IN SEARCH OF A SYNTACTIC RELATIONSHIP BETWEEN RHYTHM AND LANGUAGE

AZİZ MUHAMMED AKKAYA

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Aziz Muhammed Akkaya

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DECLARATION OF ORIGINALITY

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ABSTRACT

In Search of a Syntactic Relationship Between Rhythm and Language

Linguistic and musical syntax have been shown to rely on shared resources (Patel, 2003). In this study, we investigate the effect of an accompanying rhythm, another hierarchical domain, on sentence processing accuracy and speed. Two experiments were conducted to inspect the possible existence of shared processing of linguistic and rhythmic syntax. In the first experiment, sentences were manipulated to yield two levels of complexity: subject and object relative clauses. Rhythm was manipulated by using structured rhythms: sL, ssL, sssL, and sLL pulse sequences where “s” stands for a shorter inter-stimulus interval and L for a longer one. The s:L duration ratio was 1:2 (150ms:300ms). An isochronous (sssss..) control condition was also included. In the critical condition, the upbeat (s) that is heard right at the relative clause was presented 50 ms earlier. The dependent measure was participants' correct response rates and response times on the subsequent comprehension questions. The second experiment was identical to the first experiment with the exception that distorted rhythms were replaced with random beats to eliminate any structure in that condition. It was hypothesized that the rhythmic deviation in Experiment 1 would create competition of syntactical processing resources and hence decrease linguistic comprehension performance. In Experiment 2, we expected the random but not the structured rhythm condition to debilitate semantic processing of the sentences due to a complete "disconnectedness" between rhythmic and linguistic syntax. All the findings were null. There was no main effect of sentence and rhythm and interaction between the two in either of the experiments. This may indicate that rhythm and harmony rely on a different mechanism.

ÖZET

Dil ve Ritim Arasındaki Sentaktik İlişkinin Peşinde

Dilsel ve müziksel sentaksın ortak çalışan bellek kaynaklarına dayandığı gösterilmiştir (Patel, 2003). Bu çalışmada, büyük oranda hiyerarşik bir dizime dayanan diğer bir alan olan ritmin bir cümleye eşlik ederken cümleyi anlama netliğine ve hızına etkisini incelemekteyiz. Dilsel ve ritmik sentaksın ortak bir süreçten geçme olasılığını incelemek için iki deney yapılmıştır. İlk deneyde cümleler iki karmaşıklık seviyesi netice verecek şekilde değiştirilmiştir: özne ilgi tümceciği ve nesne ilgi tümceciği. Ritim bileşeni de iki seviyeye sahipti. Bir seviyede ritimler bozulmamış iken diğer seviyede tam ilgi tümceciği gelirken duyulan vurgusuz vuruş 50 ms önce sunulmuştur. Bağımlı değişkenler katılımcıların doğru tepki oranları ve her bir cümleyi takip eden kavrama sorularına verilen cevap süreleriydi. İkinci deney birinci deney ile tamamen aynı idi. Tek farkı ritimdeki yapıyı yok etmek adına bozuk ritimlerin rasgele ritimlerle değiştirilmesiydi. Deney 1'deki ritmik sapmanın sentaktik işleme kaynaklarında rekabete yol açacağı, dolayısıyla da dili kavrama performansını azaltacağı beklenmekteydi. Deney 2'de ritmik ve dilsel sentaks arasında tam bir "bağlantısızlıktan" dolayı hiçbir yapıya sahip olmayan rasgele ritim koşulunun cümlelerin semantik işlemesini zaafa düşüreceği beklenmekteydi. İki deneyde de anlamlı hiçbir sonuç bulunmamıştır. Cümle ve ritim koşullarının ana etkisi ve bunlar arasında bir etkileşim ortaya çıkmamıştır. Bu durum ise ritim ve armoninin farklı mekanizmalara dayandığını işaret edebilir.

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To Him who is the First and the Last, and the Outward and the Inward

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CHAPTER 1

INTRODUCTION

Researchers have been wondering about temporal processing and integration since the beginning of experimental psychology. One of the first experiments that investigated how people group incoming auditory stimuli was Bolton's (1894) seminal work on rhythm. Bolton showed that participants have a tendency to group auditory stimuli even in the absence of grouping cues. Therefore, it seems that people are inclined to structure incoming events even if the stimuli lack such structure.

After 1970s, Mari Riess Jones developed a theory that attempts to explain dynamic events by incorporating time as a dimension to external events (Jones, 1976). According to the theory, pitch, loudness and time are dimensions of stimuli in the world. People represent these dimensions and perceive the world accordingly. She criticized other theories because they treated time as something separate from stimuli. She thinks that the configuration of these dimensions determines whether participants can integrate incoming stimuli or not. One of the phenomena she mentions in her article is the so-called streaming effect. This effect happens when two simultaneously presented sound sequences are heard as two distinct sound sequences by participants: one as context sound, the other as figure sound (for an early antecedent of this view see Wertheimer, 1923). She claims that there are limits to accurately integrate sound sequences. When these limits are exceeded, participants either start to separate the sounds or chunk them. She claims that the structure of the stimulus determines whether a sequence will exceed the limits.

Furthermore, according to Jones, people are rhythmic organisms. The organism has rhythms with different frequencies. Via entrainment, internal rhythms become synchronized to external rhythms. Large and Jones (1999), later, elaborated more on attentional processes that happen in natural events. They claimed that even in the case of violations of strict rhythmic pattern, people can extract rhythmic structure. Humans can even attribute meaning to those deviations. According to the authors, people have self-sustaining oscillations that can entrain to external stimuli. One crucial feature of these self-sustaining oscillations is that they are not stable or fixed. Hence, participants can attend to small perturbations to the rhythmic pattern without loss of rhythmic structure (for a similar view in neuroscience see Buzsaki, 2019).

1.1 The shared structural integration hypothesis (SSIRH) by Patel

In the eve of the second millennium, Patel, Gibson, Ratner, Besson, and Holcomb (1998; Patel, 1998) found that both musical syntax and linguistic syntax processing produce ERP response of P600, which is considered to be responsible for linguistic syntax processing. In his experiment, participants listened to syntactically incorrect out-of-key musical scripts. P600, which was up until then believed to be unique to sentence processing, was also produced in response to out-of-key musical scripts. This led Patel to claim that musical syntax processing and linguistic syntax processing share neural working memory resources in the brain. Patel (1998, 2003) called this hypothesis Shared Structural Integration Hypothesis (SSIRH). This formulation offered a solution to the incompatible findings that people with amusia show dissociated patterns regarding music and language processing (Peretz & Coltheart, 2003). According to SSIRH, while language and music store syntactic information in distinct long-term memory regions in the brain, both share neural resources in the process of temporal integration (see Figure 1). One of the key regions that is found to be activated in response to musical syntax violations is Broca's area in the inferior left frontal hemisphere of the brain (Koelsch et. al, 2002). This region was traditionally thought to be involved only in linguistic syntax processing. Patel, Iversen, Wassenaar, and Hagoort (2008) found that people with Broca's aphasia showed deficits in musical syntactic processing as well as linguistic syntactic processing.

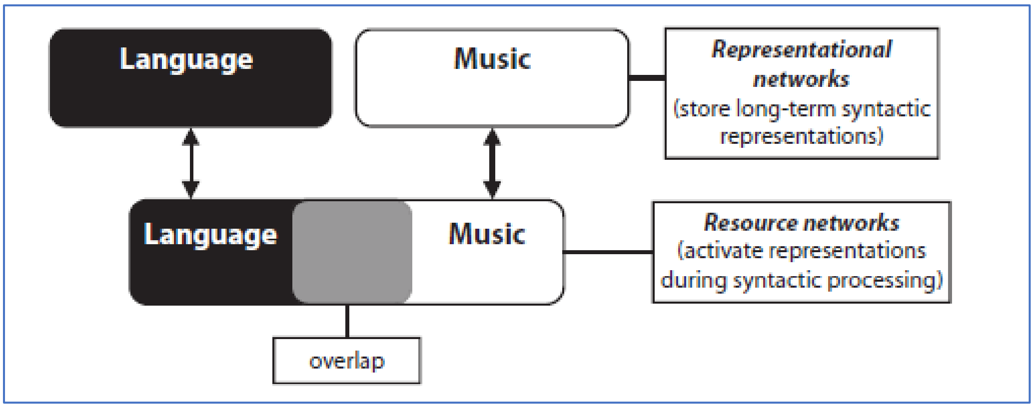

Figure 1. The relationship between musical and linguistic syntax in the brain (from Fedorenko, Patel, Casasanto, Winawer, and Gibson, 2009)

This line of research gathered much attention in the subsequent years and found some further empirical support. For example, Fedorenko and colleagues (2009) tested SSIRH using long-distance dependency sentences that produces syntactic ambiguity. They presented participants with either out-of-key musical scripts or syntactically ambiguous sentences or both. They found that participants showed decrease in comprehension for syntactically complex linguistic stimuli, particularly, if they were embedded on an out-of-key tone event. This finding supports SSIRH's prediction that participants have less resource to process syntactically incorrect musical and linguistic stimuli when they occur at the same time. Moreover, this type of interaction was not seen when syntactically ambiguous sentences were aligned with musical excerpts that had loudness instead of an out-of-key violations at the critical note event. This shows that the language and music share syntax processing but not general auditory processing.

Slevc, Rosenberg, and Patel (2009) conducted another experiment along the same line. This time they showed participants syntactic and semantic garden-path sentences (e. g., “After the trial the attorney advised the defendant was likely to commit more crimes” and “The boss warned the mailman to watch for angry pigs when delivering the mail”, respectively),. This type of sentences confer ambiguity that can be resolved in later parts of the sentence. All sentences were aligned to harmonic sequences with an in- or out-of-key chord at the critical location and participants’ task was to carefully answer subsequent comprehension questions. In a self-paced reading paradigm, they showed that musical syntax processing and linguistic syntax processing interacted even though musical syntax was task-irrelevant. In other words, participants responded slowest when syntactically incorrect sentences were aligned with out-of-key chords. Hoch, Poulin-Charronnat, and Tillmann (2011) further found a task-irrelevant musical syntax influence on lexical decision accuracy and speed for syntactically (though not semantically) expected target words. That is, a syntactically expected target word received more accurate and faster “yes” responses when it coincided with an in- as opposed to out-of-key chord. So, SSIRH’s prediction of shared resources was supported only for syntax processing in these experiments.

Further support for SSIRH has come from brain imaging studies. Koelsch et al. (2002) presented non-musicians with syntactically incorrect musical excerpts. Using fMRI, they found that brain areas that are found to be activated to linguistic stimuli responded similarly to musical stimuli. More importantly, Broca’s area that is traditionally thought to be responsible for linguistic syntax processing was activated for syntactically incorrect musical stimuli as well. Later, Koelsch, Gunter, Wittfoth, and Sammler (2005) presented non-musicians either syntactically incorrect but semantically expected sentences or syntactically correct but semantically less expected sentences. Each were presented simultaneously with syntactically regular and irregular chordal sequences. They found a language- and music-syntactic interaction such that LAN responses were reduced for syntactically correct words when presented at syntactically irregular rather than regular chords. On the other hand, the processing of words of high versus low semantic expectation as indexed by N400 was not influenced by musical syntax irregularity.

Nevertheless, there are some contradictory findings to SSIRH. Poulin-Charronnat, Bigand, Madurell, and Peereman (2005) presented participants with sung sentences that were either semantically expected or unexpected. They showed that when coupled with out-of-key musical excerpts, participants performed worse in semantically unexpected sentences. This finding poses a challenge to SSIRH because, originally, it predicted that shared resources between music and language were for language-*syntactic* processing only (and not language-semantic). However, this finding shows that semantic linguistic processing could interact with musical syntactic processing. Nonetheless, later studies yielded unclear results. Hoch and colleagues (2011) found no interaction between linguistic semantic processing and musical syntactic processing. Perruchet and Poulin-Charronnat (2013) conducted another experiment that used semantically unexpected garden-path sentences rather than semantically impossible items. This time, semantic garden-path sentences interacted with musical syntactic processing. As a result, they proposed an explanation based on attention allocation in place of SSIRH. Lastly, in an ERP study, Steinbeis and Koelsch (2008) found that ERAN that is observed to be activated in musical syntactic processing interacted when presented with linguistic syntactic violations, but not with semantic violations. On the other hand, N500, which is observed for semantic musical processing, was affected only when coupled with semantically violated sentences, but not with syntactically incorrect sentences that violate gender relations in German. They concluded that tension-resolution patterns in music, which are considered semantic, shares processing resources with linguistic semantic processing. Nevertheless, authors interpreted this result as strengthening SSIRH because language and music shared processing resources even if the stimuli were manipulated semantically instead of syntactically.

Although originally proposed to explain paradoxical findings regarding processing of syntax in music and language, SSIRH (Patel, 1998, 2003), as suggested by Steinbeis and Koelsch (2008), may not have to exclude other types of resource sharing domains. In line with this inference, in its later version of SSIRH, Patel (2012) also proposed that language and music might share processing resources for sound systems of music and language. Namely, it could be the case that phonological processing could interact with rhythm-related musical tasks. Even though Patel (2012) seems to be reluctant to endorse the view that language and music might share more general resources that encompass semantic, syntactic and rhythmic-phonological processing, the model does not exclude such a possibility either.

