The role of first and second language speech rhythm in syntactic ambiguity processing and musical rhythmic aptitude

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Contents

Introduction

Part I

In order to achieve speech comprehension in a fraction of a second the listener must segment the speech flow and recognize groups of auditory events, e.g., sounds and pauses, as words. Once words are recognized, word meaning is retrieved from the listener's mental lexicon and integrated with information from other linguistic domains, e.g., syntax and pragmatics (Cutler, Mehler, Norris, & Segui, 1986; Frazier, Carlson, & Clifton Jr, 2006; Magne et al., 2007; Schmidt-Kassow & Kotz, 2008). An essential element for speech segmentation and word recognition is rhythm.

The importance of *speech rhythm*, however, is not restricted to word segmentation and recognition only. Beyond the word level, together with intonation, rhythm organizes speech, interacting with different linguistic domains, such as morphology, syntax and semantics, creating prosodic constituents (Hayes, 1989; Inkelas, 1990; Nespor & Vogel, 1986; Selkirk, 1978). However, while intonation helps to create prosodic constituents based on prominence resulting from pitch variation, rhythm temporally organizes speech into prosodic constituents by means of intensity and duration. These prosodic constituents, may be used as processing units (Carroll & Slowiaczek, 1987; Morgan, 1996; Slowiaczek, 1981), guiding the syntactic parser during sentence segmentation (Kjelgaard & Speer, 1999; Speer, Kjelgaard, & Dobroth, 1996; Steinhauer, Alter., & Friederici, 1999), facilitating its processing and comprehension.

So far, studies addressing speech organization during sentence processing focused mainly on intonation (Beach, 1991; Bögels, Schriefers, Vonk, Chwilla, & Kerkhofs, 2009; Kerkhofs, Vonk, Schriefers, & Chwilla, 2007; Kjelgaard & Speer, 1999; Lehiste, 1973; Price, Ostendorf, Shattuck-Hufnagel, & Fong, 1991; Speer et al., 1996; Warren, Grabe, & Nolan, 1995), leaving the role of speech rhythm during sentence processing understudied.

Speech rhythm has been investigated in terms of its contribution for speech organization mainly at the word level (Cutler et al., 1986; Dupoux, Pallier, Sebastian, &

Mehler, 1997; Dupoux, Peperkamp, & Sebastian-Galles, 2001; Jusczyk, Cutler, & Redanz, 1993; Otake, Hatano, Cutler, & Mehler, 1993; Vroomen & De Gelder, 1995)[1].

In addition, previous studies investigating the role of prosody, i.e., intonation and rhythm, in speech segmentation used mostly behavioral measures[2]. Behavioral measures, e.g., accuracy rate and reaction times, may reflect only the outcome of auditory language processing, namely when comprehension is achieved. In order to fully understand when and how speech rhythm may be used during language processing, measures with higher temporal resolution are required. Understanding the time course of linguistic processes, such as the use of rhythmic information during speech processing, may confirm or refute existing linguistic theories and create new ones, together with models of language processing (Handy, 2004; Steinhauer et al., 1999).

Furthermore, in addition to the role of speech rhythm during sentence processing, it is relevant to understand possible limitations on its use. As any other linguistic information, i.e., phonologic, morphologic, semantic or syntactic, rhythm should be acquired as part of a speaker's competence in a language (Patel, 2008). During the first year of life, infants learn the relevant rhythmic information of their native language, using it to detect words' boundaries and to segment them in the speech stream (Jusczyk, 1999; Jusczyk et al., 1992, 1993).

With language acquisition, rhythmic parameters are set to optimally perceive and segment speech in that particular language (Cutler & Mehler, 1993; Otake et al., 1993; Vroomen & De Gelder, 1995). In this sense, there could be an ideal period, in which rhythmic properties of a language can be acquired and encoded as relevant linguistic information to segment speech. The acquisition of second language (L2) rhythmic properties at a later time,

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[1] A few studies addressed the interplay between meter, as word stress, and other linguistic domains, i.e., semantics (Rothermich, Schmidt-Kassow, & Kotz, 2012) and syntax (Schmidt-Kassow & Kotz, 2008; Schmidt-Kassow, Roncaglia-Denissen, & Kotz, 2011; Schmidt-Kassow, Rothermich, Schwartze, & Kotz, 2011) at the sentence level. However, none of these studies investigated the role of speech rhythm, a more complex organization device, operating beyond word stress assignment.

[2] For exception, see (Bögels, Schriefers, Vonk, Chwilla, & Kerkhofs, 2009; Kerkhofs, Vonk, Schriefers, & Chwilla, 2007; Steinhauer, Alter., & Friederici, 1999).

namely after this sensitive period, may implicate limitations on their attainment and use.

Also in the context of second language, the importance of rhythm was investigated only in terms of word segmentation and stress perception (Cutler, 1994a, 2000, 2002; Cutler, Mehler, Norris, & Segui, 1992; Field, 2003; Goetry & Kolinsky, 2000; Guion, Harada, & Clark, 2004; Schmidt-Kassow, Roncaglia-Denissen, & Kotz, 2011; Schmidt-Kassow, Rothermich, Schwartze, & Kotz, 2011). According to these studies, L2 learners do not use rhythmic information in L2 to segment words (Cutler et al., 1986; Otake et al., 1993), and do not detect word stress violation similarly to native-speakers (Schmidt-Kassow, Rothermich, et al., 2011). Nevertheless, L2 learners may learn L2 rhythmic properties, i.e., stress, and are sensitive to them to some extent (Field, 2003; Guion et al., 2004; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Trofimovich & Baker, 2006).

Sensitivity to rhythmic properties among L2 learners may result from speech rhythm relying on general acoustic properties, such as intensity and duration, which are also found in music organization (Bispham, 2006; Lerdahl & Jackendoff, 1983; Patel, 2003, 2008; Tincoff et al., 2005). Hence, when languages with different rhythmic properties and organization are mastered, this may translate into an enhanced sensitivity to similar acoustic properties, i.e., intensity and duration, in music.

This may be the case because individuals mastering two languages may rely on their rhythmic properties (Beckman, 1996; Patel, 2008; Ramus, Dupoux, Zangl, & Mehler, 2000; Ramus, Nespor, & Mehler, 1999) to recognize the language context at hand and properly select the target-language. Therefore, being more sensitive and attentive to general rhythmic properties may present a linguistic advantage for L2 learners. If sensitivity to rhythmic properties in speech could be transferred to music, enhancing musical rhythmic perception, this would provide additional evidence for shared cognitive resources between these two domains (Besson & Schön, 2001; Marques, Moreno, Castro, & Besson, 2007; Patel, 2008; Schön, Magne, & Besson, 2004; Slevc & Miyake, 2006). This would further suggest that rhythm is a general cognitive skill (Jackendoff, 1989), which may be used in different cognitive domains.

The current thesis investigates speech rhythm in three different contexts. Namely, during sentence processing in first and second languages and in terms of its transferability as a general cognitive skill to the music domain. In the second part of this dissertation, entitled **Theoretical Background**, the theoretical framework underlying and motivating the current work will be provided (Chapters 1-4) together with the relevant methodological background (Chapter 5).

The third part, entitled **Experimental Studies** (Chapters 6 to 8)**,** each one of the three addressed contexts will be experimentally investigated. In study 1 (Chapter 6), the role of speech rhythm as a segmentation device during sentence processing and comprehension will be addressed. Study 2 (Chapter 7) will address one of the possible limitations on the use of speech rhythm as a sentence segmentation device, i.e., in the context of L2 processing. Finally the transferability of speech rhythm as a cognitive skill to the music domain will be addressed in study 3 (Chapter 8). Each experimental study corresponds to an article published in a peer-review journal indicated at the beginning of each chapter.

The fourth and last part of this dissertation entitled **General Discussion and Outlook** comprises **Summary and Conclusions** (Chapter 9), **Limitations and Future Directions** (Chapter 10).

Theoretical Background

Part II

Chapter 1
Speech Rhythm

In the first part of this chapter, *speech rhythm* will be defined together with its importance for speech organization. The theoretical framework supporting the rhythmic organization of speech, namely prosodic hierarchy, will be discussed. In the last part of this chapter, a brief review and the current state of the experimental research addressing the prosodic organization of speech, i.e., intonational and rhythmic, will be provided.

1.1) Speech rhythm: Definition

In phonetics, the term *prosody* is used to describe speech properties occurring within multiple phonemes in speech that cannot be derived from one single segment. These are the so-called suprasegmental properties and comprise pitch variations, i.e., *intonation* (Bolinger, 1958; Hadding-Koch & Studdert-Kennedy, 1964), and temporal variations of segment and syllable duration, i.e., *rhythm* (Fry, 1955, 1955; Lieberman, 1960; Nooteboom, 1997). Rhythm is defined as a systematic pattern of sounds in terms of prominence, timing and grouping (Patel, 2008)

In speech flow, rhythm groups auditory events, e.g., sounds and pauses, together into words, making their boundaries acoustically prominent (Patel, 2003) and aiding the listener in terms of word segmentation and recognition. Beyond the word level, rhythm groups words together into prosodic constituents hierarchically organized (Hayes, 1989; Inkelas, 1990; Nespor & Vogel, 1986; Selkirk, 1978). At each level of this hierarchy, rhythm interacts with different linguistic domains, e.g., morphology, syntax and semantics, helping to structure the utterance. In the following section, the prosodic hierarchy will be discussed for a better understanding of the contribution of rhythm to speech organization at each prosodic level.

1.2) Prosodic hierarchy

In terms of rhythm and intonation, the unfolding sounds of the utterance are structured in an universal and hierarchical manner. This hierarchy consists of seven prosodic domains[3], namely the syllable, the metric foot, the phonological word, the clitic group, the phonological phrase, the intonational phrase and the utterance (Hayes, 1989; Nespor & Vogel, 1986; Selkirk, 1978). In these domains, phonological rules operate interacting with morphology, syntax, semantics and pragmatics, to create prosodic constituents[4]. These constituents may serve, in turn, as perceptual units during speech segmentation, guiding the syntactic parser during speech processing (Carroll & Slowiaczek, 1987; Martin, 1967; Morgan, 1996; Slowiaczek, 1981; Tyler & Warren, 1987). As follows, each prosodic domain will be presented in terms of the rhythmic contribution to its creation. In Figure 1.1 the seven prosodic domains are illustrated.

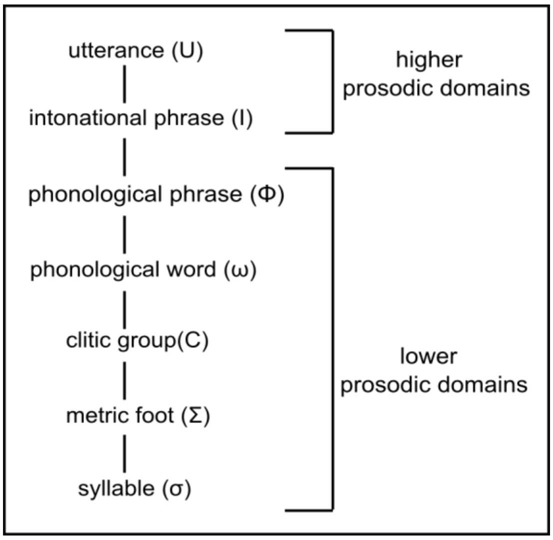

Figure 1.1: The seven prosodic domains.

[3] In its original version, there were six categories (Selkirk, 1978, 1980). The clitic group was first proposed by Nespor & Vogel (1986).

The lowest category in the prosodic hierarchy is the syllable (σ), here defined as single sonority peak (Inkelas, 1990), where syllable-internal phonological rules[5] govern and serve as input for the next prosodic domain, i.e., the metric foot. The metric foot (Σ) is the prosodic domain where rhythmic information can first be noticed by means of stress assignment to syllables within a word. The metric foot comprises one stressed syllable dominating one or more relatively weaker ones.

The phonological word (ω) is the prosodic constituent resulting from the interaction between phonology and morphology. The phonological word dominates[6] the metric foot entirely, i.e., two syllables from the same metric foot cannot belong to two distinct phonological words. According to Hayes (1989) the phonological word consists of, at least, one grammatical word and, in case of a compound word, both of its elements (Nespor & Vogel, 1986). In this prosodic domain, rhythm assigns words with primary and secondary stress. In Figure 1.2 the three lowest prosodic constituents, namely the syllable, the metric foot and the phonological word are illustrated and exemplified by the word *flowers*.

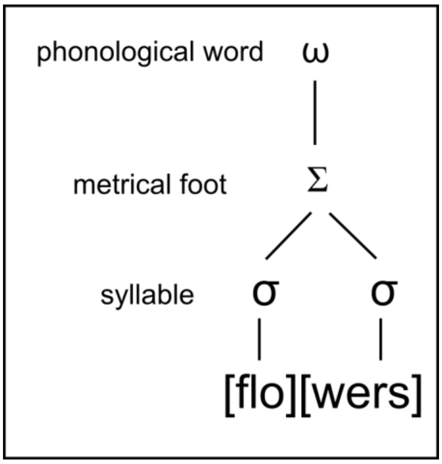

Figure 1.2: The three lowest prosodic categories.

[5] An example of syllable-internal phonological rule is the rule of schwa insertion. This rule predicts that a schwa[ə] may be inserted between a liquid consonant /l/ or /r/ and a plosive, e.g., [k], [g], [t], [d], or fricative, e.g., [s], [z], [f], [v], as it can be seen in some dialects of Dutch (Trommelen, 1983). For instance, in the words "melk" → mel[ə]k /*milk* and "twaalf" → twaal[ə]f/*twelve*;.

[6] A hierarchical domination means that a category contains another as part of its domain. For instance, the domain of the metrical foot contains the syllable, dominating it, while the domain of the phonological word contains the metrical foot.

The clitic group is the next prosodic domain in the prosodic hierarchy. Here, a content word and its grammatical adjacent items, e.g., function words, are grouped around one primary stress. In this domain, the first interactions between phonological rules and syntax[7] can be observed. An example of a clitic group is provided in Figure 1.3. In this example, the word *leave* and its adjacent element, the function word *me*, constitute two phonological words, but one clitic group only:

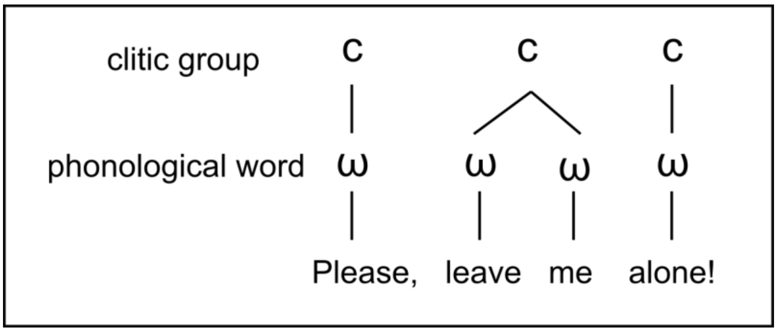

Figure 1.3: The category of the clitic group (Hayes, 1989).

