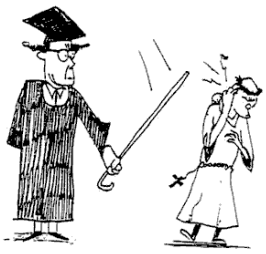
SCHENKEN

" the ballerina gives the soldier a jar"

VERKOPEN

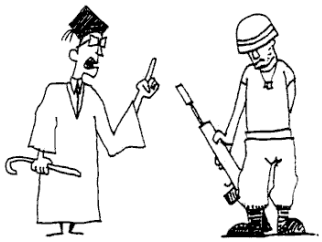
"the burglar sells a mug to the priest"

Examples of Intransitive Primes (Control Condition)



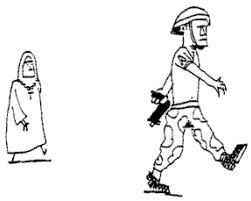
SLAAN

"the teacher hits the priest"



STRAFFEN

" the teacher punishes the soldier"

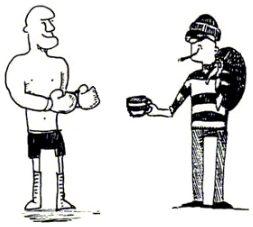


VOLGEN

"the nun follows the soldier"

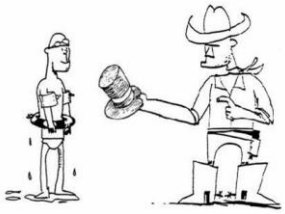
ATTACHMENT C

Examples of Target Primes



BEZORGEN

AANBIEDEN



LATEN ZIEN

"the burglar brangs the boxer the mug"	" the nun offers the doctor a cake"	"the cowboy shows the swimmer the hat"
"the burglar brangs the mug to the boxer"	" the nun offers the cake to the doctor"	"the cowboy shows the hat to the swimmer"

List of Priming Verbs

Verbs used in the transitive primes	**Verbs used in the intransitive primes**		
Doorgeven *(/ "to pass")*	Aanraken*(/ "to touch")*	Lachen(*/ "to laugh"*)	Slaan(*/ "to hit"*)
Geven (*/ "to give"*)	Boksen (*/ "to box"*)	Loslaten(*/ "to let go"*)	Straffen(*/ "to punish"*)
Schenken (*/ "to donate"*)	Duwen (*/ "to push"*)	Opheffen(*/ "to lift"*)	Vangen(*/ "to catch"*)
Uitreiken (*/ "to distribute"*)	Eten (*/ "to eat"*)	Poetsen(*/ "to clean"*)	Vasthouden(*/ "to hold"*)
Verkopen (*/ "to sell"*)	Kietelen (*/ "to sell"*)	Schieten(*/ "to shoot"*)	Volgen(*/ "to follow"*)

List of Target Verbs

Verbs used in the target pictures
Aanbieden*(/ "to offer")*
Bezorgen (*/ "to fetch"*)
Laten zien (*/ "to show"*)
Meegeven (*/ "to give"*)
Teruggeven(*/ "to give back"*)