1.2 The bottom-up processing of music

Nevertheless, SSIRH is not the only explanation for music and language interaction. There are alternative models and proposals regarding the shared resources between language and music. Bigand, Delbe, Poulin-Charronnat, Leman, and Tillman (2014) contend that musical syntax and linguistic syntax depend on different systems in their processing. They claim that whereas language depends on a more cognitive and symbolic processing, music depends more on sensory processing of information. They suggest that the Auditory Short-Term Memory (ASTM) model (Leman, 2000) could explain the evidence found in favor of cognitive processing of musical syntax. Running simulations of experiments that aimed to show the cognitive processing of musical syntax, the authors were able to demonstrate that the model can indeed explain a host of experiments that are considered to find higher-level processing of musical syntax. Instead of depending on cognitive processing, the authors claim that the structure in music can be explained with the information that sensory data provide. Hence, unlike linguistic syntax, musical syntax is an emergent property of sensory information. Nevertheless, they are not willing to totally exclude all types of cognitive mechanisms that could be at the basis of musical syntax processing. They say that ASTM model can be improved to explain musical syntax by incorporating some cognitive mechanisms.

1.3 Views on cognitive processing of music

Tillmann (2012), on the other hand, claims that expectations, structural integration and cognitive sequencing are shared by both language and music. Hence, she claims that there are more general mechanisms that underlie music and syntax and that cognitive expectations override sensory expectations. Moreover, Tillmann extends the SSIRH proposed by Patel (1998, 2003) to include not just music and language, but other domains as well. This includes arithmetic, motor behavior, and semantic processing. Lastly, she contends that at the basis of all structural integration could be cognitive sequencing that drives the temporal integration of incoming events in music and language. She says that Dynamic Attending Theory developed by Jones (1976, Jones & Boltz, 1989, Large & Jones, 1999) can explain the temporal integration of incoming stimuli and how different cognitive locales can have heightened activation.

Slevc and Okada (2014), similar to Tillmann (2012) and unlike Bigand et al. (2014), proposed that expectation-dependent cognitive control is the shared mechanism that underlies linguistic and musical syntax. Based on some contradictory evidence against SSIRH (Perruchet & Poulin-Charronnat, 2013; Steinbeis & Koelsch, 2008), the authors offer that the researchers should differentiate different types of semantic processing. According to the authors, some semantic processing is shared with syntactic processing while some are not. Syntactic errors, syntactic complexity and semantic/syntactic garden paths all share one common mechanism, which is ambiguity and reinterpretation of previous information. Some semantic tasks that induce ambiguity and require reanalysis are handled by cognitive control mechanism. Hence, those semantic tasks that do not induce strong ambiguity, like semantically surprising words ("passive processing"), are qualitatively different from semantic tasks that require reinterpretation ("active processing"). They further claim that ambiguity resolution is not unique to syntax and semantics. Meter, harmony, tonality and contrapuntal structure are different levels in music that can induce ambiguity and hence require cognitive control. The authors claim that one can create garden paths in different levels of music. They also claim that traditional cognitive control tasks like stroop task may also interfere with linguistic and musical tasks that depend on reanalysis. According to the authors, stroop task relies on cognitive control because repressing an automated response (reading what is presented on the screen) while trying to respond to an unfamiliar task (responding to the color of the presented word) relies on cognitive control mechanisms. The authors claim that this process is shared with processes underlying reanalysis and ambiguity resolution in language and music. In conclusion, the authors suggest that shared music and language processing can be explained with more general mechanisms. Different general cognitive and perceptual mechanisms might underlie music and language processing without domain-specific mechanisms.

More biologically oriented researchers claim that there might be different levels of syntax in music and language (Asano & Boeckx, 2015; Fitch, 2013; Fitch & Martins, 2014). Furthermore, inspired in part by Lashley's (1951) proposal, which identifies syntax as a guiding principle for understanding action, as well as linguistic and musical behavior, they suggest that action syntax might be at the basis of both language and music syntax processing. According to Asano and Boeckx (2015), goal of action, action planning, motor control and sensory-motor integration are components of action syntax. The authors suggest that same or at least similar, processes might underlie musical and linguistic syntactic processing. The goal of music and language determines which structure will emerge. Music serves gestural-affective and socio-intentional goals whereas language, for the most part, involves the goal of conceptual composition. "Motor program" which corresponds to goal of action, and hierarchical planning, for the authors, are the schemas that determine the structure of musical and linguistic syntax. Besides those, motor control and sensory-motor integration play roles in temporal integration and predictions of events. They claim that "domain-specific structures of music and language are projected onto temporal structures" (p. 3). As such, language, music, and action share temporal integration processes. Furthermore, the authors suggest that there is more than one level of syntax in language and music. Rhythmic syntax in music and phonological syntax in language are candidates to investigate the issue of shared mechanisms between language and music. According to them, different types of syntax processing, including action syntax, share temporal integration of events; hence, they can be compared in that respect. Nevertheless, action, music and language differ in terms of their semantics and goals, and hence cannot be directly compared. As a conclusion, the authors suggest that further research should investigate different possibilities to unravel the relationship between language, music and action.

Fitch and Martins (2014), following Lashley (1951), contend that action is basic to both language and music. They say that even though Lashley was agnostic about the cortical region in which temporal integration might be happening, accumulated evidence suggests that Broca’s area might be one of them. According to the authors, posterior regions are responsible for processing less structured material whereas anterior regions are involved in processing hierarchical structure regardless of the medium of the stimuli.

Lastly, Fitch (2013) says that pulse and meter are different constructs and should be treated so while investigating rhythmic phenomena in psychological experiments. He claims that pulse can be extracted from sequences of identical sounds. Features of pulse, for the author, are isochronicity and periodicity. Moreover, humans, as well as some other animal species, are able to entrain or synchronize to pulse. On the other hand, meter in sharp contrast to pulse *is* syntactic according to Fitch. The author defines hierarchy as having a tree structure that is acyclic, rooted and headed. Hierarchy is, then, a structure that can be graphed with edges and nodes. Conceptualized this way, definition of hierarchy includes metric structures as well. According to the author, meter has some features that differentiate it from pulse. First, sounds of a metric sequence are not identical. Some elements in a metric structure are more salient than others. This is true even when there is no sensory difference between elements (also see Bolton, 1894). In addition, unlike pulse, meter is hierarchical. Lastly, even though people entrain to pulse, while dancing they go with meter. Apart from those differentiating features, the author recounts three reasons why he distinguishes pulse from meter. Firstly, even though they occur together in a lot of cases, pulse and meter can occur independently of each other. For example, in poetry and phonology, even though there are metric structures, they are not sequenced isochronously. Secondly, their computational processes are different. Pulse is isochronous whereas meter is hierarchical. Lastly, although there is clear evidence that some animals can extract pulse, there is no clear evidence that other animal species can infer metric structures. Fitch (2013), similar to Asano and Boeckx (2015), suggests that one should consider syntax of meter to investigate similarities and differences between music and language. He says that metric hierarchy is a good candidate to compare with sentential/phonological syntax in language. Also, the author suggests that the rhythmic stimuli used in experiments should be clear in terms of whether they are pulse or meter.

1.4 Syntax, rhythm, and meter

Overall, SSIRH proposed by Patel (1998, 2003) has been very fruitful in directing research and theoretical framework. The general trend about whether music and language share resources or mechanisms is no longer limited to syntax, but instead expands to a more general resource and cognitive mechanism (cognitive control for Slevc & Okada, 2014; expectations for Tillmann, 2012; action syntax and temporal integration for Fitch & Martins, 2014 and for Asano & Boeckx, 2015). On this issue, however, Bigand et al. (2014) stands in a different position. According to them, musical processing and linguistic processing differs in that music depends more on bottom-up processes whereas language depends on top-down cognitive processes. Thus, Bigand and colleagues give a negative answer to the question as to whether language and music syntax processing share resources and mechanisms. This is in opposition to other scientists who give a positive answer to the question by resorting to more general processes that are thought to underlie music and language as well as other processes like action syntax and rhythm (Asano & Boeckx, 2015; Fitch & Martins, 2014), arithmetic skills (Tillmann, 2012) and stroop effect (Slevc & Okada, 2014).

More importantly, as indicated by Fitch (2013; also Asano & Boeckx, 2015), rhythm has hierarchical structure that is comparable to linguistic syntax (see Figure 2). This suggestion is important in several ways. First, rhythmic processing involves not just higher-cognitive mechanisms but also perceptual mechanisms like gestalt rules, which connects bottom-up and top-down processes. Secondly, rhythmic structure can be found not just in music and language, but also in a lot of other human activities. Bolton (1984) lists these other types of rhythmic activity very elegantly. For example, humans are inclined to synchronize with the rhythmic activities (Patel, Iversen, Chen, & Repp, 2005). This connects rhythm to motor activities. Thirdly, as Asano and Boeckx (2015) mentioned, musical structures have affective values that are related to synchronization with and entrainment to music which depend on rhythm. Lastly, rhythmic processing connects language and music through more general attentional processes as well. Dynamic Attending Theory developed by Jones (1976; Large & Jones, 1999) is a good candidate to explain those processes. Because of these reasons, comparing meter in music with linguistic syntax seems to be promising for new research. This line of comparison might reveal some of the common cognitive processes between language and music. More generally, rhythm research has the potential to give some answers to general questions of cognitive psychology and cognitive science. One of the questions is the relation between bottom-up and top-down processes. Another question is the relation between cognitive mechanisms and affective/motor processing and response in human organism.

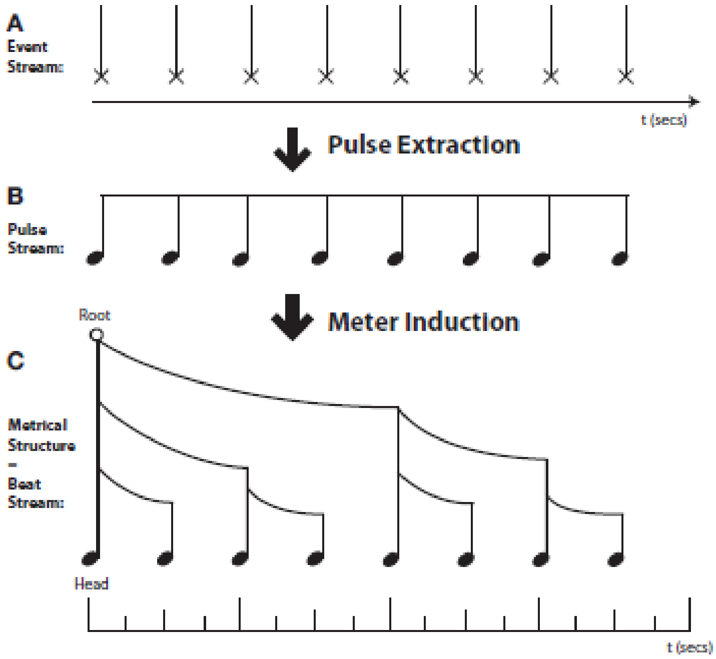

Figure 2. Difference between pulse and meter in a tree representation (from Fitch, 2013)

There is some evidence supporting the link between grammar and rhythm. In the developmental literature, Gordon et al. (2015b) conducted a study with children with typical language development. They showed that children's rhythmic abilities strongly correlated with their grammar skills. On the other hand, the correlation between rhythmic ability and phonological awareness of children was weaker. More interestingly, when IQ was controlled for, the effect seen between phonological awareness and rhythm disappeared. The same pattern was not seen between grammar and rhythm relation; namely, even after controlling for IQ, grammatical and rhythmic abilities of children strongly correlated with each other. In another article, Gordon, Jacobs, Schuele, and McAuley (2015a) reviewed the literature on the link between rhythm and grammar. This review showed that the effect they found in children with typical language development was also found in children with atypical language development. In conclusion, Gordon et al.'s study opens further venue to research on how grammar and rhythm interact.

In another line of research, Schmidt-Kassow and Kotz (2008) presented participants with three types of sentences, which were either syntactically correct or incorrect. In one condition, participants listened to normal speech; in the second condition pauses were inserted between each word of a sentence in such a way as to keep word onset time constant; in the last condition the pauses were placed between meaningful chunks instead of words (e. g. between "the pizza" and "was baked") with a constant SOA this time between onsets of chunks rather than words. The goal of inserting constant SOAs was to induce rhythmic entrainment and see whether for incorrect items enlarged P600 responses would occur due to heightened attention resulting from temporal expectation. Moreover, authors predicted such enlarged P600 particularly for the "chunked" condition since these were syntax driven. Findings showed that P600, which is evoked when syntactic violations occur, did indeed increase in the incorrect test trials in the chunked condition only. This experiment showed that syntactic prediction is possibly facilitated when presented with a rhythmic pattern that conforms to the expectations of the participants. In another study, Schmidt-Kassow and Kotz (2009) presented German native speakers with sentences made of words with first-syllable stress. In their critical "metric deviation" condition, listeners heard sentences of the same kind except that one of its words was pronunciation-wise a non-trochaic one (e.g., ver-LOH-nen instead of DUT-zen). They showed that P600 was evoked when participants heard the metrically deviated word. This study, also, supports the view that meter is processed in the same way as syntax in that both seem to rely on predictability (cf. Schmidt-Kassow & Kotz, 2008). In yet another study, Roncaglia-Denissen, Schmidt-Kassow, and Kotz (2013) presented participants with syntactically ambiguous sentences. The important manipulation was the introduction of linguistic meter that was either regular or irregular. The regular meter involved chunks of one stressed and three unstressed syllables. In the irregular condition, this orderliness was violated in the middle sections of the sentences where the critical subject- vs. object-relative sentences occurred. Findings showed that sentence comprehension was better for subject-relative sentences and facilitated by rhythmic regularity. In addition, P600, which is evoked during syntactic ambiguity resolution, was reduced for the more challenging object-relative clauses when embedded in a regular metric structure. These studies showed that metric structure interacts with syntactic structure.