Dominating the clitic group is the phonological phrase. In this domain, rhythm operates upon more complex syntactic structures, grouping syntactic heads[8] with their dependent material, i.e., grammatical and content words, around one phrasal stress (Hayes, 1989). The domain of the phonological phrase is represented in Figure 1.4, where three phonological phrases can be observed. The first one is constituted by the syntactic head *sluggers* and its dependent material *the*, the second by the syntactic head *boxed* only, and finally the third phonological phrase has *in* as its syntactic head and *the crowd* as its dependent elements.

[7] Syntax is here defined as a set of principles governing the combination of discrete and structured linguistic elements into sequences (Jackendoff, 2002).
[8] Syntactic heads are words that determine the syntactic properties of a phrase. For instance, the head in a prepositional phrase is a preposition, while in a noun phrase it is a noun (Payne, 2006).

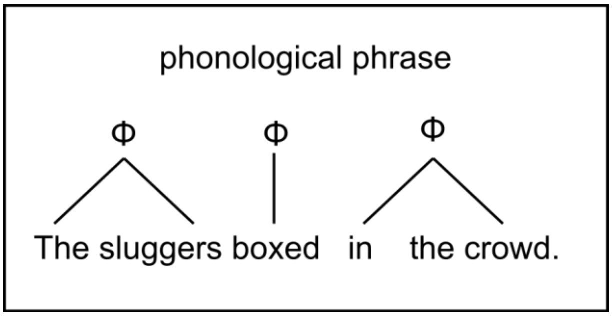

Figure 1.4: The domain of phonological phrases (Nespor & Vogel, 1986).

The intonational phrase is the domain where the intonational contour and the prosodic breaks grouping syntactic heads together can be first observed. Prosodic breaks are constituted by intonational properties, i.e., related to descending tones (Millotte, René, Wales, & Christophe, 2008) and durational ones, e.g., pre-boundary lengthening, a rhythmic manifestation (Cutler, Dahan, & Donselaar, 1997; Lehiste, 1973; Nooteboom, 1997).

Finally, the utterance (U) is the largest and most complex prosodic domain, governed by phonological rules interacting with morphology, syntax, semantics and pragmatics. These interactions are of higher complexity because they result from exchanges with the precedent and lower domains. In Figure 1.5 the prosodic categories of phonological phrase, intonational phrase and the utterance are depicted.

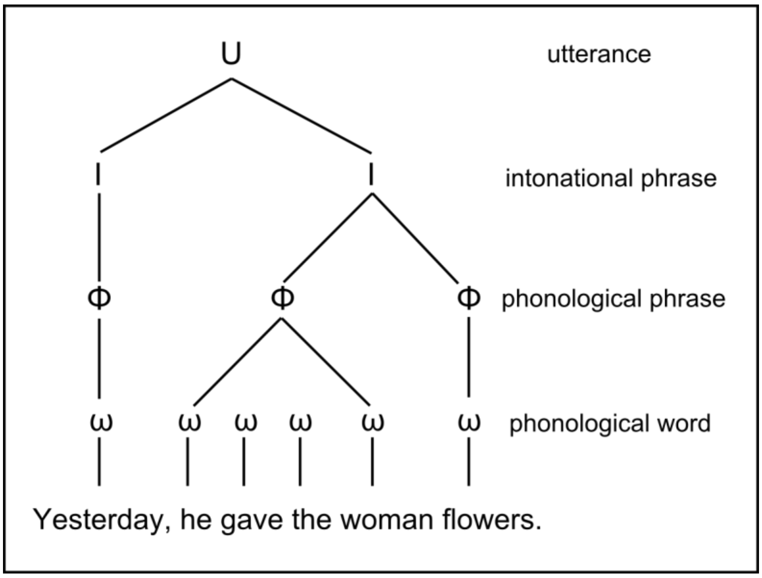

Figure 1.5: The domains of phonological words, phonological phrases, intonational phrases and the utterance.

1.3) Experimental studies on prosodic hierarchy

In the current work, speech rhythm will be addressed in terms of its function as a sentence segmentation device in the domain of the intonational phrase and the utterance, where syntactic relations between words become more complex (Hayes, 1989; Nespor & Vogel, 1986). As previously mentioned, studies investigating the use of rhythm as a speech organization device addressed mainly the lower levels from the prosodic hierarchy, from the syllable to the word level (Cutler et al., 1986; Dupoux et al., 1997, 2001; Jusczyk et al., 1993; Otake et al., 1993; Schmidt-Kassow & Kotz, 2008; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Schmidt-Kassow, Rothermich, et al., 2011; Vroomen & De Gelder, 1995). These studies investigated word segmentation strategies in different languages, such as English (Cutler et al., 1986; Jusczyk et al., 1993), French (Cutler et al., 1986), Japanese (Otake et al., 1993) and Dutch (Vroomen & De Gelder, 1995), the detection of word stress (Dupoux et al., 1997, 2001) and metric violations in sentence context (Schmidt-Kassow & Kotz, 2008).

Studies investigating the role of prosody in speech comprehension addressing higher prosodic domains focused mainly on pitch variation, i.e., intonation (Beach, 1991; Bögels et al., 2009; Kerkhofs et al., 2007; Kjelgaard & Speer, 1999; Lehiste, 1973; Price et al., 1991; Speer et al., 1996; Warren et al., 1995). This could be the case because rhythm can be more clearly observed in lower prosodic domains, while intonation in higher ones. Nevertheless, rhythm also helps to structure more complex prosodic domains, such as the intonational phrase and the utterance. Hence, for a more complete understanding of language processing and comprehension, the contribution of both prosodic facets, i.e., rhythm and intonation, should be taken into consideration.

Chapter 2
Speech Rhythm and L2 Attainment

In the first part of this chapter a brief overview of the main findings of the second-language literature for L2 attainment in different linguistic domains, including rhythm, will be presented. In the second part of this chapter, the rhythmic classification of languages will be presented within the framework of the prosodic hierarchy and its implications to the attainment of L2 rhythmic properties will be considered.

2.1) Age of acquisition and L2 outcome: A brief overview

The existence of a sensitive period for language acquisition and its constraints have been long debated in the L2 literature (Birdsong, 2006; Scovel, 2000). The importance of age of acquisition (AoA) for L2 outcome may vary according to the linguistic domain in consideration (Birdsong, 2006; Clahsen & Felser, 2006).

Studies investigating L2 late learners report similar performances as native-speakers in semantic and lexical processing (Hernandez & Li, 2007; Ojima, Nakata, & Kakigi, 2005; Sanders & Neville, 2003; Wartenburger et al., 2003) and comparable morphosyntactic processing of subject-verb (Ojima et al., 2005) and gender agreement (Sabourin & Haverkort, 2003). On the other hand, complex syntactic structures are processed by late learners as non-native-like, even with increase of L2 exposure and proficiency (Clahsen & Felser, 2006; Felser & Roberts, 2007; Love, Maas, & Swinney, 2003; Marinis, Roberts, Felser, & Clahsen, 2005; Papadopoulou & Clahsen, 2003).

Differences between native-like and L2 processing may result from, at least, four constraining factors. Namely, limitations at the level of L2 grammar attainment (Hawkins, 2001; Mueller, 2005; Papadopoulou, 2005; White & Genesee, 1996), transfer of L1 properties to L2 (Frenck-Mestre & Pynte, 1997; Hernandez, Li, & Macwhinney, 2005; Kotz, 2009; Marian & Spivey, 2003; Scheutz & Eberhard, 2004; Weber & Cutler, 2004), cognitive resources limitations, and maturational constraints. As follows these four limitations will be discussed.

Regarding L2 grammar attainment, it has been suggested that grammar acquisition in L2 is fundamentally different from L1 (Hawkins, 2001). This difference may be reflected in L2 processing, even among L2 learners showing high proficiency level in language tests and self-reported questionnaires (Clahsen & Felser, 2006). While L1 to L2 transfer has been reported with respect to phonological, orthographical, and lexico-semantic properties (Frenck-Mestre & Pynte, 1997; Hernandez et al., 2005; Marian & Spivey, 2003; Sabourin & Haverkort, 2003; Tokowicz & MacWhinney, 2005).

In terms of cognitive resources limitations, individual differences in short-term and working memory capacities may especially constraint L2 processing (Ardila, 2003) and overall proficiency attainment (Juffs & Harrington, 2011; Noort, Bosch, & Hugdahl, 2006). This may be the case because L2 learners must constantly suppress L1 in favor of L2, demanding a greater cognitive load (Bialystok, 1999; Bialystok, Craik, Green, & Gollan, 2009), leaving less resources available for a native-like L2 processing.

Finally, maturational constraints may affect not only L2 grammar attainment, but also the use of the declarative-procedural memory system (Ullman, 2004). According to this system, two types of memory are implicated during language processing. The declarative system, which is involved in the storage of a mental lexicon and structures used in a language, and the procedural system, concerning the combinatorial rules applicable to it. Hence, differently from native-speakers, late L2 learners might depend much more on the declarative than on the procedural memory during the process of complex L2 structures.

Despite much information about L2 attainment and its limitations in different linguistic domains, little is known about the acquisition of suprasegmental information in L2

(Chun, 2002; Rasier & Hiligsmann, 2007; Trofimovich & Baker, 2006), including *rhythm*. As previously mentioned, the importance of rhythm has been investigated by the L2 literature mainly in terms of word metric preference, i.e., stress assignment (Cutler, 1994a, 2000, 2002; Cutler et al., 1992; Field, 2003; Goetry & Kolinsky, 2000; Guion et al., 2004; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Schmidt-Kassow, Rothermich, et al., 2011).

On the one hand, L2 learners do not seem to use L2 rhythmic information during word segmentation (Cutler et al., 1986; Otake et al., 1993), and detect stress violation differently than native-speakers (Schmidt-Kassow, Rothermich, et al., 2011). Nevertheless, other studies suggest that, L2 learners are sensitive to and may learn L2 rhythmic information, i.e., stress (Field, 2003; Goetry & Kolinsky, 2000; Guion et al., 2004; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Trofimovich & Baker, 2006). Thus, it is possible that L2 learners are sensitive to L2 rhythmic properties to some degree but do not use them as word segmentation strategy.

Beyond the word level, no research has been conducted to investigate the role of rhythm in L2. As previously described, after word segmentation, rhythm interact with different linguistic domains, grouping words together into prosodic constituents (Hayes, 1989; Inkelas, 1990; Nespor & Vogel, 1986). Therefore, to account for a more complete understanding of the use of rhythm by L2 learners, a broader scope than the word level should be investigated.

2.2) Prosodic hierarchy, languages' metric preferences and rhythmic classifications

Within the prosodic hierarchy, some operating phonological rules are language specific and others universal (Nespor & Vogel, 1986). Lower level domains, such as the syllable and metric foot, would be operated by language specific phonological rules, assigning word stress, i.e., the word metric pattern. As a result of this specificity, languages of the world would present different metric preference, namely the trochee or the iamb (Hayes, 1985; Hay & Diehl, 2007).

Trochaic languages by default rely on a metric pattern in which a stressed syllable is followed by, at least, one unstressed syllable. German, English and Dutch are example of trochaic languages (Eisenberg, 1991; Jusczyk et al., 1993; Vroomen & De Gelder, 1995). Iambic languages, on the other hand, rely on the opposite metric pattern, namely one or more unstressed syllables followed by a stressed one. French, Hebrew and Turkish are examples of such languages (Charette, 1991; Graf & Ussishkin, 2003; Inkelas & Orgun, 2003). During first-language acquisition, a language's typical meter is used by preverbal babies to deduce a word's boundary and to develop segmentation strategies specific to that language (Jusczyk, 1999; Jusczyk et al., 1993).

Studies investigating L2 rhythmic properties have mainly focused on languages' metric preference, namely at word stress, where language specific phonological rules operate (Cutler et al., 1986; Field, 2003; Guion et al., 2004; Nazzi & Ramus, 2003; Otake et al., 1993; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Schmidt-Kassow, Rothermich, et al., 2011; Trofimovich & Baker, 2006). No research has investigated the role of speech rhythm in L2 addressing higher prosodic domains, i.e., intonational phrase and the utterance, where, according to the prosodic hierarchy, universal phonological rules operate.

The use of speech rhythm in higher and more complex prosodic domains could be less subject to language specific rhythmic properties and, therefore, to L2 AoA, than the word level. If this were the case, then rhythm as a sentence segmentation device should be detected and used by L2 learners, whose L1 and L2 are distinct in terms of their rhythmic organization.

Regarding their speech rhythmic organization, languages of the world are classified as stress-timed and syllable-timed (Abercrombie, 1967; Pike, 1945). Stress-timed languages, such as English and German, have a rhythmic organization based on the metric foot, i.e., one stressed syllable dominating one or more relatively weaker ones. In syllable-timed languages, such as French, Spanish and Turkish, on the other hand, the rhythmic structure of the utterance is based on the syllable, regardless of stress (Abercrombie, 1967; Cutler et al., 1986; Cutler & Norris, 1988; Grabe & Low, 2002; Pike, 1945; Ramus, 2002).

Additionally to these two rhythmic categories, a third one has been proposed, namely the mora (Bloch, 1950; Han, 1962; Ladefoged, 1975). The mora is a sub-unit of the syllable, consisting of a short vowel and a preceding consonant onset (Itô, 1989; Otake et al., 1993; Warner & Arai, 2001). As the mora is part of the syllable, in terms of its rhythmic classification, mora-timed languages (e.g., Japanese[9]) are closer to syllable-timed than to stress-timed languages (Grabe & Low, 2002).

Originally, this rhythmic classification was based on the idea of physical isochrony, i.e., constant duration of the rhythmic units organizing languages. Thus, stress-timed languages would present a regular recurrence and duration of the metric foot, while in syllable-timed and mora-timed languages, this would be the case for subsequent syllables and the morae respectively (Abercrombie, 1967; Grabe & Low, 2002; Ladefoged, 1975; Pike, 1945; Warner & Arai, 2001). This objective isochrony was later refuted by experimental evidence from stress-timed (Dauer, 1983; Lea, 1974; O'Connor, 1965; Roach, 1982; Shen & Peterson, 1962), syllable-timed and mora-timed languages (Beckman, 1982; Borzone de Manrique & Signorini, 1983; Hoequist, Jr., 1983b; Warner & Arai, 2001; Wenk & Wioland, 1982).

Despite the absence of an objective isochrony in temporal organization of languages, these rhythmic classifications, i.e., stress-timed, syllable-timed and mora-timed languages, are still used in the field (Grabe & Low, 2002; Höhle, Bijeljac-Babic, Herold, Weissenborn, & Nazzi, 2009; Inkelas & Orgun, 2003; Nazzi & Ramus, 2003; Nolan & Asu, 2009; Patel, 2003, 2008; Ramus, Dupoux, et al., 2000). This is the case because this classification matches a

[9] Japanese, which is the prototypical mora-timed language, has been classified by some research as being syllable-timed (Arai & Greenberg, 1997; Pamies Bertrán, 1999). This would result from being the mora a sub-unit from the syllable (Grabe & Low, 2002).

subjective rhythmic perception of these languages (Beckman, 1992; Laver, 1994; Nazzi, Bertoncini, & Mehler, 1998; Patel, 2008; Ramus, Dupoux, et al., 2000; Tincoff et al., 2005; Toro, Trobalon, & Sebastián-Gallés, 2003)[10].

[10] Although general agreement regarding languages rhythmic classification is found in the literature, this is not free of controversy (Pamies Bertrán, 1999). Some language varieties, such as Singapore English is considered being rhythmically closer to syllable-timed than to stress-timed languages (Tongue, 1979). Spanish is also a controversial case of rhythmic classification. For some researchers it is a solid syllable-timed language (Abercrombie, 1967; Pike, 1945), but for others it is considered rhythmically closer to stress-timed languages (Hoequist, Jr., 1983a, 1983b; Nolan & Asu, 2009; Pamies Bertrán, 1999). In order to handle these potential controversies Nolan and Asu (2009) argue that rhythmic properties should be understood as continuous and orthogonal dimensions instead of categorical classifications. Hence, languages could present rhythmic characteristics from different classes, but they would be identified according to the predominant and most salient one.

Chapter 3

Speech Rhythm and Language Processing Models

In this chapter, three different types of language processing and comprehension models will be presented and discussed in terms of their view on the use of prosodic information, i.e., rhythm. In addition, L2 processing will be considered based on the existing monolingual language processing models.

3.1) Language processing: Monolingual models

The psycholinguistic literature proposes two kinds of language processing and comprehension models, serial and interactive. Serial models (Frazier, 1987; Frazier & Fodor, 1978) predict that the syntactic parser commits to the simplest syntactic structure possible, based on word-category information. Only at a later stage lexico-semantic information is processed and integrated to assign the thematic role. As syntactic-first models were created based on data from reading studies, they comprise syntactic and semantic processing, disregarding prosody.

Interactive models, on the other hand, assume that different kinds of linguistic information, such as semantic, syntactic and prosodic, interact at all stages of language processing (Beach, 1991; Marslen-Wilson & Tyler, 1980; Marslen-Wilson, Tyler, Warren, Grenier, & Lee, 1992; McClelland & Rumelhart, 1981; Warren et al., 1995). Hence, information from different linguistic domains would be combined in a non-linear fashion. The notion of non-linearity implies that linguistic information may be of great relevance under certain circumstances and have little or even no effect in others (De Bot, Lowie, & Verspoor, 2007; McClelland, 1987).

A third kind of processing model was proposed by Friederici (2002) based on electrophysiological and neurotopographical data. This neurocognitive model of language processing suggests a precise time course and neuroanatomy of linguistic processes during language comprehension. According to this model three phases can be observed during auditory language processing. In phase 1 (occurring between 100-300 ms) word category information is used to form initial syntactic structures. In phase 2 (300-500 ms) lexico-semantic and morphosyntactic information is processed for thematic role assignment. The processing and integration of these two kinds of information, i.e., lexico-semantic and morphosyntactic, occur in the same time window, but are correlated with different neuroanatomical structures. In phase 3, the integration of syntactic and lexico-semantic information occurs.

The neurocognitive model is consistent with syntax-first and interactive models assuming a late interaction between different linguistic information (Friederici, 2002), as it predicts the creation of syntactic structure as input for thematic role assignment. So syntactic structure precedes semantic processing at an early stage, and interacts with it later on. In its most recent version (Friederici, 2011), the neurocognitive model predicts the interaction of prosodic information with all three proposed phases of language processing.

Despite its great contribution to a temporal and neuroanatomical understanding of language processing, the occurrence of syntactic processing prior to the processing of other linguistic information, i.e., morphosyntactic and semantic, has been questioned in recent experimental data (Hasting & Kotz, 2008; Van den Brink & Hagoort, 2004). This counterevidence of syntactic-first processing may suggest an interactive use of different linguistic information during all the stages of language processing, depending on its relevance for a particular context (non-linearity notion).

The current thesis is consistent with language processing models predicting an interactive use of prosodic information, in this case rhythm, already during early stages of language processing (Carroll & Slowiaczek, 1987; Kjelgaard & Speer, 1999; Marslen-Wilson & Tyler, 1980; Marslen-Wilson et al., 1992; McClelland, 1987; Speer et al., 1996; Watt & Murray, 1996). In this sense, rhythm may be incrementally used by the parser as language processing unfolds cueing speech segmentation and processing.

3.2) L2 and language parsing

Regarding second language processing, no specific parsing model has been proposed so far (Kotz, 2009). Therefore, monolingual parsing models have been used to support L2 sentence processing results (Frenck-Mestre, 2005; Frenck-Mestre & Pynte, 1997; Juffs & Harrington, 1996; Rossi, Gugler, Friederici, & Hahne, 2006; Swets, Desmet, Hambrick, & Ferreira, 2007). Even though it has been suggested that the same factors influencing first-language syntactic parsing may affect the processing of L2 (Frenck-Mestre, 2005) there is still a need for L2 parsing models. This is the case because L2 outcome may vary according to the linguistic domain involved (Birdsong, 2006). Thus, L2 processing models, being serial or interactive, should take variation and possible constraints in L2 attainment into account.

In terms of L2 processing, interactive processing models seem to provide a better fit to deal with constraints on L2 attainment due to the assumption of non-linearity. If L2 outcome in a certain linguistic domain is less native-like, affecting its use during language processing, this could be compensated by linguistic information from domains that are more native-like. Such reasoning could account for differences found by experimental research between L2 and monolingual language processing (Frenck-Mestre, 2005; Frenck-Mestre & Pynte, 1997; Mueller, 2005).

Chapter 4
Speech Rhythm and Music

In this chapter rhythm in speech and music will be compared in terms of their similarities and differences. It will be argued that rhythm in both domains share similar acoustic features, of which perception may be transferred as a cognitive skill across domains. In addition, a concise review of experimental data from skill transfer between language music will be presented.

4.1) Rhythm in speech and music

In language and in music rhythm organizes acoustic events in a hierarchical fashion (Hayes, 1989; Jackendoff, 1989; Lerdahl & Jackendoff, 1983; Nespor & Vogel, 1986). In music, rhythmic organization is created by two components, i.e., the metrical and the grouping structure. Metrical structure creates a regular alternation of strong and weak beats in a periodic fashion throughout the musical piece. While grouping structure arranges musical events in perceived units, e.g., motives, phrases and section, (Jackendoff, 1989; Lerdahl & Jackendoff, 1983).

In language, metric organization is found as word-internal prosody, in terms of stress assignment. However, differently than in music, one cannot speak of a periodicity in speech, i.e., spontaneous regular alternation of stress throughout the utterance (Pamies Bertrán, 1999). Nevertheless, a subjective rhythmic pattern can be found in the utterance (Beckman, 1992; Bloch, 1950; Ladefoged, 1975; Laver, 1994; Pamies Bertrán, 1999; Patel, 2008; Ramus, Dupoux, et al., 2000). In terms of grouping, speech rhythm organizes the utterance arranging linguistic elements together, e.g., morphemes and words, into prosodic constituents.

Additionally, previous research suggests that speech rhythm relies on general acoustic properties, such as duration and intensity, also found in music (Bispham, 2006; Lerdahl & Jackendoff, 1983; Patel, 2003, 2008; Tincoff et al., 2005). In language these acoustic properties are used to create units of speech organization and perception, which may serve as the basis of language rhythmic discrimination (Beckman, 1996; Patel, 2008; Ramus, Dupoux, et al., 2000; Ramus et al., 1999). Hence, mastering two languages with different rhythmic properties may enhance the sensitivity to these general acoustic features. This should be the case because rhythmic information may help L2 learners to promptly identify the language context, facilitating the selection of the target language. Therefore, being sensitive to speech rhythmic properties of two languages may present a linguistic advantage as it may contribute for a successful language selection.

If an enhanced sensitivity to speech rhythmic features can translate into an enhanced musical rhythmic perception, this would be in line with the idea of domain-specific skills may be transfer to another cognitive domain, e.g., music (Perkins & Salomon, 1989). This would provide further evidence of shared cognitive resources between music and language, paralleling with findings from previous research (Besson & Schön, 2001; Marques et al., 2007; Patel, 2008; Schön et al., 2004; Slevc & Miyake, 2006). Such a cognitive sharing between these two domains could also indicate a common evolutionary origin between them (Besson & Schön, 2001; S. Brown, 2000; Jackendoff, 1989; Levman, 1992).

4.2) Skill transfer between language and music: Experimental evidence

Previous studies providing evidence of skill transfer between language and music focused mainly on pitch variation (D. Deutsch, Henthorn, Marvin, & Xu, 2006; Elmer, Meyer, Marrama, & Jäncke, 2011; Milovanov, Huotilainen, Välimäki, Esquef, & Tervaniemi, 2008; Slevc & Miyake, 2006). Some of these studies report that musical aptitude positively impacts second language skills, such as pronunciation (Milovanov et al., 2008) and phonological perception (Slevc & Miyake, 2006). In addition, it has been shown that language skills may enhance musical aptitude, in terms of tone perception (D. Deutsch et al., 2006; Elmer et al., 2011). Nevertheless, the transfer of rhythmic skills between these two domains has been neglected.

Pitch variation, together with rhythm are the two fundamental facets of speech and music organization (Lerdahl & Jackendoff, 1983; Nooteboom, 1997). While pitch variation attributes prominence to events by assigning tone volume (high *versus* low tones), rhythm does so by means of duration and intensity. As such, for a better understanding of the shared underlying mechanisms between language and music, studies should investigate both facets, i.e., intonation and rhythm, across domains.

Chapter 5

Methodological Background

In the first part of this chapter, the choice of the linguistic material used in Experimental studies 1 and 2 will be motivated. In the second part of this chapter, behavioral and event-related potential (ERP) measures used for data collection will be presented and motivated, with a special focus on the ERP method.

5.1) Syntactic ambiguity and rhythmic regularity: Experimental studies 1 and 2

The investigation of syntactic ambiguity has been extremely helpful to understand the mechanisms underlying language parsing (Frenck-Mestre, 2005), such as the role of verb argument structure (Frenck-Mestre & Pynte, 1997; Friederici & Frisch, 2000; Mitchell, 1989; Osterhout & Holcomb, 1992), context (Spivey-Knowlton, Trueswell, & Tanenhaus, 1993), semantics (Trueswell, Tanenhaus, & Garnsey, 1994) and prosody (Beach, 1991; Kjelgaard & Speer, 1999, 1999; Lehiste, 1973). Therefore, to investigate the role of speech rhythm during sentence parsing, syntactically ambiguous sentences were used in **experimental study 1** and **2** as stimulus material.

In addition, rhythm was addressed in terms of a rhythmically regular organization of speech, marking boundaries of prosodic domains by means of primary and phrasal stresses. If prosodic domains are clearly marked, this may create reliable and predictable prosodic constituents, which may be used as processing units (Carroll & Slowiaczek, 1987; Morgan, 1996; Slowiaczek, 1981). Processing units may serve as guide to the syntactic parser (Kjelgaard & Speer, 1999; Speer et al., 1996; Steinhauer et al., 1999), facilitating sentence processing and comprehension.

5.2) Measures of data collection

In all conducted studies, behavioral measures were collected, i.e., accuracy rates (**experimental study 1**, **2** and **3**) and reaction times (**experimental study 1** and **2**). Accuracy rates and reaction times are often used in psycholinguistic studies as an indicator of cognitive outcome and task comprehension (Bader & Meng, 1999; Dupoux et al., 2001; J. S. Johnson & Newport, 1989; Kjelgaard & Speer, 1999; Marslen-Wilson et al., 1992).

Nevertheless, behavioral measures do not capture the dynamic and unfolding nature of linguistic processes, only their outcome. Because the current dissertation is interested in when and how speech rhythm may interact with the syntactic parser, guiding it through sentence processing (**experimental study 1** and **2**), the unfolding nature of this interaction is here of particular relevance. Hence, ERPs[11] present a very suitable method for such an investigation, as they capture ongoing linguistic processes (Handy, 2004) prior to full comprehension.

5.2.1) Event-related Potentials (ERP)

Event-related potentials (ERP) are electric fluctuations resulting from brain responses to external or internal events (Picton et al., 2000; Rugg & Coles, 1995) captured by electrodes placed on the scalp. Because of background noise, created by spontaneous brain activity, the brain responses of interest are not traceable. In order to make them visible, events containing the phenomenon of investigation should be presented repeatedly. When enough electrical time-locked responses are generated, these are averaged and contrasted to a pre-stimulus baseline (Kutas & Van Petten, 1994), standing out against the randomness of the background noise (Hahne, 1998; Rugg & Coles, 1995).

[11] Behavioral measures are of great relevant to guide results interpretations of neuropsychological responses, e.g., ERP, in linguistic experiments (Picton et al., 2000).

These averaged time-locked responses constitute the ERP-waveform, a sequence of negative- and positive-ongoing peaks, which are also called components. ERP components are described in terms of polarity, latency, i.e., the time delay between stimulus-onset and its detectable effect, and scalp distribution, i.e., where activity is most intense (Donchin, 1979; Kutas & Dale, 1997; Kutas & Van Petten, 1988; Rugg & Coles, 1995).

In the current work, the experimental studies using the ERP method (**1** and **2**) were conducted using the 10-20 electrode system (Picton et al., 2000; Pivik et al., 1993). In this system, the distribution of electrodes on the scalp is oriented towards brain regions (frontal, temporal, parietal and occipital), the center of the scalp as well as towards both hemispheres, i.e., right and left. Thus, each electrode is labeled with the first letter of the region of its placement (i.e., F, T, C, P or O) and a number, which can be odd, for electrodes placed on the left hemisphere, or even, for those placed on the right hemisphere. Electrodes placed on the line dividing both hemispheres, the midline, are labeled with the letter Z (zero). For power enhancement in the statistical analysis, electrodes were grouped into regions of interest (ROI). In Figure 5.1, the 10-20 system of electrode placement is shown.