In another study, Getz, Salona, Yu, and Kubovy (2015) conducted an interesting experiment using a task that they called a sentence-rhythm stroop task. They used a type of stimulus that they named auditory necklace (AN). An AN consisted of sounds and rests in a cyclical fashion. The crucial feature of it was that its starting point remained ambiguous (see Figure 3).

For example, the AN presented in Figure 3 can be represented as: …1 1 1 0 0 1 1 0 1 1 1 0 0 1 1 0 1 1 1 0 0 1 1 0… ("1"s represent sounds whereas "0"s represent rests). This stimulus was chunked in two ways: as ^110011100^ or as ^111001100^ with "^" representing a beginning/ending point. In their experiment they replaced beats with single words of a sentence, all of which consisted of five single beat words (dark circles in Figure 3) with pauses in between (light gray circles in Figure 3). They presented participants with either isochronous or syncopated AN[1] (see Figure 4).

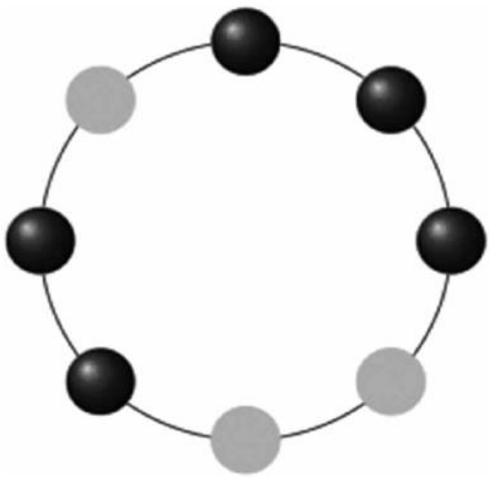

Figure 3. Example of an auditory necklace
Note: Black beads represent notes and grey discs represents rests (from Getz et al., 2015).

Listeners were asked to report which node they perceived as the first element in the sequence. They were explicitly told to fully ignore the sentences that were read and only respond to the stimulus auditorily, not linguistically. Listeners were strongly influenced by sentence clasp (which is the starting word of the sentence) across all conditions but this tendency was significantly more pronounced in the syncopated conditions. This finding suggested that complexity of rhythmic structure interfered with linguistic processing.

[1] Before conducting the original experiment, the researchers conducted a control experiment. The control experiment was conducted to determine which node participants choose as the starting point of the necklace, which the researchers called necklace clasp. They showed that for isochronous condition, participants chose the first sound of the group with two sounds (110011100). In the syncopated condition, on the other hand, participants chose the first element of the group with three sounds (111001100) (also see Figure 4).

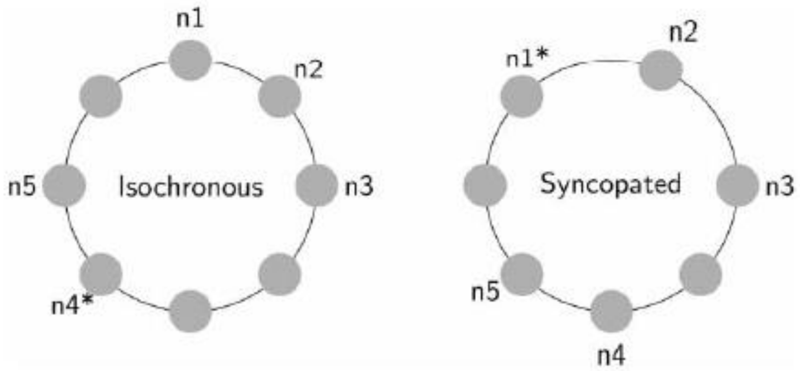

Figure 4. Auditory necklaces
Note: The necklace clasp (designated by *) is n4 for the isochronous pattern and n1 for the syncopated pattern. In the isochronous condition IOIs were 300ms, in the syncopated condition they were 450 ms for long and 300 ms for the shorter ones. "ni" marks a given word in any 5-word sentence (from Getz et al., 2015).

Lastly, in another study, Jung, Sontag, Park, and Loui (2015) presented participants with sentences embedded on isochronous chordal progressions both of which contained a syntactically expected or unexpected word/chord in sixth position. In the critical region, in which violations with either musical or linguistic or both musical and linguistic nature occurred, they placed a jitter of 115 ms such that the critical event happened either 115 ms earlier or later than expected rhythmically. Reading times were influenced by both rhythmic and linguistic expectancy. More interestingly, musical and linguistic expectancy interacted only in the rhythmically regular condition. In a second experiment, they presented participants with rhythmic sentences without the chordal accompaniment. They replicated the main effects for rhythm and language, however this time, without the musical component, the two no longer interacted with each other. This result was unexpected because the authors predicted that if rhythm and language shared attentional resources, they should have interacted. In another study, Jung (2016) conducted the same experiment, this time with ERP recordings. Both musically unexpected chords and linguistically unusual expressions elicited an early anterior negativity component. Moreover, rhythmic violations affected both music and linguistic syntactical processing.

Even though both studies yielded interesting results, it is hard to interpret those results because of the visual induction of rhythm. Patel et al. (2005) showed that rhythm can be induced reliably through auditory channel, but not through visual channel. Secondly, the two studies used rhythms that are more appropriate to be called pulse according to Fitch (2013).

Considering all these relevant data, it seems clear that there is a relationship between rhythm and syntax processing. However, the nature of the relationship is not clear yet. In the current literature, as far as I know, it is not clear whether musical meter interacts with linguistic syntax at the sentence level. Schmidt-Kassow and Kotz (2008, 2009) showed interaction between meter and syntax. However, this interaction was unique to language, and there was no musical stimulus. Gordon et al.'s (2015b) study provides an insight for the relation between rhythm and syntax. Nevertheless, their study was correlational in nature and require further testing to clarify the relationship. Getz et al.'s (2015) study was interesting in terms of their stimuli and task, but ANs depend on grouping instead of hierarchical relationship. Moreover, their use of linguistic stimuli makes it hard to determine whether the effect is syntactic or semantic. Lastly, Jung et al. (2015) used stimuli that can be called pulse according to Fitch (2013). They also presented rhythm visually, which makes the results hard to interpret.

1.5 The present study

I aim to clarify the relationship between musical rhythm and linguistic syntax. This will help us see whether there is a similar relationship between different levels of syntax in both language and music. Even though there are studies that compare harmonic syntax with linguistic syntax, there is no study that directly compares *rhythmic syntax* with linguistic syntax (see Figure 5).

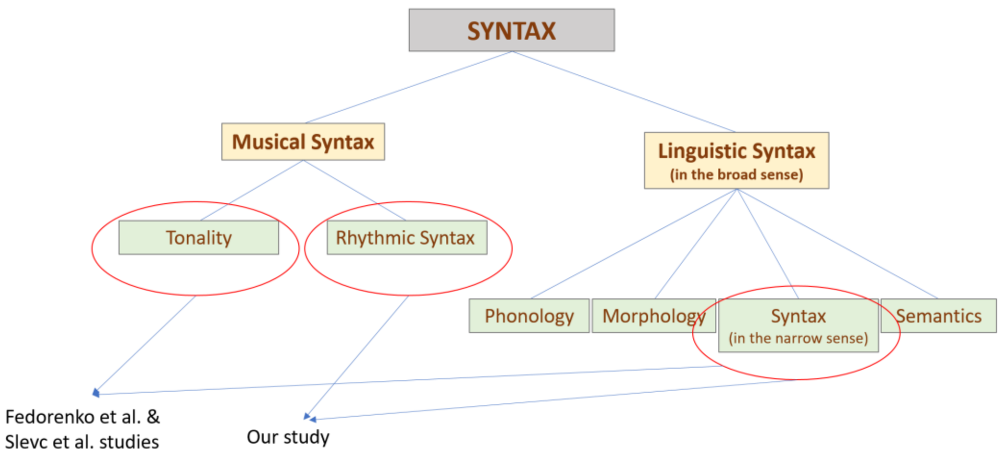

Figure 5. The position of the present research within the literature

In the current study, there are two experiments. The first experiment involved syntactic and rhythmic manipulation. The sentences had two levels of complexity: subject-relative clause (SRC) and object-relative clause (ORC). SRCs (see Figure 6) have less complex structure compared to ORCs (see Figure 7) because the relativized element moves further in the tree for ORCs than SRCs. This difference in complexity is reflected in psychological measures as well. In English (King & Just, 1991; Traxler, Morris, & Seely 2002) and many other languages (for Japanese Ishizuka, Nakatani, & Gibson, 2003; for Spanish Betancort, Carreiras, & Sturt, 2009 etc.; see Gibson & Wu, 2013 for the opposite effect in Chinese), ORCs are found to be harder to process. This manifested itself in longer reading times, less accuracy, and longer fixation times with eye tracking method (see Lewis and Vasishth, (2005), and Gibson (2000) for different models that explain this phenomenon).

Even though the experimental data on relative clause complexity in Turkish is less clear, there are some indications that the same is true for Turkish, too. Aydın (2007) showed that intermediate L2 learners of Turkish made more mistakes regarding ORCs in the picture selection task. Similarly, Altan (2016) found that L2 learners of Turkish make more mistakes with ORCs in a production task. Furthermore, acquisition data show that children make more errors in ORCs and use them less often than SRCs (Slobin, 1986; as cited in Altınkamış & Altan, 2016). Furthermore, Bulut, Yarar, and Wu (2019) found that native Turkish speakers exhibited less accuracy in ORCs, and they spent more time in the spillover region compared to SRCs. They also conducted a corpus analysis and found that ORCs are less common than SRCs. On the other hand, Demiral, Kaya, Mungan, and Tekman (unpublished manuscript) found no such difference between ORC and SRC in their eye tracking study. Even though the picture is not complete, based on these findings, SRC and ORC constructions were implemented to introduce a structural manipulation similar to the experiment conducted by Fedorenko and colleagues (2009).

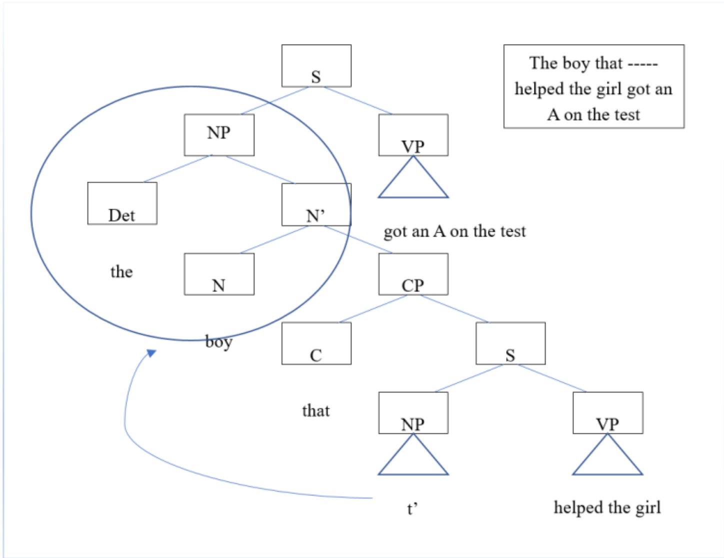

Figure 6. Tree representation of SRC
Note: The head of relative clause moves less than head of an ORC.

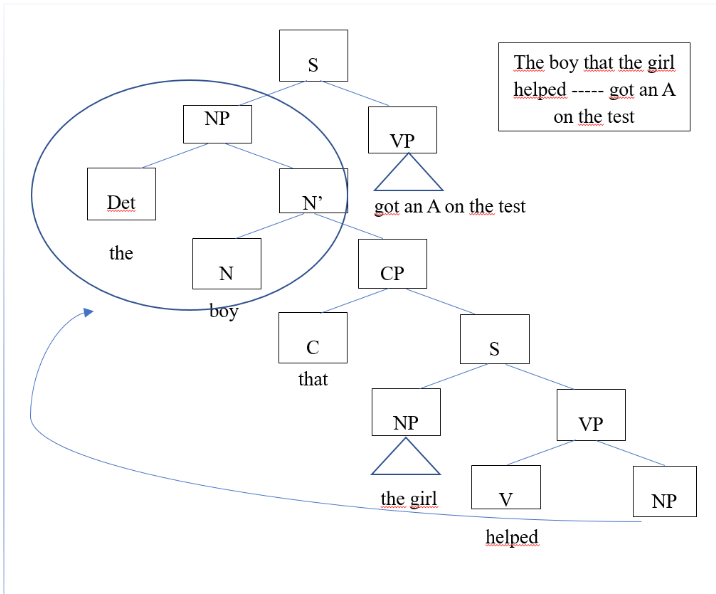

Figure 7. Tree representation of ORC
Note: The head of relative clause moves more than head of an SRC.