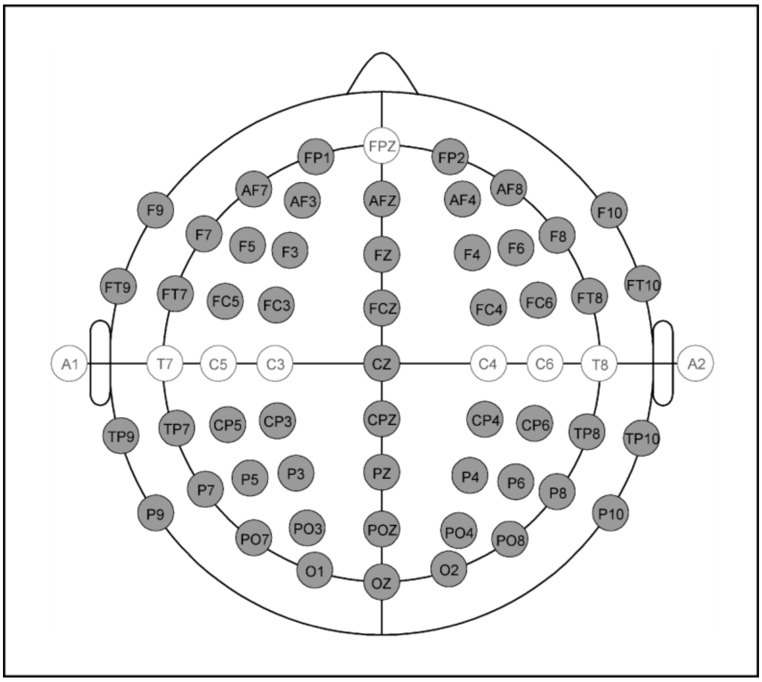

Figure 5.1: The 10-20 system of electrode placement.

In terms of their classification, ERP components can be divided into *exogenous* and *endogenous* components (Rösler & Heil, 1998). Exogenous components occur as a response to physical stimuli, while endogenous ones are associated with internal factors, such as individual's prior experiences, intention and decisions, modulated by task parameters and instructions (Donchin, Ritter, & McCallum, 1978).

Despite this classification, it is known that almost all exogenous components may be modulated by internal factors, while endogenous components may be influenced by physical events. Hence, a more appropriate classification of ERP components would be in terms of the time window of their occurrence, as earlier components tend to be more exogenous whereas later ones more endogenous (Donchin et al., 1978; Rugg & Coles, 1995).

Examples of early ERP components are the Missmatch Negativity (MMN) and the component complex comprising the N100 and P200, i.e., N1-P2 complex. The MMN is a centro-frontal pre-attentive response, elicited around 100 ms after stimulus-onset, to deviant stimuli randomly presented in a sequence of standard ones (Alho, 1995). The N1-P2[12] complex is elicited by attended and unattended stimulus physical properties (Näätänen & Picton, 1987). Regarding the late components, the most investigated ones are the P300, LAN, N400 and the P600. As follows, these late components will be described and special attention will be given to the P600, the ERP component of relevance for the current dissertation.

The P300 component (a positivity peaking around 300 ms after stimulus-onset) can be divided in two kinds, namely the frontally localized P300a and the centro-parietal P300b (Courchesne, Hillyard, & Galambos, 1975; Donchin et al., 1978; Naumann et al., 1992). The P300a is associated with the identification of a stimulus as a target and with directing the response towards a new stimulus (Yamaguchi & Knight, 1991). The P300b, on the other hand, is elicited when a deviant stimulus is encountered in a sequence of standard ones, to which the

[12] While the N100 has been associated with response to physical properties of stimuli, the P200 is also found to be modulated by complexity in cognitive processing (Dunn, Dunn, Languis, & Andrews, 1998; Lijffijt et al., 2009). However, because these two components always occur together, the N1-P2 complex is regarded as an early and exogenous complex.

individual's attention has been directed, this is the so-called oddball-paradigm (Donchin et al., 1978; Spencer, Dien, & Donchin, 1999).

The LAN (Left Anterior Negativity) is a component peaking between 300 and 500 ms after stimulus-onset. It is linked to morphosyntactic violations of gender, number and tense agreement (Coulson, King, & Kutas, 1998; A. Deutsch & Bentin, 2001; Friederici, Pfeifer, & Hahne, 1993; Gunter, Friederici, & Schriefers, 2000) and is modulated by working memory load (Coulson et al., 1998; King & Kutas, 1995).

The N400 is a negativity peaking around 400 ms after stimulus-onset, with a distribution accentuated over the centro-parietal area. This component is modulated by word frequency (Halgren et al., 2002), repetition (Van Petten, Kutas, Kluender, Mitchiner, & McIsaac, 1991), semantic priming (Holcomb & Neville, 1990), and difficulty in lexical integration (Bornkessel, McElree, Schlesewsky, & Friederici, 2004).

5.2.2) Speech rhythm and the P600

The P600 is a positivity with a centro-parietal distribution and a latency peaking around 600 ms after stimulus-onset. This ERP component has been associated with morphsyntactic and syntactic violations (Coulson et al., 1998; Friederici, Hahne, & Mecklinger, 1996; Friederici et al., 1993; Hagoort & Brown, 2000; Hagoort, Brown, & Groothusen, 1993; Kutas & Hillyard, 1983; Neville, Nicol, Barss, Forster, & Garrett, 1991; Schmidt-Kassow & Kotz, 2008), as well as with syntactic reanalysis (Bögels et al., 2009; Friederici & Frisch, 2000; Friederici, Mecklinger, Spencer, Steinhauer, & Donchin, 2001; Friederici, Steinhauer, Mecklinger, & Meyer, 1998; Frisch, Schlesewsky, Saddy, & Alpermann, 2002; Mecklinger, Schriefers, Steinhauer, & Friederici, 1995)[13]. In Figure 5.2, the

[13] It has been suggested that the P600 is not an ERP correlate elicited exclusively during syntactic processing, but is also found in response to different kinds of violations, such as semantic and orthographic (Kuperberg, 2007; Münte, Heinze, Matzke, Wieringa, & Johannes, 1998).

illustration of EEG measurement and idealized ERP components are shown.

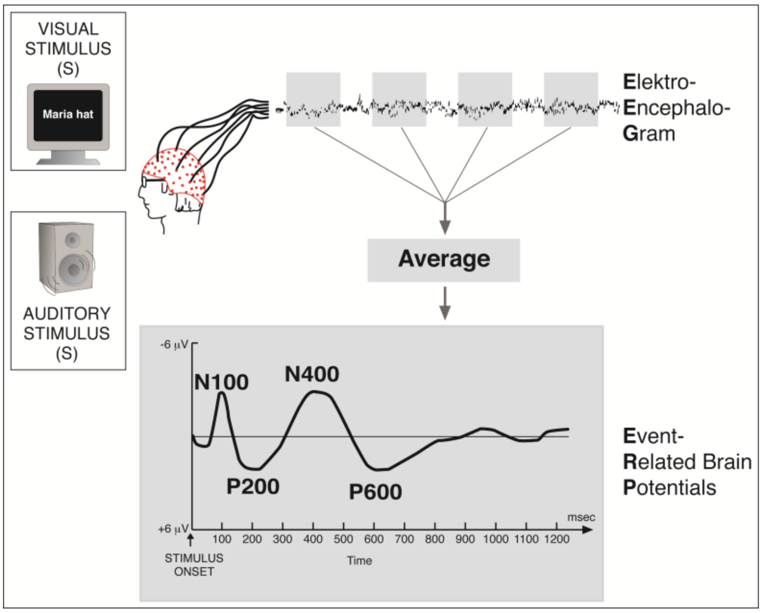

Figure 5.2: EEG measurement and idealized ERP components.

The present research focuses on the P600 as an indicator of syntactic reanalysis in face of case ambiguous structures, i.e., subject-first *vs.* object-first order, and whether it can be modulated by rhythmic regularity. Previous studies investigating case ambiguous subject-object sentences reported an enlarged P600 for the less-preferred syntactic order, i.e., object-first sentences. This P600 had a somewhat earlier latency, peaking around 350 ms after stimuli onset (Friederici et al., 2001, 1998; Mecklinger et al., 1995; Steinhauer, Mecklinger, Friederici, & Meyer, 1997). This early latency would reflect a less severe type of structural ambiguity (Gorrell, 2000) and the ease with which it would be resolved during language processing (Friederici & Mecklinger, 1996; Friederici et al., 2001; Steinhauer et al., 1997).

The theoretical framework and methods of choice presented in the second part of this dissertation serve as basis for the investigations carried out in the three experimental studies. In the next chapters (**Chapter 6-8**) each one of these studies will be presented and discussed.

Experimental Studies

Part III

Chapter 6

Speech Rhythm Facilitates Syntactic Ambiguity Resolution: ERP Evidence

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Abstract

In the current event-related potential (ERP) study, we investigated how speech rhythm impacts speech segmentation and facilitates the resolution of syntactic ambiguities in auditory sentence processing. Participants listened to syntactically ambiguous German subject- and object-first sentences that were spoken with either regular or irregular speech rhythm. Rhythmicity was established by a constant metric pattern of three unstressed syllables between two stressed ones that created rhythmic groups of constant size. Accuracy rates in a comprehension task revealed that participants understood rhythmically regular sentences better than rhythmically irregular ones. Furthermore, the mean amplitude of the P600 component was reduced in response to object-first sentences only when embedded in rhythmically regular but not rhythmically irregular context. This P600 reduction indicates facilitated processing of sentence structure possibly due to a decrease in processing costs for the less-preferred structure (object-first). Our data suggest an early and continuous use of rhythm by the syntactic parser and support language processing models assuming an interactive and incremental use of linguistic information during language processing.

Keywords: speech rhythm; syntactic ambiguity; P600; auditory processing

Introduction

Over the past decades, several psycholinguistic studies have addressed the importance of prosody in sentence comprehension (Lehiste, 1973; Marslen-Wilson et al., 1992; Price et al., 1991; Warren, 1985; Watt & Murray, 1996). It has been shown that prosody is used in early stages of sentence parsing (Carroll & Slowiaczek, 1987; Marslen-Wilson et al., 1992; Watt & Murray, 1996) and that it can help to resolve structural ambiguity (Lehiste, 1973; Price et al., 1991; Warren, 1985). In addition, appropriate prosody can be used as a local cue to facilitate syntactic processing or make it more difficult when inconsistent with syntactic structures (Beach, 1991; Bögels et al., 2009; Kjelgaard & Speer, 1999; Lehiste, 1973; Marslen-Wilson et al., 1992; Price et al., 1991; Schafer, Carter, Clifton, & Frazier, 1996; Speer et al., 1996; Steinhauer et al., 1999; Streeter, 1978; Swets et al., 2007; Warren et al., 1995). Furthermore, prosody has been shown to influence several linguistic functions, such as phonology (Warren et al., 1995), semantics and pragmatics (Gussenhoven, 1984; Rothermich, Schmidt-Kassow, & Kotz, 2012; Schafer, 1997; Schafer et al., 1996; Shriberg, Stolcke, Hakkani-Tür, & Tür, 2000; Slowiaczek, 1981), and syntax (Eckstein & Friederici, 2006; Schmidt-Kassow & Kotz, 2008).

Prosody can be understood as the acoustic features of spoken languages, such as duration, amplitude and fundamental frequency (Lehiste, 1970), manifested in at least two facets: intonation and rhythm. While intonation concerns the speaker-controlled pitch variation in course of an utterance, rhythm regards the temporal organization of the speech, allowing for segmentation of events in the utterance, i.e., sounds and pauses, and structuring them in a pattern of recurrence in time (Hayes, 1995; Magne, Aramaki, Astesano, Gordon, & Ystad, 2004; Nooteboom, 1997; Patel, 2008).

So far, studies investigating the importance of prosody to disambiguate syntactic structure have mainly addressed its intonational facet (Beach, 1991; Kjelgaard & Speer, 1999; Lehiste, 1973; Price et al., 1991; Speer et al., 1996; Warren, 1985). To our knowledge no study has specifically investigated the role of *rhythm* as a sentence segmentation cue to disambiguate syntactic structure and to facilitate sentence comprehension. Regarding the role of speech rhythm in auditory speech and language comprehension, previous studies suggest that listeners are sensitive to rhythmic regularity in speech (Dilley & McAuley, 2008; Niebuhr, 2009) that a word's metric property influences lexical access (Robinson, 1977), interacts with semantics (Magne et al., 2007; Rothermich et al., 2012) and with syntax (Dooling, 1974; Schmidt-Kassow & Kotz, 2008; Warren et al., 1995).

However, speech rhythm should also be investigated as a broader phenomenon rather than just a local one during sentence processing. When speech rhythm operates, it not only organizes sounds into words, but also words into larger prosodic units (Carroll & Slowiaczek, 1987; Slowiaczek, 1981) as part of a prosodic hierarchy (Hayes, 1989; Nespor & Vogel, 1986), which may constitute units of perception (R. E. Johnson, 1970; Jusczyk et al., 1992; Morgan, 1996; Tyler & Warren, 1987). Rhythm allows to segment relevant linguistic information, e.g., sounds, as speech flows, grouping it into meaningful linguistic units, e.g., words. These linguistic units may then be integrated with information from other linguistic domains, such as semantics and syntax, so comprehension is achieved (Cutler et al., 1986; Frazier et al., 2006; Magne et al., 2007; Schmidt-Kassow & Kotz, 2008). Given its significant contribution to speech organization, the role of rhythm should be investigated, not only when it operates as a local cue at the lexical level, but also when it serves as a sentence segmentation device, i.e., prior to and during the processing of syntactic complexity.

To our knowledge, there have been no studies investigating the role of rhythm as a sentence segmentation device during syntactic ambiguity resolution using the ERPs . ERPs are of great advantage while investigating unfolding language processes, such as the use of speech rhythm in sentences segmentation, because they capture the exact time course, in which these processes occur (Handy, 2004). In this sense, the use of ERPs may contribute to a better understanding of ongoing linguistic processing, allowing to expand theories and models of language processing (Handy, 2004; Steinhauer et al., 1999).

So far, a few studies have used ERPs to investigate the role of prosodic breaks, as a local cue and influencing the syntactic parser during ambiguity processing (Kerkhofs et al., 2007; Steinhauer et al., 1999). In these studies, the ERP component Closure Positive Shift (CPS) was associated with the occurrence of prosodic breaks, while an enlarged N400 was elicited by the less-preferred syntactic structure, object-first sentences. This enlarged N400 was previously associated with difficulty in lexical integration (Bornkessel et al., 2004; Bornkessel & Schlesewsky, 2006; Haupt, Schlesewsky, Roehm, Friederici, & Bornkessel-Schlesewsky, 2008), such as the encounter of an intransitive verb when a transitive one would be preferred (Bögels et al., 2009; Steinhauer et al., 1999). In addition, an enlarged P600 elicited by object-first structures was found (Kerkhofs et al., 2007; Steinhauer et al., 1999), which was linked to the re-analysis of this less-preferred syntactic structure (Friederici et al., 2001; Frisch et al., 2002; Vos, Gunter, Schriefers, & Friederici, 2001).

In the current study, we investigated the role of *rhythm* as a sentence segmentation cue, grouping words together in regular rhythmic chunks so as to facilitate the processing of syntactically ambiguous sentences. In previous experimental work, it has been suggested that the parser makes use of prosodic information, in our case rhythm, to create low-level syntactic structures, grouping words in "chunks" (1989; Murray, Watt, & Kennedy, 1998; Watt & Murray, 1996). These chunks would remain unattached until enough morphosyntactic information is provided, reducing memory load, without forcing the listener to commit to a possibly wrong syntactic analysis. Our view is consistent with the existence of a prosodic representation available already during early stages of sentence processing (Eckstein & Friederici, 2006; Kjelgaard & Speer, 1999; Marslen-Wilson et al., 1992; Schafer, 1997; Speer et al., 1996) that interacts with the syntactic parser prior to, during, and after syntactic ambiguity is encountered (Kjelgaard & Speer, 1999; Schafer, 1997; Speer et al., 1996).

Therefore, we presented participants with German sentences containing syntactic ambiguity, spoken in either regular or irregular rhythmic patterns. Rhythmic regularity was established by using one stressed syllable followed by three unstressed ones that created clitic groups (groups of grammatical words carrying one primary stress only (Hayes, 1989)) of constant size.

In order to focus on syntactic re-analysis and avoid lexical integration difficulty, we used only transitive verbs (i.e., verbs requiring an accusative argument). In this sense, we expected to find a P600 response, which has been interpreted to indicate syntactic re-analysis of a less-preferred structure, i.e., object-first order (Friederici et al., 2001; Steinhauer et al., 1999; Vos et al., 2001).

By presenting ambiguous sentences in rhythmically regular context, we provide a reliable segmentation cue, namely stress patterns, creating rhythmic chunks. These rhythmic chunks operate clustering linguistic constituents, such as morphemes and grammatical words sharing one common primary stress (i.e., a clitic group; (Nespor & Vogel, 1986)). As a result of their acoustic salience, i.e., shared primary stress, these clusters constitute perceptual units in the speech stream. Perceptual units may guide the syntactic parser (Carroll & Slowiaczek, 1987; R. E. Johnson, 1970; Jusczyk et al., 1992; Morgan, 1996; Slowiaczek, 1981; Tyler & Warren, 1987) when structures of greater syntactic complexity are encountered (i.e., object-first sentences), facilitating their processing.

It could be the case that rhythm facilitates the processing of both syntactic structures, i.e., subject-first and object-first order, however, its benefits should be more valuable and, therefore, more apparent during the processing of sentences with enhanced processing costs (i.e., object-first sentences), as in such cases, any facilitation cue can be used. Such facilitation should be confirmed by a significant reduction in the P600 mean amplitude response to object-first rhythmically regular sentences compared to the same structure in a rhythmically irregular context. Furthermore, behavioral results, such as higher accuracy rates and faster response times, should also be found for the less-preferred syntactic structure, i.e., object-first sentences, in rhythmically regular context in comparison to their rhythmically irregular counterparts.

Methods

Ethics statement

This study was approved by the ethics committee of the University of Leipzig. All individuals in this study gave their written informed consent for data collection, use, and publication.

Participants

Thirty-two participants (17 males; M_{age} = 25.59, *SD* = 2.53) participated in an initial rating study of the material, while twenty-four different participants (12 female; M_{age} = 26.33, *SD* = 1.97; all right-handed) took part in the EEG experiment. Participants from both studies were students of the University of Leipzig, native speakers of German, and were paid for their participation. None of the participants reported any neurological impairment or hearing deficit, and all had normal or corrected-to-normal vision.

Material

Originally, we created 480 sentences using 60 transitive verbs (requiring an accusative complement combined with 120 different common and proper nouns. By using transitive verbs instead of intransitive ones (i.e., verbs requiring dative complements) we focused on sentence reanalysis (P600; (Friederici et al., 2001; Mecklinger et al., 1995; Steinhauer et al., 1999)), avoiding responses to difficulties in lexical integration, N400 (Bornkessel et al., 2004; Haupt et al., 2008). Half of the sentences constituted experimental items, whereas the other half were filler sentences. Experimental sentences consisted of one main clause followed by a relative clause, i.e., the clause of interest, and were presented in a 2x2 design, with the factors *argument position* (subject-first *vs.* object-first order) and *rhythm* (irregular *vs.* regular rhythm). This resulted in sentence quadruplets, with each sentence corresponding to one of the four experimental conditions: subject-first rhythmically irregular, SFI; subject-first rhythmically regular, SFR; object-first rhythmically irregular, OFI; object-first rhythmically regular, OFR. Fillers and experimental sentences were between 17 and 19 syllables long (M = 17.1, SD = 0.36).

Rhythmic regularity was established by a constant metric pattern of one stressed syllable followed by three unstressed ones, while rhythmic irregularity was achieved through the use of proper nouns of different syllable numbers, and common nouns that varied in terms of lexical stress and the number of syllables (for illustration of these properties, see Figure 6.1). Word frequency for common nouns was counterbalanced across the rhythmically regular and irregular sentence conditions and were not significantly different, z = 0.13, $p > 0.1$.

Proper nouns		Common nouns	
masculine 2 syllables	'Jonas	2 syllables trochaic foot	'Rentner *pensioner*
feminine 2 syllables	'Jana	3 syllables trochaic foot	'Fußgänger *pedestrian*
masculine 3 syllables	Ri'cardo	2 syllables iambic foot	Pas'sant *pedestrian*
feminine 3 syllables	Lo'rena	3 syllables iambic foot	Pensio'när *pensioner*

Figure 6.1: Proper nouns and common nouns used. The ‘ sign marks stressed syllables.

The original 480 sentences were pseudo-randomized and arranged in 32 different written questionnaires to be rated by participants in terms of sentence content, according to a 7-point acceptability rating scale (1 = *unacceptable* and 7 = *highly acceptable*). Sentences with a mean rate of less than 4 points on the acceptability scale were removed from the stimulus material together with their experimental condition counterparts and matching fillers. This resulted in a total of 352 sentences (73.4% from the original sentences), i.e., 44 per condition, with corresponding fillers to be used as final stimulus material in the EEG experiment. The four experimental conditions, as well as their corresponding filler items, are presented in Figure 6.2.

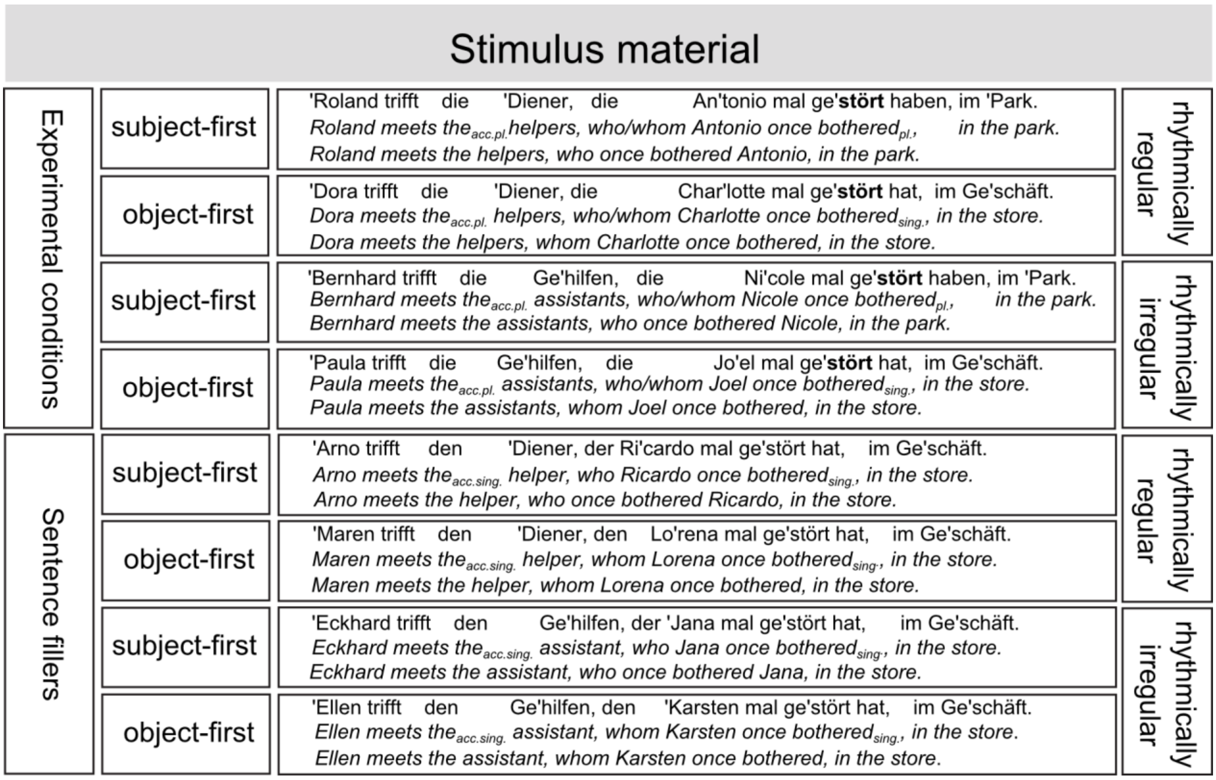

Figure 6.2: Experimental and filler sentences. The ' sign marks stressed syllables, while the critical item is marked in bold.

These 352 final sentences were spoken by a German female professional speaker at a normal speech rate and digitally recorded via a computer with a 16-bit resolution and a sampling rate of 44.1 kHz. In order to prevent participants having access to any prosodic information other than speech rhythm, such as pitch contour variations, sentences were constructed with the application of a cross-splicing procedure.

Cross-splicing. The cross-splicing procedure, i.e., the procedure of replacing an existing sound with another one, was conducted separately for each sentence quadruplet (SFI, SFR, OFI and OFR). Stimuli cross-splicing was accomplished in four steps, using the software Praat (version 5.2.13).

Subject-first rhythmically irregular (SFI) sentences from each quadruplet were chosen as “standards”; i.e., their words were used as replacements for equivalent words in the remaining experimental conditions of the quadruplet. This was the case because SFI sentences present the preferred syntactic order in German, i.e., subject-first order, and their rhythm is natural (not experimentally manipulated). Because of this, we could create a more natural stimulus material which is also closer to natural speech. In a first step, the German plural relative pronoun (“die”/*the*) from the standard sentence (SFI) replaced its equivalents in the other conditions, i.e., SFR, OFI, OFR. Second, we utilized the segment immediately after the proper noun, containing the adverb and the participle of the main verb, from the standard sentence (SFI) to replace its equivalent in the other conditions (SFR, OFI, OFR). Third, the critical item, the auxiliary verb (“haben”/ *have*), from the standard sentence (SFI) was used to replace its equivalent in its counterpart SFR sentence. Fourth, the same procedure as in step three was adopted, but this time, the auxiliary verb (hat/*has*) in the OFI sentence was used as a replacement for its equivalent in its counterpart OFR sentence. After applying the cross-splicing procedure, sentences were presented to 3 German native speakers and naïve listeners, who evaluated the naturalness of the sentences. None of the listeners reported hearing cuts, co-articulations or unnatural sounds in the sentences.

Procedures

Participants were tested individually in a sound-attenuating booth, seated in a comfortable chair and requested to move as little as possible during the experiment. Participants performed a comprehension task, evaluating if the content of an auditorily presented sentence matched the content of a subsequently presented visual sentence. Prior to the experiment, participants received a short training session with 2 blocks of 16 sentences each (2 per condition and 8 equivalent fillers).

Each trial started with a red asterisk presented on the center of a black computer screen. After 1500 ms, the red asterisk was replaced by a white one and, at the same time, a sentence was presented via loudspeakers. With the offset of the auditory sentence, participants saw a written rephrased version of the previously heard relative clause. Participants were instructed to press the response keys of a button box as quickly and accurately as possible: with the "yes"-key if the content of the auditorily and visually presented sentences matched, or the "no"-key, if this were not the case. If, after 2.5 s participants failed to press any response key, a new trial was presented. The position of the correct-response key (left or right side) was counterbalanced across participants.

Sentences were pseudo-randomized and presented in 8 blocks of about 5.5 min each. Experimental blocks contained either rhythmically regular or irregular sentences and were presented in an alternating fashion. Sentences were presented in blocks of rhythmically regular or irregular sentence context which, in case of regularity, was hypothesized to provide a reliable segmentation cue during the disambiguation of syntactic structures. All participants started with a rhythmically irregular block to prevent possible facilitation/entrainment effects that may result from exposure to rhythmic regularity. After each context block, participants were offered a break. At the end of the session, participants were briefly asked about their perception of the stimulus material used, namely if they had perceived the use of rhythmic regularity in the spoken sentences. No participant reported having perceived rhythmic regularity in any of the presented sentences.

Electrophysiological recordings. The EEG signal was recorded from 59 scalp sites by Ag/AgCl electrodes placed in an elastic cap (Electro Cap Inc, Eaton, OH, USA). Bipolar horizontal and vertical electro-occulograms (EOG) were recorded to allow for eye artifact correction. Electrodes were online re-referenced to the left mastoid and offline re-referenced to averaged left and right mastoids. Recording impedance was kept below 5kΩ. EEG and EOG signals were recorded with a sample frequency of 500 Hz, using an anti-aliasing filter of 140 Hz. Trials affected by artifacts, such as electrode drifting, amplifier blocking and muscular artifact, were excluded from analysis (M = 4.78%, SD = 6.23), while trials containing eye movements were individually corrected, using an algorithm based on saccade and blink prototypes (Croft & Barry, 2000). Trials were averaged separately per condition, i.e., SFI, OFI, SFR and OFR, and per participant (subject-average), and across all participants (grand average). Chosen epochs ranged from the onset of the critical item (i.e., the auxiliary verb and the disambiguating word; "haben"/*have* and "hat"/*has*) to 900 ms after its offset (i.e., at the onset of the visually presented sentence), and were calculated with a baseline of -200 to 0 ms. Further, all incorrectly answered trials were excluded from data analysis (M = 9.02%, SD = 10.04). For graphical display only, data were filtered off-line using a 7 Hz low pass filter.

Statistical analysis. For accuracy rates (correct *vs.* incorrect responses) a logistic regression analysis was conducted using *argument position* (subject-first *vs.* object-first order) and *rhythm* (regular vs. irregular rhythm) as predictors.