The concurrent structural manipulation for rhythms was introduced by distorting the timing of the beats. The distortion was heard right when the relativizer was heard in the sentence. The beat was played 50 ms earlier than expected. In the second experiment, everything was the same with the first experiment, with the exception that distorted rhythms were replaced with random beats to provide a baseline level.

1.6 Hypotheses

The hypotheses of the present study were as follows:

i. Based on the findings in the literature on the difference between ORC and SRC constructions, there will be a main effect of linguistic manipulation in terms of response time and accuracy in both experiment 1 and 2.

ii. There will be a main effect of rhythmic manipulation in the first experiment in terms of response time and accuracy because distortion will introduce a structural confusion.

iii. There will be an interaction between rhythmic manipulation and linguistic manipulation in the first experiment due to competition for syntactical processing resources in the first experiment in terms of response time and accuracy. Hence, slowest response times are expected for ORC sentences with concurrent pulse deviation.

iv. There will be a main effect of rhythmic manipulation in the second experiment in terms of response time and accuracy because unstructured rhythmic condition will distract listeners and hence debilitate the semantic processing of the sentences.

v. There will not be an interaction between the rhythmic (structured versus unstructured) and linguistic (SRC versus ORC) conditions in the second experiment since there will not be a competition for syntactic processing resources.

CHAPTER 2

EXPERIMENT 1

2.1 Method

2.1.1 Participants

Seventy two participants were recruited. Participants were either volunteers or students from Boğaziçi University who were taking the introduction to psychology course at the time. Boğaziçi students were compensated with one credit for their participation. Participants' age ranged from 18 to 25 (*M* = 20.36, *SD* = 1.38). All the participants were native speakers of Turkish. No participant reported having a diagnosis of dyslexia or any other language impairment. One participant reported having hearing loss, and another participant reported having extreme hearing loss in the right ear, yet they were not excluded from the analyses because they did not come out as outliers and the results did not change in terms of significance level except in one comparison when they were excluded. Participants also provided self-reports on their loud and silent reading fluency, rhythm perception, and keeping with the beat (see Appendix A). Nineteen participants reported having music or dance training for 1-2 years, six reported 3-5 years of music or dance training, and four reported having received a music or dance training for more than 5 years.

2.1.2 Materials

The sentences were adapted from Demiral et al. (unpublished manuscript). The sentences were created to yield SRC and ORC versions with the same content. SRCs were created with the suffix -An while ORCs were created with the suffix -DIK. The subject of the sentence was the head of the relative clause. The subject of the main verb was always an agent as is the inner argument of the relative clause. The names chosen were professions or related to a professional setting. The main verb was intransitive whereas the verb in the relative clause was transitive. The sentences started with filler components. These were adverbs of time and place (see Table 1). In the construction of sentences, two versions of the same sentence was created. In one version, the relative clause was SRC, in the other version it was ORC. Forty pairs of sentences were created with this procedure. 20 sentences with ORC and 20 with SRC were randomly chosen from this pool. 10 filler sentences were created with varying structures (see Appendix B for all the sentences used in the experiments). The sentences were recorded in a quiet room on Audacity at a natural pace by a female speaker.

After every sentence, participants were shown the sentence once again without the adverbial component (e.g., “yesterday morning on the street” for “dün sabah caddede”). Thereafter, they had to decide whether this was correct according to the sentence. Correct trials were identical to the original sentence, except that they lacked the adverbial component. In the incorrect trials, the inner argument of the RC was swapped with the subject of the main sentence (see Table 2).

The rhythmic stimuli consisted of sounds and rests. Bongo sound was used to create the rhythms. Bongo sound was 100 ms. Inter onset interval for both sounds and rests was 150 ms. The total duration of rhythm files was six seconds. Five types of rhythm were used in the experiment to prevent habituation. These were isochronous, 2 short-1 long (ssL), 1 short-1 long (sL), 3 short-1 long (sssL), and 1 short-2 long (sLL). The disrupted rhythms were created by presenting the beat that occurs right at the relativizing element 50 ms earlier than expected. We used 50 ms deviation because Mungan and Kaya (2020) showed that 45 ms deviation was enough for participants to detect the deviation. The total duration of rhythms was not changed in the distorted rhythms and remained six seconds. Rhythmic stimuli were created on Audacity.

Table 1. Examples of Sentences Used in the Experiments

Example of SRC and ORC						
	time adverb	place adverb	subject/object of RC	RC verb	subject(head of RC)	main verb
ORC	Dün sabah	cadde-de	yolcu-nun	gör-düğ-ü	şoför	dur-du
	yesterday morning	street-LOC	passenger-GEN	see-PART-1SG.POSS	driver	stop-PF
	The driver who the passenger saw yesterday morning on the street stopped					
SRC	Dün sabah	cadde-de	yolcu-yu	gör-en	şoför	dur-du
	yesterday morning	street-LOC	passenger-ACC	see-PART	driver	stop-PF
	The driver who saw the passenger yesterday morning on the street stopped					

Note: (düğü) in the ORC sentence is ORC suffix in Turkish whereas (en) in the SRC sentence is SRC suffix.

Table 2. Examples of Questions Used in the Experiments

Example of Correct and Incorrect Sentences				
Correct	Yolcu-nun	gör-düğ-ü	şoför	dur-du
	passenger-GEN	see-PART-1SG.POSS	driver	stop-PF
	The driver who the passenger saw stopped			
Incorrect	Şoför-ün	gör-düğ-ü	yolcu	dur-du
	driver-GEN	see-PART-1SG.POSS	passenger	stop-PF
	The driver who saw the passenger stopped			

Rhythms and sentences were added on top of each other in a way that will ensure the occurrence of the upbeat right when the relativizer is heard (see Figure 8). Because of this, the onsets of the sentences were not uniform. They changed depending on the length of the sentence and on where the upbeat occurs in the respective rhythm. The sentences started approximately after 1-2 seconds the rhythms started.

Lastly, participants received an individual differences test before the main experiment to measure their rhythm perception. The items for this test were taken from Harrison and Müllensiefen's (2018) Computerized Beat Alignment Test (CA-BAT). There were 16 of these items with difficulty levels around zero so as to assess their individual differences at the most basic level of beat alignment perception.

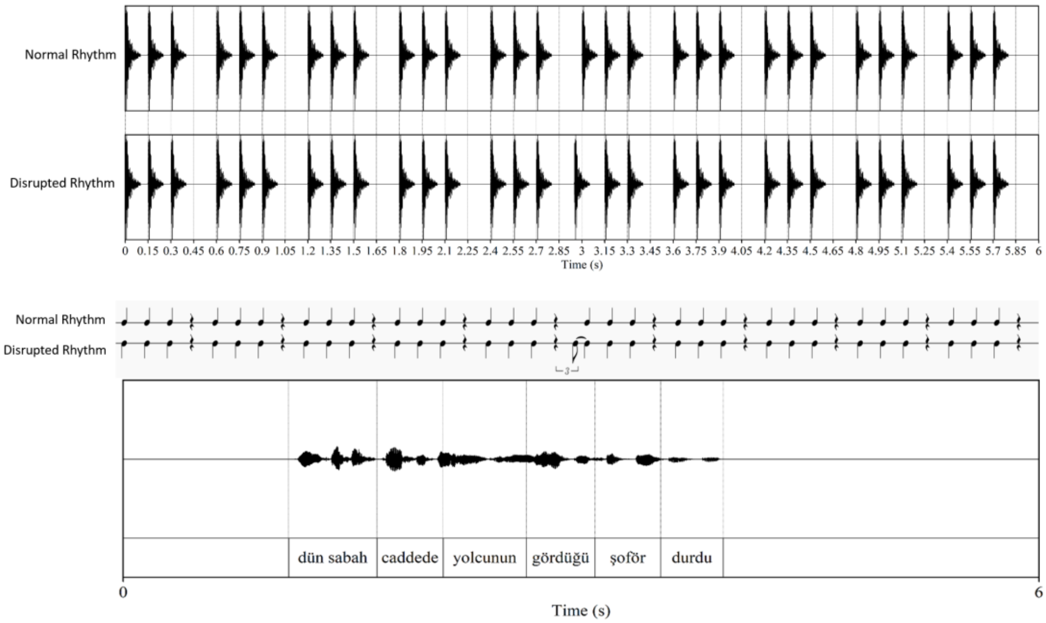

Figure 8. An example of disrupted and normal rhythm and how it is superimposed on the sentence
Note: The red box shows where the 50-ms distortion happens. It is the upbeat of the rhythm and aligned with the relativizing suffix.

2.1.3 Design and procedure

The experiment is 2 by 2 within-subject design with two factors: rhythm manipulation (normal vs disrupted) and sentence manipulation (SRC vs ORC). All participants heard each stimulus. There were 10 stimuli in each condition (10 for SRC-normal, 10 for SRC-disrupted, 10 for ORC-normal, and 10 for ORC-disrupted). Participants heard 50 elements in total with filler sentences included.

After the participants entered the experiment room, they were seated before the computer. Before the experiment started, the participants were informed about the experiment and provided their informed consent. They then put on the headphones and made them fit their heads. The experiment started when they clicked the OK button on the computer screen. In the first part of the experiment, participants were presented with Computerized Beat Alignment test. In CA-BAT, participants were presented with a piece of music. A rhythmic sequence with a beep sound accompanied the piece of music. Participants listened to two instances of the same piece in each trial. In one of the two instances, the rhythm accompanying the piece was on the beat whereas in the other instance, the beep track was off the beat. Participants had to decide which one was on the beat. If the first instance was on the beat, they were told to press the ‘F’ button on the keyboard whereas if the second instance was on the beat, they were told to press the ‘J’ button. Before taking the actual test, participants first listened to examples of what aligned and non-aligned rhythms sounded like. After that, they received two practice trials to habituate them with the task. They received feedback in the practice part, but not in the test phase.

After completing the CA-BAT, participants read the instructions for the main part. Then, they received two practice trials with feedback. In each trial, they heard the stimulus. While listening to the stimulus, they were told to fixate on a plus sign in the middle of the computer screen. The aim of this was to ensure that participants did not get distracted by their immediate physical surroundings. After the stimulus ended, they were immediately presented with a question related to the sentences. Participants were told to respond to the question as fast as they could. The questions were simple yes/no questions. They had to press the “F” button for yes, and the “J” button for no. After the experiment ended, participants received a questionnaire with various background questions (see Appendix A). After this, whenever possible, participants were asked open-ended questions about the experiment. The questions were “How did you find the experiment, was it fun, was it boring?”, “Did you implement any strategy answering the questions?”, “Were there any parts that you found easy or difficult?" Participants were also encouraged to freely share their experiences and feelings about the study. The experiment was conducted on PsychoPy (Peirce et al., 2019). Philipps Shp 1900 headphones were used for the presentation of the stimuli. The study was approved by the Ethics Committee of Boğaziçi University (see Appendix C).

2.1.4 Dependent variables

There will be two types of dependent variables. Response time data was collected based on the time it took participants to answer the questions by clicking either yes or no. Secondly, comprehension accuracy. This is determined based on whether participants gave a correct response or not.

2.1.5 Data analysis

Statistical analyses were performed on R (R Core Team, 2022). For response time data, main and interaction effects were explored via step-wise model comparison using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). Rhythm and sentence type were added as fixed effects. Participants and sentence items were included as varying intercepts in the model. Subsequently, rhythm and sentence factors were added to the model one by one and were compared with the null model using anova function to see if they contributed to the model. Lastly, the interaction model was tested. The interaction model was compared with the model with only the main effects. P values were obtained by likelihood ratio test in all comparisons.

As an exploratory analysis, individual differences test results were used to divide the participants into two groups based on the median. Then, these two groups underwent the same procedure as above to see if they yield different results from the total data.

2.2 Results

2.2.1 Questionnaire

No participant reported being diagnosed with dyslexia or any other language impairment. Two participants reported having hearing loss. One of them specified it as only in the right ear. Participants rated their loud reading fluency, silent reading fluency, rhythm perception, and beat alignment ability (see Table 3).

2.2.2 Main effects and interaction

Because accuracy data showed a ceiling effect, statistical analyses were not performed using accuracy data (see Appendix D, Table D1 for descriptive statistics of accuracy data). All subsequent analyses are on reaction time data in seconds. For the analyses, participants and sentence items were added as varying intercepts in the model. Then, sentence conditions was added to the model as fixed effect. The comparison of sentence conditions only model (M_{ORC} = 1.45, SE_{ORC} = .02; M_{SRC} = 1.53, SE_{SRC} = .03) with null model revealed no effect of sentence type ($\chi 2(1) = 0.75$, $p = 0.39$, *AIC difference* = 1.3). The comparison of rhythm conditions only model ($M_{Disrupted}$ = 1.46, $SE_{Disrupted}$ = .03; M_{Normal} = 1.51, SE_{Normal} = .03) with the null model did not reveal significant effect either ($\chi 2(1) = 1.15$, $p = 0.28$, *AIC difference* = 0.9).