For the reaction times analysis, a repeated-measures analysis of variance (ANOVA) was conducted using the two experimental factors *argument position* and *rhythm* as within-subject factors. In addition, as rhythmically regular sentences contained, on average, significantly less syllables (M = 9.23, SD = 0.50) than their rhythmically irregular counterparts (M = 9.74, SD = 0.972), z = 5.56, $p < 0.01$, for *reaction times* analysis the *number of syllables* was used as covariate.

For the ERP data analysis, the time window ranging from 350 to 550 ms was chosen based on visual inspection and previous studies (Friederici et al., 2001, 1998; Mecklinger et al., 1995; Steinhauer et al., 1997). In these studies an earlier than the classical positivity (P600) was elicited during the processing of case ambiguous subject-object relative clauses. It has been suggested that case ambiguous sentences, i.e., subject-first *vs.* object-first order, lead to a less severe Garden Path (Friederici et al., 2001) for structural reasons (Gorrell, 2000) as well as for lower processing costs [56]. Consequently, the early latency in the positive response would result from the ease of reanalyzing a case ambiguous sentence (Friederici & Mecklinger, 1996). However, some of the previous research also reported a late positivity together with an early one (Friederici et al., 2001, 1998). The combined elicitation of two positivities may result from a more complex experimental setting, i.e. half of the sentences have to disambiguated at the final auxiliary verb (similarly to studies encountering an early positivity) and the other half at an earlier point of the sentence (noun phrase). Thus, it has been suggested that the late positivity may account for a secondary verification of structural adequacy, and more likely occurring in experimental settings containing different types of case ambiguous sentences.

Furthermore, a repeated-measures ANOVA quantifying the mean amplitude data was conducted using the two experimental factors *argument position* (subject-first *vs.* object-first order) and *rhythm* (regular *vs.* irregular rhythm), and two topographical factors *region* (anterior *vs.* posterior region) and *hemisphere (*left *vs.* right hemisphere) as within-subject factors. *Region* and *hemisphere* comprised four regions of interest (ROIs), constituted by 6 electrodes each: *left anterior* (F1, F3, F5, FC1, FC3, FC5), *right anterior* (F2, F4. F6, FC2, FC4, FC6), *left posterior* (CP1, CP3, CP5, P1, P3, P5) and *right posterior* (CP2, CP4, CP6, P2, P4, P6). To focus on main results, only significant main effects and interactions of critical factors, namely *argument position* (subject-first *vs.* object-first order) and *rhythm* (irregular *vs.* regular rhythm), are reported.

Results

Behavioral results

Accuracy rates. Overall correct response rates were above 90% (M_{SFI} = 93.95%, *SD* = 23.84, M_{OFI} = 91.25%, *SD* = 28.25, M_{SFR} = 95.12%, *SD* = 21.54 and M_{OFR} = 92.69%, *SD* = 26.02). The full logistic model was significant, indicating that the experimental factors significantly predict participants' scores (X^2 = 14.99, p < 0.001 with df = 2). The Wald criterion revealed that argument position (X^2 = 10.14, $p < 0.01$) and rhythm (X^2 = 4.88, $p < 0.05$) made a significant contribution to prediction for participants' scores (p < .001). A follow-up analysis indicates that participants had higher scores for subject-first sentences (*M* = 94.54%, *SD* = 22.72) than for object-first order (*M* = 91.97%, *SD* = 27.16) and for rhythmically regular sentences (*M* = 93.91%, *SD* = 23.99) in comparison to rhythmically irregular ones (*M* = 92.61%, *SD* = 27.16). Figure 6.3 the accuracy rates for *argument position* and *rhythm* in the comprehension task and Table 6.1 presents the logistic regression analysis of participants' accuracy rates.

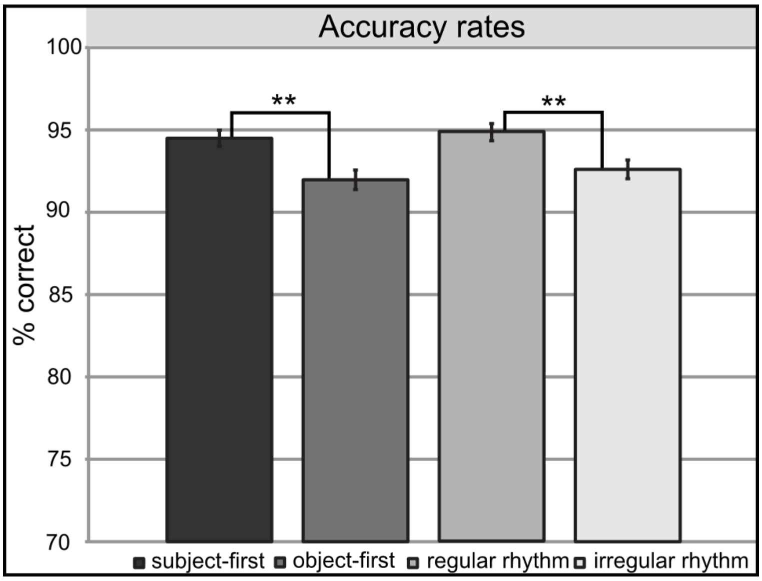

Figure 6.3: Participants' accuracy rates for argument position and rhythm. Error bars indicate standard error.

Predictor	B	*SE* β	*Wald's* X^2	*Df*	*P*	e^{β} *(odds ratio)*
Constant	-2.6869	0.1093	604.6390	1	*<0.001*	NA
Argument position (subject-first = 0, object-first order = 1)	0.3952	0.1232	10.1383	1	*0.0015*	1.4850
Rhythm (irregular = 0, regular = 1)	-0.2722	0.1241	4.8825	1	*0.0271*	0.7620
Test			X^2	*Df*	*P*	
Overall model evaluation						
Likelihood ratio test			15.2171	2	0.0005	
Score test			15.1416	2	0.0005	
Wald test			14.9871	2	0.0006	
Goodness-of-fit Test						
Hosmer & Lemeshow			0.1270	2	0.9385	
Kendall's Tau-a = 0.0170; Goodman-Kruskal Gamma = 0.1750; Somers's Dxy = 0.1320; c-statistic = 56.60%. For statistical precision, all statistics here reported use 4 decimal places. NA = not applicable.						

Table 6.1: Logistic regression analysis of participants' accuracy rates.

Reaction times. Overall participants' reaction times were faster than 1100 ms (M_{SFI} = 989.82 ms, *SD* = 487.63, M_{OFI} = 1044.86 ms, *SD* = 514.80, M_{SFR} = 907.79 ms, *SD* = 451.86 and M_{OFR} = 926.35 ms, *SD* = 446.88). Results revealed a significant main effect of *argument position,* $F(3,75) = 3.14$, $p < 0.05$, with faster responses for subject-first (*M* = 963 ms, *SD* =

472) than for object-first order (*M* = 1004 ms, *SD* = 484). Mean reaction times for subject-first and object-first sentences are presented in Figure 6.4. Contrary to what we initially expected, no significant effect of *rhythm* and no interaction between the two experimental factors were found.

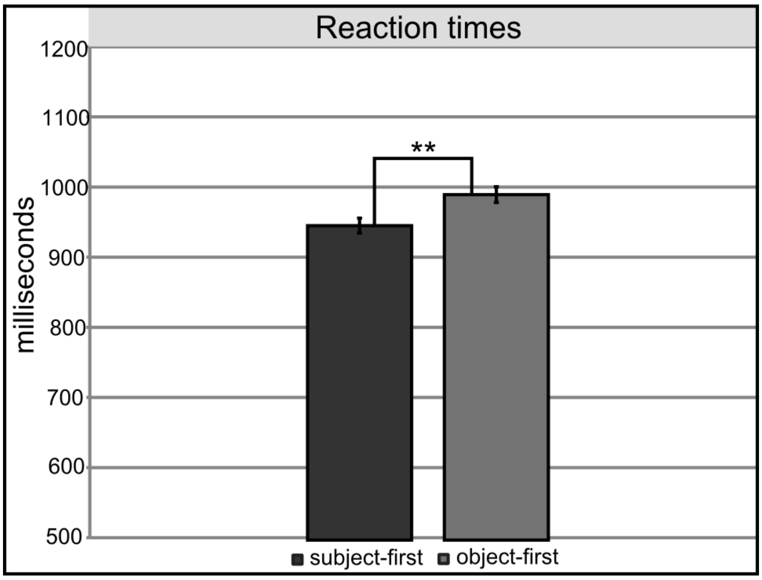

Table 6.4: Participants' reaction times for argument position. Error bars indicate standard error.

ERP data

A repeated-measures ANOVA revealed a significant interaction between *argument position* and *rhythm,* $F(1, 23) = 6.66$, $p < 0.05$. When resolving this interaction for *argument position,* a significant main effect of *rhythm* was found for object-first sentences only, $F(1, 23) = 4.36$, $p < 0.05$, with a smaller P600 mean amplitude in rhythmically regular sentences (*M* = 1.10µV, *SD* = 2.95) than in their rhythmically irregular counterparts (*M* = 2.04µV, *SD* = 2.06), corroborating our initial hypothesis. For subject-first sentences, the analysis did not yield statistically significant differences between rhythmically regular and irregular sentences, $p > 0.1$; also in line with what we initially expected. No further significant interactions or main effects for the critical factors were found. Figure 6.5 depicts ERP responses for experimental conditions in the time window of interest.

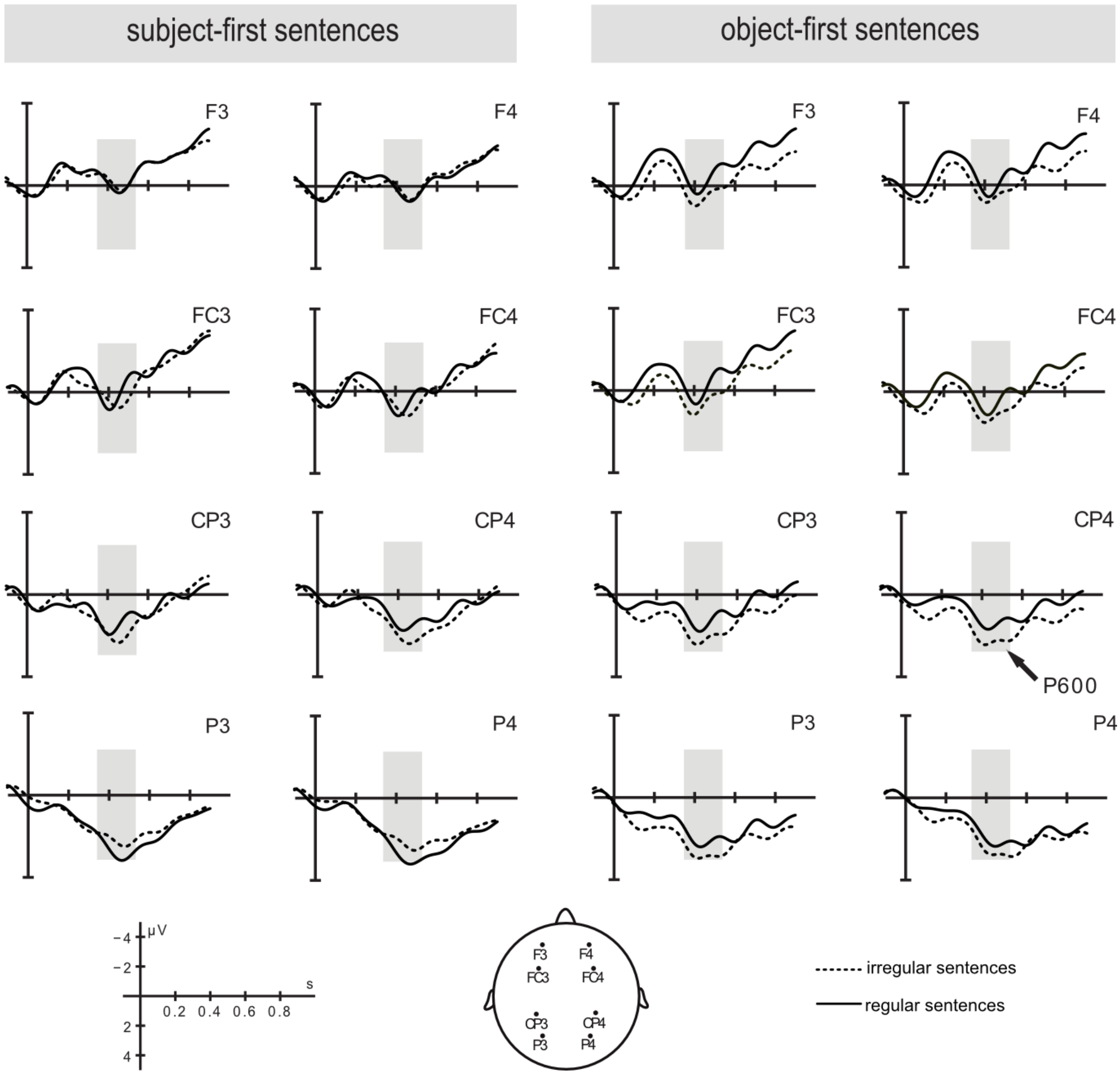

Figure 6.5: Event-related potentials elicited by the critical item for argument position in rhythmically regular and irregular contexts. Gray bars indicate the significant time window (350 – 550 ms).

Discussion

In the current work, we utilized ERPs as well as behavioral measures to investigate the impact of speech rhythm as a segmentation cue during the processing of sentential syntactic ambiguity. We presented participants with syntactically ambiguous sentences embedded in regular and irregular rhythmic contexts. By providing participants with a rhythmically regular context, we expected to see a reduction of processing costs for the less-preferred syntactic structure, i.e., object-first sentences if regular rhythm works as a sentence segmentation device.

Our results partially corroborate the proposition that regular rhythm facilitates the processing of the less-preferred syntactic structure, i.e., object-first sentences. On the one hand, behavioral results, confirm rhythmic facilitation of overall accuracy rates, but independent of sentence structure type. On the other hand, in line with our hypothesis, ERP data confirm a significant rhythmic facilitation effect for the less-preferred syntactic order only (i.e., object-first sentences). This rhythmic facilitation effect is revealed by a significantly reduced P600 mean amplitude response to object-first sentences in rhythmically regular context only. .

One possible explanation why behavioral results not to depict an interaction between rhythm and sentence structure type may be due to the fact that behavioral measures may only capture the outcome of the syntactic disambiguation, at the end of sentence processing. If an interaction of *rhythm* and *argument position* occurs as the sentence unfolds, then behavioral measures may not be sensitive enough to reveal such an interaction. In order to depict the complexity of an ongoing process (i.e., the use of rhythm as a sentence segmentation cue), online measures, such as ERPs, may be better suited for detecting the more immediate effects of rhythm. An alternative explanation for the differences between the behavioral and the ERP results could be based on participants' qualitatively different online and task specific responses. While behavioral measure may reflect the decision of whether the auditory and the visual rephrased sentence are the same, ERPs may reflect the response to the encountered ambiguity. Thus different task and non-task related aspects may be reflected in the two measures.