Table 3. Results of the Questionnaire in Experiment 1

Questions	Ratings	N (%)
Loud reading fluency	really good	11 (15.3%)
	good	26 (36.1%)
	as good as others	27 (37.5%)
	bad	8 (11.1%)
	really bad	0
Silent reading fluency	really good	16 (22.2%)
	good	34 (47.2%)
	as good as others	18 (25%)
	bad	3 (4.2%)
	really bad	1 (1.4%)
Rhythm perception	really good	8 (11.1%)
	good	27 (37.5%)
	as good as others	26 (36.1%)
	bad	9 (12.5%)
	really bad	2 (2.8%)
Keeping the tempo	really good	12 (16.7%)
	good	29 (40.3%)
	as good as others	19 (26.4%)
	bad	11 (15.3%)
	really bad	1 (1.4%)

Even though there were no fixed effects of sentence and rhythm conditions because the original hypothesis expected interaction between the two, the full model with the interaction term between sentence and rhythm conditions was created (see Appendix E, Table E1). To test the interaction, the model without interaction term was compared with the model with the interaction term between sentence condition and rhythm condition (see Figure 9). The result revealed no interaction ($\chi 2(1) = 0.12$, $p = 0.73$, *AIC difference* = 1.9). Overall, there was no main effect of relative clause type and rhythm manipulation. We did not see significant interaction between these two variables, either.

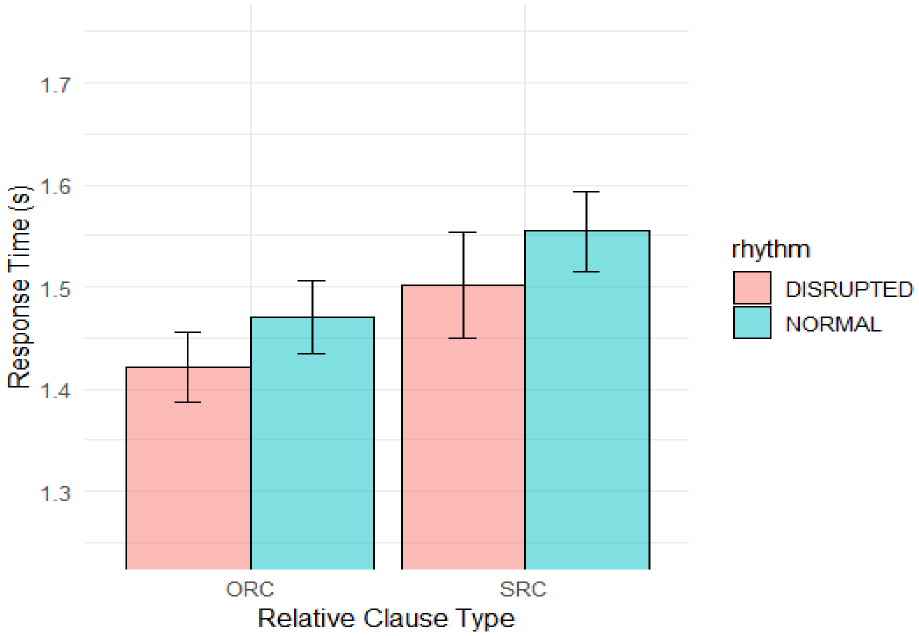

Figure 9. Average response times based on rhythm and sentence factors in bar graph
Note: Error bars represent standard error of means.

2.2.3 Analyses of CA-BAT results

As an exploratory analysis, the data set was divided into two groups based on the median of the CA-BAT results. Each correct answer in CA-BAT was given the value of one, and incorrect answers were given the value of zero. The total scores were calculated by summing up ones for each participant. The range of total CA-BAT scores was between 8 and 16 (M = 11.76). The median value was 12. The data set was split into two groups based on the median.

The same analyses for the total data set were carried for the two groups (M_{upper} = 1.49, SE_{upper} = .03; M_{lower} = 1.49, SE_{lower} = .03) separately. The upper group revealed no main effects of sentence type and rhythm condition or interaction (all *p*s > 0.05). In the lower group, sentence condition showed no effect ($\chi 2(1)$ = 0.54, p = 0.46, *AIC difference* = 1.5). However, comparison of rhythm condition only ($M_{Disrupted}$ = 1.43, $SE_{Disrupted}$ = .04; M_{Normal} = 1.55, SE_{Normal} = .04) model with null model revealed a marginally significant effect ($\chi 2(1)$ = 3.46, p = .06, *AIC difference*

= -1.4).[2] Namely, participants in the lower group responded faster in the disrupted condition compared to the normal condition. There was no interaction either ($\chi 2(1) = 0.061$, $p = .81$, *AIC difference* = 1.9).

Rhythm condition and CA-BAT grouping were added as fixed effects without the interaction term to inspect the effect of rhythm in the total data set with respect to the lower group. This model, then, was compared to the model with the interaction term (see Figures 10 and 11; Appendix E, Table E2). The result showed an interaction ($\chi 2(1) = 4.25$, $p = .04$, *AIC difference* = -2.3).[3] Bonferroni outlier test in car package (Fox & Weisberg, 2019) was performed on the models to see if there are any outliers. Based on the result of the outlier test, five data points were typed as missing data. The analysis was run once again if the significance would still persist. According to the result, the significance level dropped ($\chi 2(1) = 3.78$, $p = .05$, *AIC difference* = -1.8). Overall, we found an effect of rhythm manipulation in the lower group. Nevertheless, there was no effect of rhythm in the upper group. Moreover, we did not find an effect of relative clause type of interaction in either group.

[2] When the participants with hearing loss were totally removed from the dataset, the significance level dropped ($\chi 2(1) = 2.8$, $p = .09$, *AIC difference* = -0.8).

[3] In other analyses, nothing changed in terms of significance level after participants with hearing loss were totally removed from the dataset (all *p*s > .05). Nevertheless, the interaction that we see between CA-BAT grouping and rhythm in the total dataset dropped after participants with hearing loss were removed ($\chi 2(1) = 3.4$, $p = .065$, *AIC difference* = -1.4).

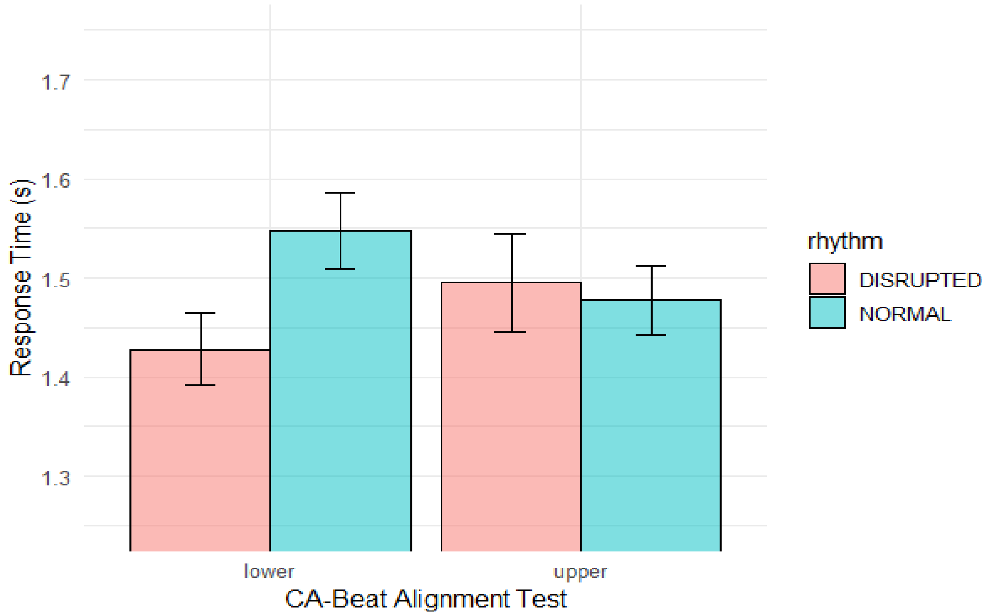

Figure 10. Average response times by rhythm for the upper and lower groups in a bar graph
Note: The upper and lower groups are created by splitting the data set from the median based on CA-BAT scores. Error bars represent standard error of means.

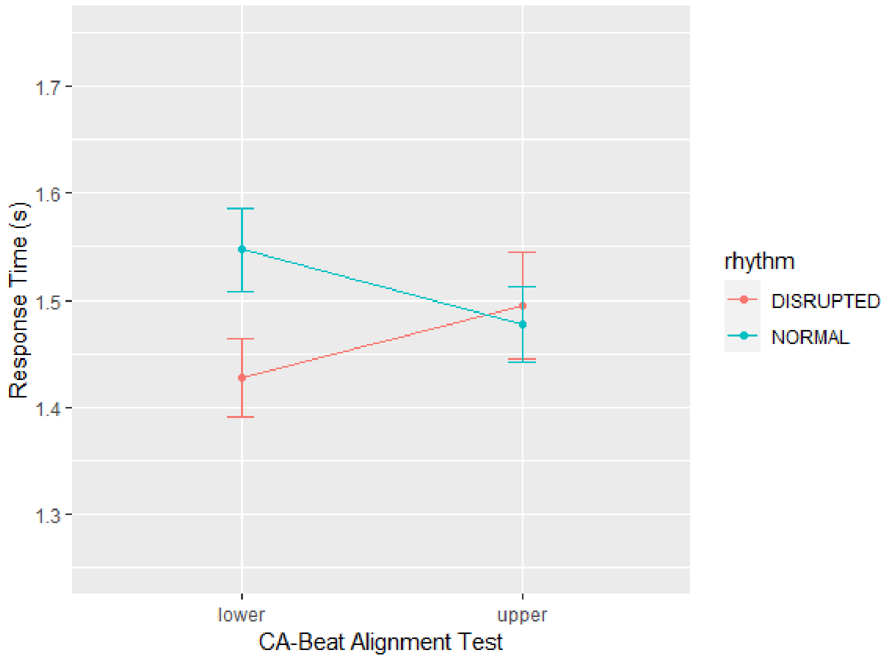

Figure 11. Average response times by rhythm for the upper and lower groups in a line graph
Note: The upper and lower groups are created by splitting the data set from the median based on CA-BAT scores. Error bars represent standard error of means.

CHAPTER 3

EXPERIMENT 2

3.1 Method

3.1.1 Participants

Fifty two participants were recruited. Participants were either volunteers or students from Boğaziçi University who were taking the introduction to psychology course at the time. Boğaziçi students were compensated with one credit for their participation. Participants' age ranged from 18 to 35 (*M* = 21.25, *SD* = 2.48). All the participants were native speakers of Turkish. No participant reported having a diagnosis of dyslexia or any other language impairment. One participant reported having hearing loss in the left ear from birth, which was treated with a hearing aid. Nevertheless, data from this participant were not excluded from the final analyses because it was not an outlier and no result changed when that participant was removed from the dataset. Moreover, when the same analyses were done without this participant, the results did not change. Participants also provided self-reports on their loud and silent reading fluency, rhythm perception, and keeping with the beat (see Appendix A). Eighteen participants reported having music or dance training for 1-2 years, four reported 3-5 years of training, and two reported having training more than 5 years.

3.1.2 Material

All the stimuli were identical to the first experiment. The only difference was that disrupted rhythms were replaced with random, unstructured beats. The total length was again six seconds. 25 bongo sounds were placed within that 6-second-long file. To do that, first, the six seconds were divided into 40 slots. Each of these slots was

150 ms. The place of sounds was determined by randomly selecting 25 slots (see Figure 12). Random selection was done via R. The empty slots remained as rests. Five different types of random sounds were created in total.

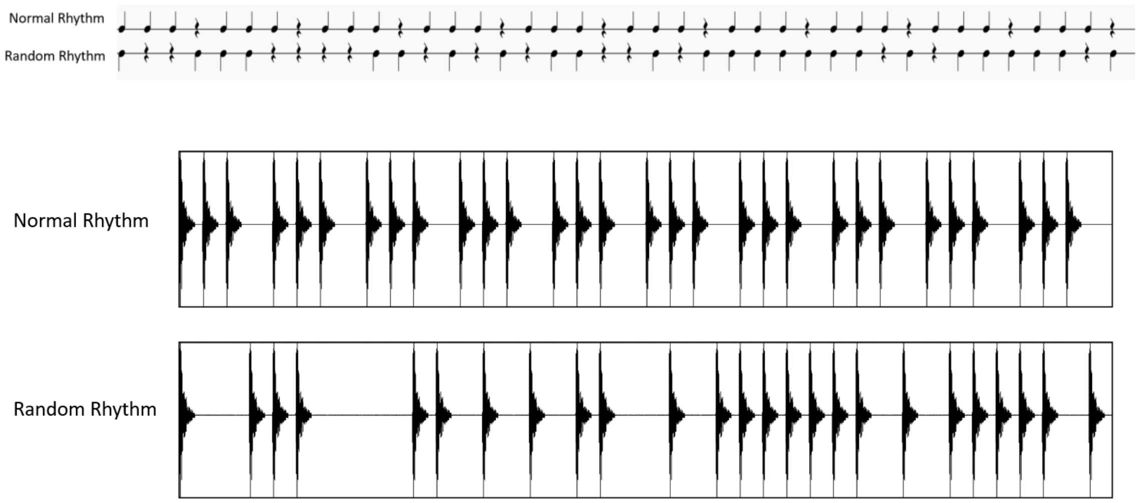

Figure 12. Demonstration of a random stimulus and a normal stimulus

3.1.3 Dependent variables

Dependent variables were response time and accuracy as in the first experiment.

3.1.4 Design and procedure

The design and procedure were identical to the first experiment.

3.2 Results

3.2.1 Questionnaire

No participant reported being diagnosed with dyslexia or any other language impairment. One participant reported having hearing loss in the left ear, which is treated. Participants rated their loud reading fluency, silent reading fluency, rhythm perception, and beat alignment ability (see Table 4).

Table 4. Results of the Questionnaire in Experiment 2

Questions	Ratings	N (%)
Loud reading fluency	really good	6 (11.5%)
	good	25 (48.1%)
	as good as others	18 (34.6%)
	bad	3 (5.8%)
	really bad	0
Silent reading fluency	really good	10 (19.2%)
	good	23 (44.2%)
	as good as others	13 (25%)
	bad	5 (9.6%)
	really bad	1 (1.9%)
Rhythm perception	really good	7 (13.5%)
	good	19 (36.5%)
	as good as others	14 (26.9%)
	bad	12 (23.1%)
	really bad	0
Keeping the tempo	really good	10 (19.6%)
	good	19 (37.3%)
	as good as others	10 (19.6%)
	bad	12 (23.5%)
	really bad	0

3.2.2 Main effects and interaction

Accuracy data were not used for the analysis because of ceiling effect (see Appendix D, Table D2). For the analysis of response time data, participants and sentence items were added as varying intercepts. Then, sentence condition (M_{ORC} = 1.68, SE_{ORC} = .03; M_{SRC} = 1.66, SE_{SRC} = .03) was added to the model as a fixed effect. This model was compared to the null model. The result showed no significance ($\chi 2(1) = 0.07$, p = .79, *AIC difference* = 1.9). Comparison of rhythm only model (M_{Random} = 1.68, $SE_{Disrupted}$ = .03; M_{Normal} = 1.66, SE_{Normal} = .03) with the null model did not show a significant result either ($\chi 2(1) = .001$, p = .97, *AIC difference* = 2). Even though there were no effects of sentence and rhythm, interaction model (see Appendix E, Table E3) was tested to inspect the full model (see Figure 13). This test showed no interaction ($\chi 2(1) = .06$, p = .81, *AIC difference* = 2). Overall, there was no main effect of sentence type and rhythm manipulation. We did not find an interaction effect, either.

3.2.3 Analyses of CA-BAT results

As an exploratory analysis, the data set was divided into two groups again based on the median of the CA-BAT results. Each correct answer in CA-BAT was given the value of one, and incorrect answers were given the value of zero. The total scores were calculated by summing up ones for each participant. The range of total CA-BAT scores was between 4 and 12 (M = 8.62). The median value was 9. The data set was split into two groups based on the median.

Then, similar analyses were performed in the lower (M_{lower} = 1.7, SE_{lower} = .03) and upper group (M_{upper} = 1.64, SE_{upper} = .03) separately. There were no effects of sentence, rhythm, or interaction in either group (all ps > .05). Overall, all the results were insignificant for both upper and lower groups.

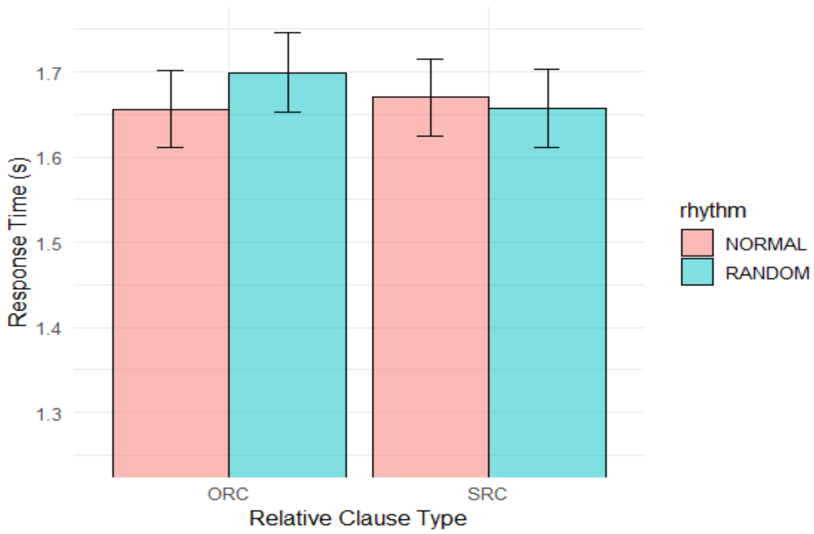

Figure 13. Average response times for different rhythmic and sentential levels in bar graph
Note: Error bars represent standard error of means.

CHAPTER 4

DISCUSSION

Two experiments were conducted to test the interaction between rhythm and linguistic syntax. The first experiment tested whether rhythmic distortion would induce a hierarchical complexity (or disruption) so as to interfere with linguistic complexity. The distortion was implemented by presenting the beat 50 ms earlier (i.e., after 100 ms rather than 150 ms) at the place where the relativizing suffix was heard. The relativizing suffix was aligned with an upbeat in the rhythm for all the stimuli, thus, the distortion happened in the upbeat for all stimuli. Sentence complexity was manipulated by creating sentences with either SRC or ORC.

The result showed no significant results for the main effect of sentence and rhythm manipulation or interaction. However, when the data was split into two based on the CA-BAT results, the lower group showed a marginal difference in the rhythm condition. Participants with lower beat alignment performance responded faster in the disrupted rhythm condition. In the second experiment, distorted rhythms were replaced with unstructured “rhythms”. Again, there was no significant result for the rhythm and sentence or interaction. The same median-split procedure was performed for the second experiment’s data. This time, no difference was found between the two groups across conditions.

Hypotheses were:

i. Based on the findings in the literature on the difference between ORC and SRC constructions, there will be a main effect of linguistic manipulation in terms of response time and accuracy in both experiment 1 and 2.

ii. There will be a main effect of rhythmic manipulation in the first experiment in terms of response time and accuracy because distortion will introduce a structural confusion.

iii. There will be an interaction between rhythmic manipulation and linguistic manipulation in the first experiment due to competition for syntactical processing resources in the first experiment in terms of response time and accuracy. Hence, slowest response times are expected for ORC sentences with concurrent pulse deviation.

iv. There will be a main effect of rhythmic manipulation in the second experiment in terms of response time and accuracy because unstructured rhythmic condition will distract listeners and hence debilitate the semantic processing of the sentences.

v. There will not be an interaction between the rhythmic (structured versus unstructured) and linguistic (SRC versus ORC) conditions in the second experiment since there will not be a competition for syntactic processing resources.

4.1 SRC-ORC difference

There was no significant effect of SRC-ORC manipulation in either of the experiments. This is in contrast with the many findings in the literature about relative clause processing. In English and many other languages, ORCs are processed slower than SRCs (Gibson, 2000; Fedorenko et al., 2009). However, the data in Turkish is not so clear partly due to a lack of experimental investigation on the subject and partly due to differing results. There are some indications that ORCs are processed slower than SRCs in Turkish. It has been found that L2 learners of Turkish makes more errors with ORCs compared to SRCs (Aydın, 2007; Altan, 2016). Furthermore, Turkish-speaking children acquire ORCs later than SRCs (Slobin, 1986). Furthermore, an eye-tracking study showed a difference between SRC and ORC processing in the spillover region (Bulut et al., 2019).

On the other hand, in an unpublished study, Demiral and colleagues (unpublished manuscript) did not find such a difference between ORC and SRC. Furthermore, Bulut and colleagues (2019) also found that ORCs are less frequent than SRCs. Therefore, it might be the case that the difference between SRCs and ORCs, if it exists, is not a structural one, but a frequency-based effect. Since our participants were native speakers of Turkish, the frequency effect may not have shown up. In line with that, Altan (2016) found that L1 speakers of Turkish use ORCs more than L2 learners or Turkish. Moreover, the task that was used in the experiments may not be appropriate to detect the difference between the two constructions. Since the task was to respond to a yes/no question, it was quite easy for participants to perform the task. This is actually reflected in the comments participants gave after they completed the experiment. Many participants commented that the task was too easy.

To interpret the findings in light of sentence processing models, Gibson's dependency locality theory would suggest that the dependencies between elements in a sentence are what causes processing difficulties. According to his theory, our sentences were identical because of Turkish's head-final structure (see Figure 14).

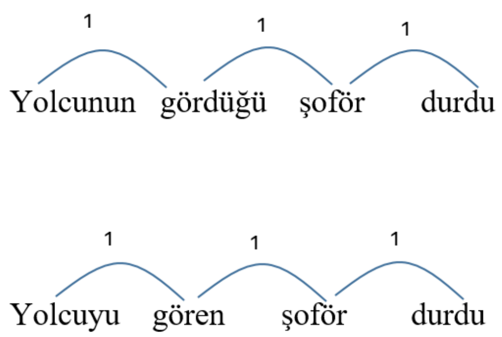

Figure 14. Predictions of the dependency locality theory (Gibson, 2000)

4.2 The effect of rhythmic distortion and randomness

In the first experiment, we did not find a difference between disrupted and normal conditions. On the other hand, there was a difference in the lower half of the median-split data. Namely, those who scored less on CA-Beat Alignment Test were faster in the disrupted condition than in the normal condition. This finding was somewhat surprising since we expected that the disruption would consume the same working memory mechanism and consume more resources from it, which would, cause slower response times in the disrupted condition.

One explanation for the absence of the effect of rhythmic distortion in the overall data could be the Dynamic Attending Theory (Jones, 1976). This theory suggests that humans are capable of accomodating some variability in the rhythmic structure once they extract the pattern of the rhythm. Since our rhythmic stimuli were quite robust and had the distortion in one place, it might be the case that participants were able to attend to the rhythms and they could ignore the small distortion. This is also supported by the comments participants gave after the experiment. Most participants reported not having detected the distortion in the rhythms. They also reported that after a few trials they stopped attending to the rhythms since there was no task related to the rhythmic stimuli.

Based on the participants' comments, it might also be the case that 50 ms disruption in one place may not be enough to induce an effect. A study by Jones and McAuley (2005) supports this possibility. The researchers presented participants with different sequences of sound with varying IOIs. Then, they asked participants to judge the duration of two sounds. They found no difference between different intervals in the judgments. However, in the other experiments, they showed that the global context of the sound sequence affects judgment. So, as a counter argument, it could be said that one small distortion in one area may not change the overall perception of the rhythm.

Regarding the significant effect of rhythm in the lower group, if we assume that the marginal significance we get in the lower group is real, these accounts do not explain why we found an opposite effect in the lower group. After all, the theory would predict an absence of an effect. One possible reason why we found an effect in the opposite direction is that participants in the lower group may be less sensitive to rhythmic stimuli and might have ignored the rhythm altogether in the disrupted condition. This might, then, have facilitated the attending to the linguistic task. On the other hand, those who scored higher in the CA-BAT might be more sensitive to rhythmic stimuli and showed an absence of an effect, which would be predicted by the aforementioned accounts.

The insignificant results in the second experiment might also be because participants totally ignored the rhythmic stimuli during the experiment. This was again reflected in the comments participants gave. Many participants reported not attending to the rhythms. Some participants also reported that in some trials the rhythm and the sentence did not match while in some others they matched. Some even reported being disturbed by the random rhythms. So, it could be that participants totally ignored the rhythms, especially in the random condition because it was not linked to the task and disturbing at the same time. One change in our experiment could be to add a task related to the rhythmic patterns so that participants would attend to the rhythms.

4.3 Interaction between linguistic complexity and rhythmic complexity

Many studies in the literature investigate the relationship between the tonal structure of music and the syntactic structure of language. These studies found an interaction between the two domains with many different methodologies (Fedorenko et al., 2009, Slevc et al., 2009, Hoch et al., 2011 for behavioral measures; Patel et al., 1998, Koelsch et al., 2005, Patel et al., 2008 for neuroimaging and neurological studies). However, there were not many studies that investigate the relationship between language and rhythm in terms of their hierarchical structure. One study that examined the effect of rhythm on language was conducted by Jung et al. (2015). In their study, they used a paradigm similar to Slevc and colleagues' (2009) study. They showed participants sentences that were either unambiguous or garden-path sentences. They also presented participants with a chordal progression. They manipulated rhythm with the presentation of the stimuli. In the normal condition, inter-onset intervals were fixed whereas in the distorted condition the stimuli were presented either early or late. They found that the interaction between language and chordal progression was present only in the unperturbed condition. In a second experiment, they conducted the experiment without the chordal progressions. They found main effects of rhythm and sentence type, but no interaction.

Our experiments differ from theirs in that they induced rhythm in the temporal unfolding of the words of each sentence, but not in terms of auditory rhythm. So, it is not easy to compare the two experiments. However, the fact that we induced the distortion only in one place might be why we could not find any effect of rhythm because it was not enough to induce a structural ambiguity in the rhythmic stimuli. Even in the second experiment, there was no jitter in terms of where the beats were going to be heard. The inter-onset interval was still fixed in the second experiment. The manipulation was done with the ordering of the sound events. In the second experiment, the sounds were ordered randomly. So, instead of randomizing the stimuli, we could add some jitter in the rhythms and inspect the result with these stimuli. The jitter could serve to temporal expectancy between each slot. This would, then, ensure the lack of structure in the rhythmic stimuli.