Yet, one may also argue that the use of a constant metric pattern does not occur naturally in spontaneous speech, and therefore our result reflects an artificial consequence of our manipulation. However, this reasoning seems unlikely, because a post-experimental debriefing revealed that participants did not perceive rhythmic regularity in any of the sentences they listened to. This suggests that even though rhythmicity was manipulated, this was done in a natural not obvious (i.e. as spoken by a metronome) fashion.

Our findings provide new evidence of how prosodic information may affect the disambiguation of syntactic structure during sentence processing. First, while previous research has focused exclusively on the role of *intonation* (Carroll & Slowiaczek, 1987; Kjelgaard & Speer, 1999; Schafer, 1997; Schafer et al., 1996; Stirling, 1996; Warren et al., 1995) on syntactic processing, this is the first study to address the temporal nature of prosody, namely *rhythm*, during the disambiguation of syntactic structures. Second, previous research has investigated the role of intonation, i.e., prosodic breaks, as a local cue which may be used to facilitate syntactic processing (Bögels et al., 2009; Kerkhofs et al., 2007; Steinhauer et al., 1999). Here, we addressed the role of rhythm during ongoing sentence processing, that is even before encountering syntactic ambiguity. Hence we investigated a broader scope of how rhythm operates as a segmentation cue during online sentence processing.

Our work is consistent with the idea of an existing prosodic representation available already in early stages of language processing, which interacts with the syntactic parser, guiding it through the processing of syntactic constituents (Kennedy et al., 1989; Kjelgaard & Speer, 1999; Murray et al., 1998; Schafer, 1997; Speer et al., 1996). Further, our work is based on the idea that prosodic units, in our case rhythmic groups, constitute perceptual units (Martin, 1967; Morgan, 1996; Tyler & Warren, 1987), which in turn operate as processing units (Carroll & Slowiaczek, 1987; Slowiaczek, 1981), reducing the memory load and facilitating language processing (Kennedy et al., 1989; Murray et al., 1998; Schafer, 1997). Thus, in the current work, we provided participants with a prosodic representations based on rhythmic regularity, which created a reliable segmentation context for the unfolding sentence, reducing the processing costs of the less-preferred syntactic structure, i.e., object-first sentences.

The importance of rhythm for speech segmentation in first language acquisition has already been shown. Studies conducted with preverbal infants reveal that infants rely on rhythmic information from their native language in order to segment speech and encode their first words (Höhle et al., 2009; Nazzi & Ramus, 2003; Ramus, 2002). During this process, they appear to refine their ability to discriminate rhythmic information in their native language (Jusczyk, 1999, 2002), encoding rhythm as phonological information (Gerken, 1996).

Once encoded, rhythm helps the listener to organize sounds and pauses in spoken language in form of a prosodic hierarchy that helps to structure an utterance at several levels and various points in time (Nespor & Vogel, 1986). Thus, rhythm organizes sounds and pauses in the speech flow into words that can be grouped together in a clitic group (a group of grammatical words presenting one common primary stress only). Clitic groups, in turn, can be combined to create phonological phrases (i.e., clusters of clitic groups), which can be integrated into intonational phrases (a linguistic segment with one complete intonational contour, (Hayes, 1989)).

Our results are in line with previous studies suggesting that prosodic units may act as processing units, guiding the syntactic parser through the speech stream (Carroll & Slowiaczek, 1987; Kjelgaard & Speer, 1999). Our research corroborates previous findings revealing that prosody, in our case rhythm, facilitates information processing when larger information chunks are provided (Bor, Duncan, Wiseman, & Owen, 2003; Carpenter & Just, 1989). Thus, keeping all sentential cues constant (i.e., phonological, semantic, syntactic, pragmatic and intonational) rhythm may become a salient segmentation cue, which, in turn, may increase efficiency in sentence processing. Hence, rhythm is used to guide the syntactic parser through the processing of larger information units.

One could also argue that rhythm operates as a sentence segmentation cue regardless of which syntactic structure is being processed. However, its benefit may only become apparent when syntactic difficulty increases. Therefore, future studies should investigate the role of rhythm in a broader range of syntactic complexities during sentence processing.

In this sense, the two prosodic facets, i.e., *intonation* and *rhythm*, help to facilitate syntactic processing though in a different manner. On the one hand, *intonation* may provide complementary information to be integrated by the syntactic parser when syntactic ambiguity occurs, and thus facilitates processing (Bögels et al., 2009; Kjelgaard & Speer, 1999; Marslen-Wilson et al., 1992; Steinhauer et al., 1999; Warren et al., 1995). On the other hand, as our study reveals, *rhythmic* regularity may already impact sentence segmentation prior to ambiguity resolution, thus facilitating information processing, and consequently reducing the overall processing costs for syntactically ambiguous sentences. Our results provide evidence of the early and continuous use of rhythm by the syntactic parser. This evidence is consistent with language processing models assuming an interactive and incremental use of linguistic information during sentence processing (Carroll & Slowiaczek, 1987; Kennedy et al., 1989; Kjelgaard & Speer, 1999; Murray et al., 1998; Schafer, 1997; Slowiaczek, 1981; Speer et al., 1996).

In view of these results, some questions remain. Is facilitation by means of rhythmic regularity a language-dependent or language-independent phenomenon? Some studies have shown that the perception of speech rhythm and its use as a word segmentation cue is language dependent (Cutler, 1994a, 1994b; Mattys, Jusczyk, Luce, & Morgan, 1999). Other studies investigating the cognitive ability of listeners have provided evidence that rhythm in its function of grouping elements together facilitates syllable and word recall independent of the rhythmic class of a language (Boucher, 2006; Henson, Burgess, & Frith, 2000; Hitch, 1996). Therefore, even though rhythm as a device to segment the speech stream may be language specific, perhaps its use beyond the word level, i.e. when grouping words together, may not be.

If the use of rhythm in grouping organizing the speech stream is a universal and language-independent property, second language (L2) learners may also use rhythmic regularity in the L2 to facilitate syntactic processing. Thus, further investigations regarding the perception and the use of rhythmic regularity as a sentence segmentation cue in the context of L2 processing are called for. Such investigations should shed more light on the perception and use of rhythm in a broader sense, i.e., beyond the level of word segmentation, as a potential cross-linguistic or language-dependent phenomenon.

Conclusion

In the current work we investigated the role of rhythm as a sentence segmentation cue during the disambiguation of syntactic structures. Rhythmic regularity was achieved by the use of a constant metric pattern of three unstressed syllables between two stressed ones. Accuracy rates suggest that rhythmic regularity facilitates overall sentence comprehension. ERP results indicate a reduction of the P600 mean amplitude in response to the less-preferred syntactic structure, i.e., object-first sentences, in rhythmically regular context only. Our results suggest that rhythm may be used as a reliable sentence segmentation cue, facilitating the processing of non-preferred syntactic structures, i.e., object-first sentences, and improving sentence comprehension.

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Chapter 7

On the Impact of L2 Speech Rhythm on Syntactic Ambiguity Resolution

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Abstract

In an event-related potential (ERP) study we investigated the role of age of acquisition (AoA) on the use of second language rhythmic properties during syntactic ambiguity resolution. Syntactically ambiguous sentences embedded in rhythmically regular and irregular contexts were presented to Turkish early and late second language (L2) learners of German and to German monolingual controls. Regarding rhythmic properties, Turkish is syllable-timed and prefers the iamb as its metric foot, while German is stress-timed, relying on the trochee. To utilize rhythm during the processing of syntactic ambiguity in L2, Turkish early and late L2 learners of German must master different rhythmic properties than in their first language. ERPs reveal a reduction in the P600 response to object-first sentences presented in rhythmically regular, but not in rhythmically irregular contexts for early learners and monolinguals only. No such effect was found for late L2 learners. Results indicate an interactive use of rhythmic information during the processing of syntactic ambiguity by monolinguals and early learners. Further, data from late L2 learners suggest that the acquisition of rhythmic properties may have to occur in a sensitive learning period.

Keywords: Speech rhythm, syntactic ambiguity, L2, AoA, P600

Introduction

Age of acquisition (AoA) and its constraints on second language (L2) learning have been the focus of many studies in the L2 literature (Flege, Yeni-Komshian, & Liu, 1999; Scovel, 2000). It has been suggested that the impact of AoA on L2 outcome varies according to the language domain involved (Birdsong, 2006; Clahsen & Felser, 2006).

In the lexical and semantic domains, for instance, L2 learners often show similar performance as native speakers (Hahne & Friederici, 2001; Hernandez & Li, 2007; Ojima et al., 2005; Sanders & Neville, 2003; Wartenburger et al., 2003). Similarly, comparable morphosyntactic processing of subject–verb (Ojima et al., 2005) and gender agreement (Sabourin & Haverkort, 2003) has been reported for L2 learners and native speakers. On the other hand, complex syntactic structures tend to be processed less efficiently by late L2 learners even with increase in L2 exposure and proficiency (Clahsen & Felser, 2006; Felser & Roberts, 2007; Love et al., 2003; Marinis et al., 2005; Papadopoulou & Clahsen, 2003).

Even though a great amount of research has been conducted investigating L2 outcome in various linguistic domains, such as morphosyntax and semantics, little is known about the acquisition of suprasegmental information in L2 (Chun, 2002; Rasier & Hiligsmann, 2007; Trofimovich & Baker, 2006). Suprasegmentals comprise intonation, i.e. pitch variation across the utterance (Hart, Collier, & Cohen, 1990), and rhythm, i.e. the temporal organization of sounds and pauses in the speech stream (Nooteboom, 1997). In L2 research, the impact of age on the acquisition of suprasegmentals has been addressed in terms of speech rate (Guion et al., 2000), global foreign accent (Flege et al., 1999; Neufeld, 1978; Piske, MacKay, & Flege, 2001a; Scovel, 1969), and frequency in pitch accents (Huang & Jun, 2011).

Regarding the importance of AoA in the acquisition of L2 language rhythmic properties, studies have mostly focused on the use of word segmentation strategies and stress perception among L2 learners (Cutler, 1994b, 2000, 2002; Cutler et al., 1992; Field, 2003; Goetry & Kolinsky, 2000; Guion et al., 2004; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Schmidt-Kassow, Rothermich, et al., 2011).

Accordingly, early L2 learners seem to not rely on L2 rhythmic information in word segmentation (Cutler et al., 1986; Otake et al., 1993) and late learners may detect stress violation differently than native speakers (Schmidt-Kassow, Rothermich, et al., 2011). However, other studies suggest that late L2 learners are sensitive to and may learn L2 rhythmic information, i.e. stress (Field, 2003; Goetry and Kolinsky, 2000; Guion et al., 2004; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Trofimovich and Baker, 2006). It is, however, entirely possible that despite being able to use a rhythmic segmentation strategy in one language only, L2 learners may still be sensitive to rhythmic information of a second language to some degree when acquiring it (see Goetry and Kolinsky, 2000). So far, L2 studies focusing only on speech rhythm using sentences have mainly focused on word segmentation and stress perception at the word level, leaving the role of rhythm as a sentence segmentation device rather understudied (for addressing some aspect of rhythmic information in L2, please see Guion et al., 2004; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Schmidt-Kassow, Rothermich, et al., 2011; Trofimovich and Baker, 2006).

It has been suggested that language-specific phonological rules operate in lower prosodic domains, such as the domain of the phonological word where language metric preference is assigned. Higher prosodic domains, on the other hand, may be operated by language universal rules (Nespor and Vogel, 1986), such as a rising pitch marking the beginning of an event group or a pre-boundary lengthening that offsets another (Vaissière, 1983). Therefore, the use of speech rhythm in higher and more complex prosodic domains, e.g. the intonational phrase level, could be less subject to language-specific rhythmic properties than word-internal prosody.

Beyond the word level, rhythm continues to structure speech by grouping words into larger prosodic constituents in a hierarchical fashion (Hayes, 1989; Inkelas, 1990; Nespor & Vogel, 1986; Selkirk, 1980). Prosodic constituents may operate as units of speech perception (R. E. Johnson, 1970; Jusczyk et al., 1992; Morgan, 1996; Tyler & Warren, 1987), cueing the syntactic parser through sentence segmentation.

These perception units may constitute syntactic ‘chunks’, which remain unattached until enough syntactic information is gathered and the correct syntactic analysis is undertaken. Using syntactic chunks as processing units may be of great advantage for the syntactic parser, as they may reduce memory load and the risk of a possibly incorrect syntactic analysis (see Watt and Murray, 1996).

Moreover, previous studies addressing speech rhythm in L2 context made use of behavioral measures, such as accuracy rates and reaction times (Cutler et al., 1992; Field, 2003; Guion et al., 2004; Otake et al., 1993). Behavioral measures only reflect the outcome of a linguistic process, disregarding its dynamic and unfolding nature. In the current study we investigated the impact of rhythm on L2 using event-related potentials (ERPs). ERPs provide a great advantage when investigating ongoing language processing, because of their sensitivity to capture the precise time course of unfolding linguistic processes (Handy, 2004) prior to full comprehension.

ERPs studies investigating the role of speech rhythm during sentence processing have primarily focused on the perception of word stress (Schmidt-Kassow and Kotz, 2008; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011; Schmidt-Kassow, Rothermich, et al., 2011). For exceptions, please see Roncaglia-Denissen et al., 2013). The current work aims to investigate speech rhythm in its potential function as a sentence segmentation device in L2 syntactic processing.

Consistent with interactive processing models, our work predicts an incremental use of linguistic information, in this case speech rhythm, during early stages of language processing (Kjelgaard & Speer, 1999; Marslen-Wilson et al., 1992; Schafer, 1997; Speer et al., 1996). Because speech rhythm may interact with (Hayes, 1989; Nespor and Vogel, 1986) and guide the syntactic parser while the utterance unfolds (Kjelgaard and Speer, 1999; Schafer, 1997; Speer et al., 1996), ERPs therefore present a very suitable method for the current investigation.

To address the interaction between rhythm and the syntactic parser in L2, we used the same stimulus material as in a recent study, i.e. case-ambiguous sentences with either a regular or irregular rhythmic pattern (Roncaglia-Denissen et al., 2013; for details on the stimulus material, please see Section II). Studies investigating case-ambiguous sentence in German report an enlarged P600 elicited by object-first in comparison to subject-first order, which has been linked to higher processing costs and syntactic reanalysis (Friederici & Mecklinger, 1996; Friederici et al., 2001, 1998; Mecklinger et al., 1995; Roncaglia-Denissen, Schmidt-Kassow, & Kotz, 2013; Steinhauer et al., 1997).