Moreover, Fedorenko and colleagues (2009) found an interaction between harmony and relative clause structure. In their experiments, the sentences were sung conforming to a chordal progression. In the out-of-key conditions, the note in the critical item was sung from an out-of-key note. The sentences were manipulated as in our experiment. They manipulated the structure of sentences by creating sentences with SRCs and ORCs. In their experiments, they found a main effect of sentence structure and an interaction between language and music such that there was a bigger difference between SRC and ORC in the out-of-key condition. They also added an auditory anomaly condition as a control condition. Auditory anomaly involved a loudness manipulation at the critical region (see Figure 15). They did not find an effect of the anomaly manipulation in their experiment. This experimental design is the most similar one in terms of its design. Just like them, we manipulated sentences as two different structural levels: SRC vs ORC. As in their experiment, we manipulated rhythms in two different ways. Yet, unlike them, instead of using chordal progressions we used purely nonmusical rhythmic stimuli. In the first experiment, we aimed to create a structural difference when we played one beat at the critical region 50 ms second earlier than expected. In the second experiment, we aimed to create an auditory manipulation that acts as a control variable to see the effect of two levels of structural manipulation in the first experiment. However, we were not able to find any difference in either of the experiments.

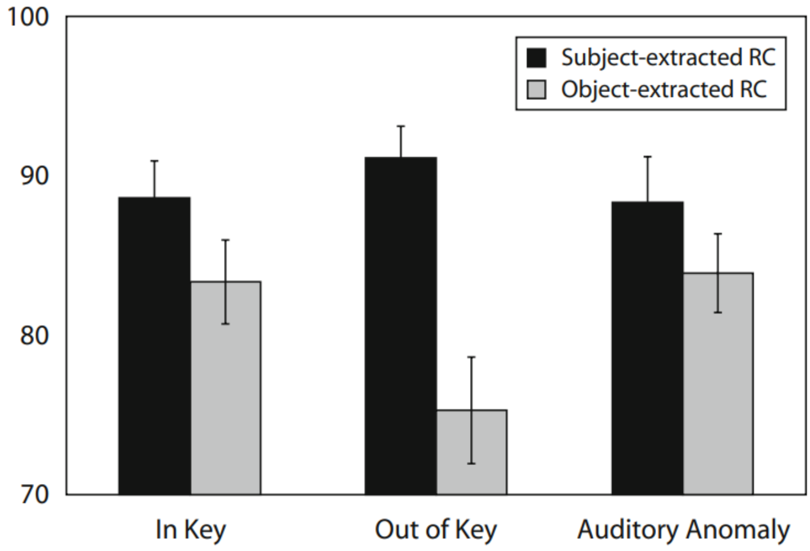

Figure 15. Results of accuracy data by Fedorenko et al. (2009)

The lack of any significant difference might be related to what Fedorenko and colleagues (2009) faced in their experiments. They reported that the response time data they collected did not reveal any difference between conditions. All the results were based on the accuracy of yes/no responses. The problem in our study was that there was a ceiling effect in the accuracy data. Because of that, we were not able to run any analysis on the accuracy data. Even though they also presented participants with yes/no questions, their questions were in the form of “who did what to whom”. On the other hand, in our experiment, after participants listened to the sentences, we asked participants whether the sentence they saw on the screen was correct according to the original sentence they listened to. The correct sentences were identical to the original sentence (except for the absence of adverbs of time and place). In the incorrect sentences, on the other hand, the subject of the matrix sentence and the head of the relative clause were switched. This type of question was obviously too easy for the participants. This was reflected in their comments as well. Most participants said that the questions were too easy. They also reported that after some trials they only attended to the subject of the sentence and checked whether it was correct or not. Therefore, it might be the case that they did not fully process the sentences but focused solely on the subject position, which was just before the verb in all experimental conditions. One thing we could do was to ask harder questions that would require the processing of the whole sentence. Another possibility would be to add more filler sentences that had varying structures.

From another perspective, as Peretz (2006) suggests, the modules for rhythm and tonal encoding may be different in the brain. Even though rhythm has a hierarchical structure, it may be the case that these two domains evolved through different stages and go through different mental processes in the brain. It may be the case that while rhythm is more associated with timing and grouping, harmony involves structural mental processes similar to language. This is also supported by the fact that there may be tonal structure in a loose rhythmic context. Moreover, rhythm in the general sense is not limited to music. Many types of behavior involve rhythmic cycles and grouping, from walking to talking and sleeping. Therefore, unlike what Fitch (2013) says, the structure of the rhythm is not immediately extracted from a rhythmic context. To be able to extract a fully-fledged hierarchical structure, humans may need to have some *content* to imply some structure. Related to our experiments, if we indicated the structure with some other feature on top of rhythmic grouping such as pitch and/or volume (e.g., sL where L is accented by being presented at a higher pitch and/or volume), this may have given a better sense of structure to participants. This, then, would interact better with the linguistic structure.

Supporting this, a study conducted by Ladinig, Honing, Haden, and Winkler (2009) induced the metrical structure by playing different timbres in different regions of the metrical structure. The authors manipulated the rhythms by omitting the metrically salient beats in the stimuli. There were omissions in the metrically most important region, second most important region and the least important regions. They found that participants detected omissions in the strong metrical region faster and more accurately compared to omissions in the weak metrical regions. They conducted an EEG study to inspect whether participants detect deviation in the metrical structure even when they did not attend the rhytmic stimuli. In the unattend condition, they found more increase in MMN response (an ERP component that is elicited in response to auditory deviation) when there is an omission in the strong metrical position compared to the omissions in the weak metrical position. This study may suggest that metrical structure is not immediately extracted but needs to be induced by other factors like pitch and timbre differences in difference regions of the metrical structure.

Overall, it could be the case that our stimuli were not strictly metrical in the sense that they did not possess a hierarchical structure. Instead, they were sequences of pulses that formed groups of sound events. Here, Fitch's (2013) distinction may be useful. He suggests that there is a difference between meter and pulse. Pulse is non-hierarchical whereas meter involves a hieararchical organization of sounds. Meter implies diversity in prominence among the sounds within a sequence. In metric stimulus, while some sounds are more prominent, others are subordinate to these metrically strong sounds. From this perspective, it may the case that our manipulation in the rhythmic stimuli (isochronous, ssL, sL, sssL, and sLL) was not enough the induce a metric structure.

4.4 The effect of rhythmic perceptual ability on rhythm

In our experiments, we used an adapted version of the CA-Beat Alignment Test as an individual differences test before the main part began. In the analysis part, CA-BAT data were used to split the total data set into two based on the median. In the first experiment, we found a marginal main effect of rhythm in the lower group. The two groups were taken as a between-subject variable in the total data set, and another comparison was made to see if there is any interaction between rhythm and median-split groups. We found an interaction such that the lower group responded to questions whose sentences were presented with disrupted rhythms. This finding was somewhat surprising because a difference in the opposite direction was to be expected such that the *rhythmic disruption* rather than *rhythmic regularity* was to cause a debilitating effect on sentence processing.

Even though this result could still be a coincidence, let’s for once assume that the effect of rhythm in the lower group was real. One possible explanation is that because participants in the lower group are less sensitive to rhythms, they may have ignored rhythms in the disrupted condition, but allocated more time to the normal rhythms because they needed more time to process normal rhythms compared to the upper group, who were superior in their ability to perceive rhythms.

4.5 Limitations

This study was limited in a number of ways. First of all, the questions that were asked after every sentence were too easy for participants. This situation caused a ceiling effect in the accuracy data. So, harder questions that require the processing of the whole sentence can be used instead of simple yes/no questions. Also, getting response time to easy questions was most possibly not sensitive enough to compare different conditions in our experiments. Instead of collecting response time data, more sensitive or online measurement techniques can be exploited to investigate the mutual interaction between language and rhythm.

Furthermore, in the present experiment, items were designed as between-item. Instead of this, a within-item design can be implemented to increase the power of the study. Namely, instead of choosing 20 sentences for SRCs and ORCs, Latin square design can be used. Hence all 40 items can be used in the experiment.

Moreover, in the present experiments, the head of the relative clauses was always the subject of the main sentence. This increased the predictability of sentences, hence making the sentences even easier to process for participants. Therefore, the variability in the sentence structure can be increased by creating sentences in which the head of the relative clause is the object of the main sentence in some trials.

Related to rhythmic stimuli, we induced the distortion only by playing the upbeat in the critical region 50 ms earlier than expected. 50 ms could be too small to cause any decrease in performance. Instead, longer disruptions could be done on the rhythmic stimuli. Furthermore, instead of just playing the upbeat earlier, there can be trials in which the upbeat is played later than expected. For example, McAuley and

Kidd (1998) found that whether a rhythmic sequence is presented earlier or later than expected has an effect on the tempo judgments of the sequences.

Apart from adding more variability in the distortion in rhythmic stimuli, the structure of the rhythms can be made more salient by changing the loudness or timbre of hierarchically higher beats. This will allow participants to extract the structure of the rhythmic stimuli, which can otherwise be perceived as groups of sounds, and not hierarchical structures.

4.6 Future Research

As listed in the limitation section, some improvements in the stimuli can be done in future research. Firstly, more variability and complexity can be added to sentences by creating sentences in which the head of the relative clause is the object of the main sentence. Secondly, more variability can be added to rhythms by also creating rhythms in which upbeat is not only played earlier but also later than expected. Moreover, the magnitude of distortion can be increased to 75-100 ms to ensure that participants perceive it. Thirdly, the structure of the rhythms can be made salient by introducing a loudness or timbre difference in the hierarchically salient beats in the rhythm. Fourthly, we might introduce the distortion in the downbeat rather than the upbeat. Fifthly, ERP markers (P600 or MMN) might reveal differences in the expected conditions which were not detectable at the behavioral level. Lastly, the questions after every sentence can be made harder and more variable to ensure that participants try to understand the whole sentence instead of focusing only on some particular parts of the sentence (i.e. subject of the sentence).

On top of these improvements, the possibility that rhythm does not immediately induce structure in the mind of the perceiver must be investigated. As

Peretz (2006) suggests rhythm and tonality might be the result of different evolutionary processes. Moreover, as in Jones' (1976) Dynamic Attending Theory, rhythm might be what guides the allocation of attention in various contexts. So, instead of being a structure in and of itself, rhythm might be the template where the structure is mapped. Moreover, the processes that underlie rhythm might be Gestalt grouping principles because these principles do not entail assumptions about hierarchy. Rather, Gestalt principles rely on perceptual cues like proximity and continuity. Therefore, experiments testing these possibilities can be conducted in the future.

4.7 Conclusion

The interaction between language and rhythm was investigated in two experiments. In the first experiment ORC- and SRC-sentences were coupled with normal and disrupted rhythms to inspect the effect of the structural complexity of each domain on the other. The findings did not reveal any main effect or interaction. If these null findings indicate a lack of any effect in the real world, the proposal by Fitch (2013) and Asano and Boeckx (2015) that rhythm has a hierarchical structure similar to other domains is not correct. Only a marginal effect of rhythm was found in the lower group based on CA-BAT scores. Even though it is highly probable that this result is a coincidence, it may reflect differences in rhythmic perceptual abilities.

The second experiment was identical to the first experiment with one difference. Instead of distorted rhythms, random sound sequences were presented. Similar to the first experiment, all the results were insignificant. This result strongly suggests that our measurement was not sensitive to gauge the effect of rhythm on structural differences in sentences.

Overall, the result suggests that rhythm and tonality have different relations with language. Our results urge a close examination of the structure of rhythm before examining its relationship with language. It could be that humans cannot extract the hierarchical structure in a rhythm without any perceptual difference between different beats in the sound sequence.

APPENDIX A

QUESTIONNAIRE

Bölüm-1: Temel Bilgiler *(Part-1: Basic Information)*

1. Katılımcı ID *(Participant ID)*

2. Kaç yaşındasınız? *(How old are you?)*

3. Disleksi tanısına sahip misiniz? *(Do you have the diagnosis of dyslexia?)*

    - Evet *(Yes)*
    - Hayır *(No)*

4. Sesli okuma akıcılığınızı nasıl değerlendirirsiniz?

(How is your loud reading fluency?)

- Çok kötüyümdür *(really bad)*
- Kötüyümdür *(bad)*
- Herkes kadar iyiyimdir *(as good as others)*
- İyiyimdir *(good)*
- Çok iyiyimdir *(really good)*

5. Sessiz okuma akıcılığınızı nasıl değerlendirirsiniz?

(How is your silent reading fluency?)

- Çok kötüyümdür *(really bad)*
- Kötüyümdür *(bad)*
- Herkes kadar iyiyimdir *(as good as others)*
- İyiyimdir *(good)*
- Çok iyiyimdir *(really good)*

6. Herhangi bir duyma bozukluğu tanısına sahip misiniz?

(Do you have any hearing impairment?)

- Evet *(Yes)*
- Hayır *(No)*

7. Bir önceki soruya cevabınız evet ise sahip olduğunuz tanı nedir?

(If you answered previous question positively, what is your diagnosis?)

8. Herhangi bir dilsel bozukluk tanısına sahip misiniz?

(Do you have any language impairment?)

- Evet *(Yes)*
- Hayır *(No)*

9. Bir önceki soruya cevabınız evet ise sahip olduğunuz tanı nedir?

(If you answered previous question positively, what is your diagnosis?)

Bölüm-2: Ritim Algısı *(Part-2: Rhythm)*

1. Müzik dinlerken ritimleri algılamakta

(How are with perceiving the rhythm while listening to music?)

- Çok kötüyümdür *(really bad)*
- Kötüyümdür *(bad)*
- Herkes kadar iyiyimdir *(as good as others)*
- İyiyimdir *(good)*
- Çok iyiyimdir *(really good)*

2. Müzikle birlikte tempo tutmakta

(How are you with keeping the tempo with music?)

- Çok kötüyümdür *(really bad)*
- Kötüyümdür *(bad)*
- Herkes kadar iyiyimdir *(as good as others)*
- İyiyimdir *(good)*

- Çok iyiyimdir *(really good)*

Bölüm-3: Müzik eğitimi *(Part-3: Musical training)*

1. Hayatınızda müzik veya dans eğitimi aldınız mı?

(Have you received any training in music or dance?)

    - Evet *(Yes)*
    - Hayır *(No)*

2. Aldıysanız kaç sene eğitim aldınız (yıl olarak)?

(If you have received, how many years (in years)?)

    - 1-2
    - 3-5
    - 5+

3. Ne tür bir eğitim aldınız? *(What kind of training have you received?)*

    - Telli çalgılar (saz, gitar, mandolin, piyano vs.)

    (String instruments (saz, guitar, mandolin, piano etc.))

    - Vurmalı çalgılar (bateri, kudüm, def, davul vs.)

    (percussion (battery, kudüm, def, drum etc.))

    - Nefesli çalgılar (ney, klarnet, yan flüt vs.)

    (wind instruments (ney, clarinet, flüte etc.))

    - Dans veya folklör *(dance or folk dancing)*
    - Diğer *(others)*

APPENDIX B

LIST OF SENTENCES

ORC sentences:

Geçen hafta sınıfta öğrencinin cevapladığı öğretmen oturdu.

(The teacher who the student answered in the class last week sat)

Bütün gün atölyede kalfanın beklediği usta ayrıldı.

(The master who the journeyman waited in the workshop all day left)

Geçen hafta partide palyaçonun kovaladığı cambaz yoruldu.

(The acrobat who the clown chased in the party las week got tired)

Geçen gün yolda avcının taşıdığı köylü acıktı.

(The villager who the hunter carried on the way the other day got hungry)

Dün akşam toplantıda valinin uğurladığı kaymakam evlendi.

(The district governor who the governor bade farewell yesterday night in the meeting got married)

Dün gece dükkanda terzinin suçladığı kadın kaçtı.

(The woman who the tailor blamed in the shop yesterday night ran away)

Önceki hafta mahkemede hakimin gösterdiği katip telaşlandı.

(The scribe who the judge pointed in the court the other week got anxious)

Geçen hafta camide müezzinin savunduğu imam göründü.

(The imam who the müezzin defended in the mosque last week appeared)

Önceki ay fabrikada işçinin küçümsediği patron değişti.

(The boss who the worker despised last month in the factory was replaced)

Bu sabah yıkıntıda tefecinin korkuttuğu borçlu sarardı.

(The debtor who the usurer scared in the ruins this morning turned pale)

Geçen ay eğitimde pilotun vurduğu asker kayboldu.

(The soldier who the pilot shot during training last month disappeared)

Geçen ay inşaatta mühendisin kandırdığı mimar öldü.

(The architect who the engineer deceived in the construction area last month died)

Dün sabah caddede yolcunun gördüğü şoför durdu.

(The driver who the passenger saw on the Street yesterday morning stopped)

Geçen gün avluda bahçıvanın izlediği kahya şaşırdı.

(The butler who the gardener watched in the yard the other day was surprised)

Geçen gün sokakta kuryenin hatırladığı satıcı utandı.

(The salesman who the courier remembered on the Street the other day blushed)

Geçen hafta matbaada çevirmenin zorladığı editör konuştu.

(The editor who the translator forced in the printing house last week spoke)

Dün gece mahallede çırağın andığı bakkal ağladı.

(The grocer who the grocery boy remembered in the neighborhood yesterday night cried)

Bu sabah gemide kaptanın düşürdüğü görevli kıkırdadı.

(The officer who the captain caused to fall in the ship this morning giggled)

Geçen gün pazarda zabıtanın fark ettiği darbukacı sustu.

(The drummer who the policeman noticed in the bazaar the other day kept quiet)

Bu sabah panayırda şerbetçinin kurtardığı beyefendi susadı.

(The gentleman who the sherbet-seller saved in the fair this morning got thirsty)

SRC sentences:

Dün gece konserde şarkıcıyı iten sunucu bayıldı.

(The reporter who pushed the singer in the concert yesterday night fainted)

Dün sabah pazarda balıkçıyı dinleyen müşteri gülümsedi.

(The buyer who listened to the fisherman in the market yesterday morning smiled)

Geçen ay sergide ressamı öpen piyanist sevindi.

(The pianist who kissed the painter in the exhibit last month got happy)

Dün akşam büroda avukatı kovan sekreter üzüldü.

(The secretary who fired the lawyer in the office yesterday night felt bad)

Dün sabah durakta makinisti azarlayan tayfa öfkelendi.

(The crew who scolded the mechanic in the stop yesterday morning got angry)

Önceki gün merkezde terapisti dolandıran danışan sinirlendi.

(The client who swindled the therapist in the center the other day got angry)

Dün sabah dernekte müdürü döven memur endişelendi.

(The officer who beat the manager in the association yesterday morning got anxious)

Geçen gün sahilde aşığı büyüleyen çiçekçi kapandı.

(The florist who mesmerized the lover in the beach the other day closed)

Bu öğlen apartmanda kapıcıyı aydınlatan profesör şenlendi.

(The professor who enlightened the janitor in the building this afternoon got happy)

Bu akşam kuaförde berberi gözlemleyen iş adamı kasıldı.

(The businessman who observed the barber in the coiffeur this evening tightened up)

Dün akşam hastanede hemşireyi çağıran hasta uyudu.

(The patient who called the nurse in the hospital yesterday night slept)

Geçen gün fuarda şairi eleştiren yazar hastalandı.

(The author who criticized the poet in the fair the other day got sick)

Dün gece karakolda jandarmayı uyaran polis gizlendi.

(The policeman who warned the gendarme in the police station yesterday night hid)

Geçen akşam restoranda aşçıyı gözleyen yamak sırıttı.

(The apprentice who observed the cook in the restaurant last night grinned)

Önceki sabah bedestende kuyumcuyu duyan alıcı vazgeçti.

(The buyer who heard the jeweler in the bazaar the other morning withdrew)

Dün sabah okulda filozofu tanıyan adam heyecanlandı.

(The man who recognized the philosopher in the school yesterday morning got excited)

Geçen hafta denizde cankurtaranı bulan çocuk sakinleşti.

(The child who found the lifeguard in the sea last week calmed down)

Geçen gün meydanda simitçiyi durduran yaya kızardı.

(The pedestrian who stopped the bagel seller in the square the other day blushed)

Dün akşam ofiste eczacıyı saklayan doktor rahatladı.

(The doctor who hid the pharmacist in the office yesterday night relaxed)

Dün gece gösteride sihirbazı şaşırtan izleyici güldü.

(The viewer who surprised the magician on the show yesterday night laughed)

Filler sentences:

Dün sabah markette kasiyer çılgına döndü.

(The cashier turned mad in the grocery store yesterday morning)

Bütün gün eve kargocu uğradı.

(The delivery person stopped by the house all day)

Bütün sabah amfide okutman öğrencilere yardım etti.

(The lecturer helped the students in the classroom all morning)

Dün akşam sahnede oyuncu iyi performans sergiledi.

(The actor performed well on the stage yesterday night)

Öğlen vakti otobüste kombici aradı.

(The repairman called in noon time in the bus)

Hafta sonu işyerinde saatçi onarım yaptı.

(Wacthmaker did repairment in the work place on weekend)

Geçen hafta otobanda kamyoncu sürat yaptı.

(Truck driver speeded on the highway last week)

Geçen gün festivalde hokkabaz gösteri düzenledi.

(The juggler performed in the festival the other day)

Geçen ay imalathanede marangoz işçi alımı yaptı.

(The carpenter recruited a worker in the workshop last month)

Geçen sefer mahallede seyyar sahaf çok kitap sattı.

(The mobile book seller sold many books in the neighborhood the last time)

APPENDIX C

ETHICS COMMITTEE APPROVAL

T.C. BOĞAZİÇİ ÜNİVERSİTESİ
Sosyal ve Beşeri Bilimler İnsan Araştırmaları Etik Kurulu (SBİNAREK)

18.02.2019

Dr. Öğr. Üyesi Esra Mungan
Boğaziçi Üniversitesi,
Fen-Edebiyat Fakültesi,
Psikoloji Bölümü,

Sayın Araştırmacı,

"In Search of Influences of Music and Language on Rhythm Perception" başlıklı projeniz ile Boğaziçi Üniversitesi Sosyal ve Beşeri Bilimler İnsan Araştırmaları Etik Kurulu (SBİNAREK)'e yaptığınız 2019/02 kayıt numaralı başvuru 04.02.2019 tarihli ve 2019/02 sayılı kurul toplantısında incelenerek etik onay verilmesi uygun bulunmuştur.

Saygılarımızla bilgilerinizi rica ederiz.

Doç. Dr. Osman Sabri Kıratlı (Başkan)
Uygulamalı Bilimler Yüksek Okulu
Uluslararası Ticaret Bölümü
Boğaziçi Üniversitesi, İstanbul

Prof. Dr. Fatoş Gökşen (Üye)
Fen Edebiyat Fakültesi
Sosyoloji Bölümü
Koç Üniversitesi, İstanbul

Prof. Dr. Ayşecan Boduroğlu (Üye)
Fen-Edebiyat Fakültesi
Psikoloji Bölümü
Boğaziçi Üniversitesi, İstanbul

Dr. Öğr. Üyesi C. Taylan Acar (Üye)
Fen-Edebiyat Fakültesi
Sosyoloji Bölümü
Boğaziçi Üniversitesi, İstanbul

Dr. Öğr. Üyesi Işıl Erduyan (Üye)
Eğitim Fakültesi
Yabancı Diller Eğitimi Bölümü
Boğaziçi Üniversitesi, İstanbul

Dr. Öğr. Üyesi Selcan Kaynak (Üye)
İktisadi ve İdari Bilimler Fakültesi
Siyaset Bilimi ve
Uluslararası İlişkiler Bölümü
Boğaziçi Üniversitesi, İstanbul

Dr. Öğr. Gör. Suzan Üsküdarlı (Üye)
Mühendislik Fakültesi
Bilgisayar Mühendisliği Bölümü
Boğaziçi Üniversitesi, İstanbul

APPENDIX D

DESCRIPTIVES OF ACCURACY DATA

Table D1. Descriptive Statistics of Accuracy Data in Experiment 1

EXP1								
Conditions	ORC		SRC		Disrupted		Normal	
Answer	yes	no	yes	no	yes	no	yes	no
N	1355	85	1356	84	1354	86	1357	83
%	94%	6%	94%	6%	94%	6%	94%	6%

Table D2. Descriptive Statistics of Accuracy Data in Experiment 2

EXP1								
Conditions	ORC		SRC		Random		Normal	
Answer	yes	no	yes	no	yes	no	yes	no
N	1000	40	1003	37	994	46	1009	31
%	96%	4%	96%	4%	96%	4%	97%	3%

APPENDIX E

ESTIMATES OF FULL MODELS

Table E1. Estimates of Full Data with Sentence and Rhythm Conditions as Fixed Effects in Experiment 1

EXP-1			
Full model	response_timeLog ~ sentence * rhythm + (1 | participant) + (1 |sentence_item)		
Fixed effects	Estimate	SE	t value
intercept	1.25	1.05	4.99
sentence	1.05	1.04	0.38
rhythm	1.02	1.04	0.52
interaction	1.02	1.06	0.35

Note: Even though the model was based on logarithmically transformed data, the number above are back transformed.

Table E2. Estimates of Full Data with Screening Group and Rhythm Conditions as Fixed Effects in Experiment 1

EXP-1			
Exploratory model	response_timeLog ~ screening_group * rhythm + (1 | participant) + (1 |sentence_item)		
Fixed effects	Estimate	SE	t value
intercept	1.24	1.05	4.15
screening_group	1.02	1.07	0.35
rhythm	1.07	1.04	1.83
interaction	0.94	1.03	-1.95

Note: Even though the model was based on logarithmically transformed data, the number above are back transformed.

Table E3. Estimates of Full Data with Sentence and Rhythm Conditions as Fixed Effects in Experiment 2

EXP-2			
Full model	response_timeLog ~ sentence * rhythm + (1 | participant) + (1 |sentence_item)		
Fixed effects	Estimate	SE	t value
intercept	1.46	1.05	7.36
sentence	0.99	1.05	-0.03
rhythm	1	1.05	0.19
interaction	0.98	1.07	-0.24

Note: Even though the model was based on logarithmically transformed data, the number above are back transformed.

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