The current study addresses two main issues. First, whether L2 learners can use rhythmic information in their second language to facilitate syntactic processing. Second, whether the use of rhythmic properties in L2 as a sentence segmentation cue is subject to L2 age of acquisition (AoA). To address these issues, Turkish early and late learners of German were tested. To control for individual differences that may impact performance, participants were tested on a number of cognitive measures including phonological memory and working memory capacities (for further details on the chosen measures, please see Section II).

Turkish and German were chosen as language pair for this investigation because of their rhythmic properties. German is considered a stress-timed language relying on the metric foot, i.e. one stress syllable dominating at least one relatively weaker one, as its primary unit of speech organization and segmentation. Turkish, on the other hand, is considered a syllable-timed language, using the syllable, regardless of stress, as its main speech organization unit (Inkelas & Orgun, 2003; Yavaş; & Topbaş, 2004). As German and Turkish present lexical stress, native speakers of both languages should perceive stress variation. However, while German prefers the trochee as word-internal prosody, i.e. a sequence of a stressed syllable followed by an unstressed one, Turkish relies on the opposite metric preference, i.e. unstressed syllable followed by a stressed one; the iamb (Eisenberg, 1991; Féry, 1997; Inkelas & Orgun, 2003; Slobin, 1986).

Hence, if Turkish L2 learners of German make use of rhythmic information in L2 during language processing, a rhythmic facilitation effect is expected in response to objectfirst sentences embedded in a rhythmically regular pattern in comparison to rhythmically irregular ones.

Under the assumption that object-first sentences are less preferred and their processing costs more effortful than of subject-first sentences (Friederici & Mecklinger, 1996; Gorrell, 2000), rhythmic regularity may particularly affect the parsing of the first rather than the second sentence type (De Bot et al., 2007; McClelland, 1987). Such facilitation should translate into faster reaction times and higher accuracy rates in response to object-first rhythmically regular sentences than to their rhythmically irregular counterparts. Furthermore, a facilitation effect should also lead to a P600 amplitude reduction in response to object-first sentences in a rhythmically regular sentence context (RoncagliaDenissen, et al., 2013).

Methods

Participants

Forty-five right-handed participants (24 females) were tested in two different sessions, i.e. a cognitive pre-test session, to assess participants' phonological and working memory capacities, and a session of electroencephalography (EEG). Participants were divided in three experimental groups, i.e. 15 Turkish early L2 learners of German (8 females, M_{age} = 26.93, SD = 4.41, mean age of L2 first exposure, AoL2FE = 1), 15 Turkish late L2 learners of German (8 females, M_{age} = 28.93, SD = 3.51, M_{AoL2FE} = 18.66, SD = 6.01) and 15 German monolingual controls (8 females, M_{age} = 25.60, SD = 1.99). Participants were either university students or had recently graduated and were paid for their participation. None of the participants reported any neurological impairment or hearing deficit and all had normal or corrected-to-normal vision. This study was approved by the ethics committee of the University of Leipzig and all participants gave written informed consent for data collection, use, and publication.

Material

Cognitive pre-test session. To assess and control for potential individual differences in cognitive abilities, which may affect subjects' performance in language processing (Just & Carpenter, 1992), we tested participants' phonological memory and working memory capacities.

Phonological memory capacity, i.e., the ability to store familiar and novel sounds (Baddeley, 1986; Baddeley, Gathercole, & Papagno, 1998), has been associated with L2 vocabulary learning (Cheung, 1996; Dufva & Voeten, 1999), L2 oral performance (O'Brien, Segalowitz, Freed, & Collentine, 2007) and L2 grammar learning (French & O'Brien, 2008). Participants' phonological memory was assessed using the Mottier test (1951), a non-word repetition task, consisting of sets with 6 non-words, ranging from 2-6 syllables each. The stimulus material consisted of non-words with the syllabic structure of a consonant followed by a vowel (CV) and was spoken by a female professional speaker.

Working memory (WM) capacity regards ability to maintain information active while cognitive processes are being executed (Baddeley, 2003; Conway et al., 2005) and has been associated with individuals' general intelligence (Conway et al., 2005; Daneman & Carpenter, 1980; Engle, Tuholski, Laughlin, & Conway, 1999; Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000; Unsworth & Engle, 2007). To assess participants' working memory capacity, we utilized the reading span (Daneman & Carpenter, 1980; Friederici et al., 1998; Vos et al., 2001). This task consisted of 88 unrelated sentences, divided in 5 sets with 2-5 sentences each and 3 sets containing 6 sentences to be read aloud by participants.

Furthermore, early and late L2 learners were given a language history questionnaire concerning both their first (L1) and second language (L2). With this questionnaire, we assessed language competence, such as listening, writing, reading and speaking skills, age of first exposure to both languages, situations in which each language was acquired, and current language use. Self-reported language questionnaires have been successfully used to assess L1 and L2 acquisition history and skills (Elston-Güttler, Paulmann, & Kotz, 2005; Marian, Blumenfeld, & Kaushanskaya, 2007; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011) and are a good indicative of language ability (Marian et al., 2007; Ross, 1998; Shameem, 1998). Based on participants' reading and listening skills, i.e., relevant skills for the current study, as well as on their own perception of language preference (Marian et al., 2007), German was regarded as L2 in both groups.

EEG session. The stimulus material is the same used in previous study conducted with German monolinguals (Roncaglia-Denissen et al., 2013). It consisted of 352 sentences, being half of the sentences experimental items (176 sentences), while the other half were filler sentences. Experimental sentences contained one main clause followed by a relative clause, i.e., the clause of interest, and presented a 2x2 design, with the factors *rhythm* (irregular *vs.* regular rhythm), and *argument position* (subject-first *vs.* object-first order). This resulted in sentence quadruplets, with each sentence corresponding to one of the four experimental conditions: subject-first rhythmically irregular (SFI), subject-first rhythmically regular (SFR), object-first rhythmically irregular (OFI), object-first rhythmically regular (OFR). Fillers and experimental sentences were between 17 and 19 syllables long (*M* = 17.1, *SD* = 0.36). Exemplary items for the four experimental conditions as well as for their corresponding fillers are presented in Figure 7.1.

Stimulus material			
Experimental conditions	subject-first	'Roland trifft die 'Diener, die An'tonio mal ge'**stört** haben, im 'Park. *Roland meets the*$_{acc.pl.}$ *helpers, who/whom Antonio once bothered*$_{pl.}$*, in the park.* *Roland meets the helpers, who once bothered Antonio, in the park.*	rhythmically regular
	object-first	'Dora trifft die 'Diener, die Char'lotte mal ge'**stört** hat, im Ge'schäft. *Dora meets the*$_{acc.pl.}$ *helpers, who/whom Charlotte once bothered*$_{sing.}$*, in the store.* *Dora meets the helpers, whom Charlotte once bothered, in the store.*	
	subject-first	'Bernhard trifft die Ge'hilfen, die Ni'cole mal ge'**stört** haben, im 'Park. *Bernhard meets the*$_{acc.pl.}$ *assistants, who/whom Nicole once bothered*$_{pl.}$*, in the park.* *Bernhard meets the assistants, who once bothered Nicole, in the park.*	rhythmically irregular
	object-first	'Paula trifft die Ge'hilfen, die Jo'el mal ge'**stört** hat, im Ge'schäft. *Paula meets the*$_{acc.pl.}$ *assistants, who/whom Joel once bothered*$_{sing.}$*, in the store.* *Paula meets the assistants, whom Joel once bothered, in the store.*	
Sentence fillers	subject-first	'Arno trifft den 'Diener, der Ri'cardo mal ge'stört hat, im Ge'schäft. *Arno meets the*$_{acc.sing.}$ *helper, who Ricardo once bothered*$_{sing.}$*, in the store.* *Arno meets the helper, who once bothered Ricardo, in the store.*	rhythmically regular
	object-first	'Maren trifft den 'Diener, den Lo'rena mal ge'stört hat, im Ge'schäft. *Maren meets the*$_{acc.sing.}$ *helper, whom Lorena once bothered*$_{sing.}$*, in the store.* *Maren meets the helper, whom Lorena once bothered, in the store.*	
	subject-first	'Eckhard trifft den Ge'hilfen, der 'Jana mal ge'stört hat, im Ge'schäft. *Eckhard meets the*$_{acc.sing.}$ *assistant, who Jana once bothered*$_{sing.}$*, in the store.* *Eckhard meets the assistant, who once bothered Jana, in the store.*	rhythmically irregular
	object-first	'Ellen trifft den Ge'hilfen, den 'Karsten mal ge'stört hat, im Ge'schäft. *Ellen meets the*$_{acc.sing.}$ *assistant, whom Karsten once bothered*$_{sing.}$*, in the store.* *Ellen meets the assistant, whom Karsten once bothered, in the store.*	

Figure 7.1: Exemplary experimental and filler sentences.

Rhythmic regularity was established by a constant metric pattern of one stressed syllable followed by three unstressed ones. Rhythmic irregularity was achieved through the use of proper nouns of different syllable length and common nouns varying in terms of lexical stress and the number of syllables. Word frequency for common nouns was counterbalanced across the rhythmically regular and irregular sentence conditions and no statistically significant differences were found, z = 0.13, $p > 0.1$.

The selected stimulus material was spoken by a German female professional speaker at a normal speech rate and digitally recorded with a 16-bit resolution and a sampling rate of 44.1 kHz. To ensure that participants only listen to speech rhythm rather than other prosodic cues such as pitch variation, spoken sentences underwent a careful crosssplicing procedure. In this procedure, existing sounds are replaced by other ones using the software Praat (version 5.2.13). Words from subject-first rhythmically irregular sentences were chosen as 'standards' to replace their equivalents in sentences from other conditions, i.e. subject-first rhythmically regular, object-first rhythmically irregular and object-first rhythmically regular conditions. In a first step, the plural relative pronoun *die* ('the') from the standard sentence replaced its equivalents in the other conditions. Second, the segment immediately after the proper noun, i.e. the adverb and the participle of the main verb, from the standard sentence replaced its equivalent in the other conditions. In the third step, the auxiliary verb *haben* ('have') (the critical item), from subjectfirst and object-first irregular sentences were used to replace their equivalent in the rhythmically regular counterpart conditions (for more details on the cross-splicing procedure, please see Roncaglia-Denissen et al., 2013).

Procedure

Cognitive pre-test session. Participants were tested individually and received written instructions for each task on separate instruction sheets. Practice trials were provided for each task and participants were allowed to repeat them until the respective task was fully understood. At the end of the session, which last approximately half an hour, participants from the two L2 learners groups were given a history language questionnaire, which took between 25-40 minutes to be completed. For these participants the cognitive session lasted approximately one hour. The order of phonological and working memory tests was counter-balanced across participants.

In the Mottier test, participants heard the first non-word via headphones at the same time as a visual cue was presented in the center of the computer screen. Participants were instructed to repeat it as accurately and as fast as possible. After the repetition, the next non-word was presented and the same procedure was adopted until the end of the word set, when participants were given a short break. The test was terminated when participants failed to recall a minimum of 4 items of a set correctly.

In the reading span participants were presented with cards containing one sentence each and were instructed to read it aloud at their own pace, memorizing the last word of each sentence. As soon as the participant finished reading the sentence, another card was placed on top of it and the same procedure was adopted until a blank card signaled the end of the set, when participants were asked to recall the last word of each sentence they memorized. The test was terminated when participants failed to recall three (from the 5 sets containing 2-5 sentences) or two (from the 3 sets with six sentences) final word set correctly.

EEG session. Participants performed a comprehension task, evaluating whether the content of an auditorily presented sentence matched the content of a subsequently presented visual sentence. Prior to the experiment, participants received a short training session with 2 blocks of 16 sentences each (2 per condition and 8 filler sentences).

Each trial started with a red visual cue presented in the center of a black computer screen. 1500 milliseconds after the onset of the red visual cue, this was replaced by a white one and, at the same time, a sentence was presented via loudspeakers. With the offset of the auditory sentence, participants saw a written rephrased version of the previously heard relative clause. Participants were instructed to press, as quickly and accurately as possible, the "yes"-key if the content of the auditorily and visually presented sentences matched, or the “no”-key, if this were not the case. The position of the correct-response key (left or right side) was counterbalanced across participants.

Sentences were pseudo-randomized and presented in 8 blocks of about 5.5 min each. Experimental blocks contained either rhythmically regular or irregular sentences and were presented in an alternating fashion. Sentences were presented using a block-design in order to provide participants with a rhythmic context. All participants started with a rhythmically irregular block to prevent any possible facilitation or entrainment effects of rhythmic regularity on the processing of rhythmically irregular sentences. After each block, participants were offered a break. At the end of the session, participants were asked about their perception of the stimulus material, i.e., if they had perceived rhythmic regularity in any of the spoken sentences. No participant reported perceiving rhythmic regularity in any of the presented sentences or blocks.

Electrophysiological recordings. The EEG signal was recorded from 59 scalp sites by Ag/AgCl electrodes placed in an elastic cap. Bipolar horizontal and vertical electro-occulograms (EOG) were recorded to allow for eye artifact correction. Electrodes were online referenced to the left mastoid, and offline re-referenced to linked mastoids. Recording impedance was kept below 5kΩ. EEG and EOG signals were recorded with a sample frequency of 500 Hz, using an anti-aliasing filter of 140Hz. Trials affected by artifacts, such as electrode drifting, amplifier blocking and muscular artifact, were excluded from analysis (M = 4.88%, SD = 5.94). Trials containing eye movements were individually corrected, using an algorithm based on saccades and blinks prototypes (Croft & Barry, 2000).

Trials were averaged separately per condition, i.e., SFI, SFR, OFI, OFR, and participant (subject-average). Finally, a trial average was created across participants in each group (grand average). Chosen epochs ranged from the onset of the critical item (i.e., the auxiliary verb and the disambiguating word “haben”/*have* and “hat”/*has*) up to 900 ms after its offset (i.e., at the onset of the visually presented sentence), and were calculated with a baseline of -200 to 0 ms. Incorrectly answered trials were excluded from data analysis (*M* = 20.28%, *SD* = 15.68). For graphical display only, data were filtered offline using a 7 Hz low pass filter.

Statistical analysis. For accuracy rates and reaction times in the EEG session an analysis of covariance (ANCOVA) was conducted using *argument position* (subject-first *vs.* object-first relative clause) and *rhythm* (regular *vs*. irregular rhythm) as within-subject factors. *Group* (i.e., Turkish early and late L2 learners and monolingual controls) was entered as a between-subjects factor, while participants' scores in the cognitive measures and self-reported reading and listening skills in German were used as covariates. As rhythmically regular sentences contained, on average, significantly less syllables (M = 9.23, SD = 0.50) than their rhythmically irregular counterparts (M = 9.74, SD = 0.972), z = 5.56, $p < 0.01$, for the dependent variable *reaction times, number of syllables* was also used as a covariate.

For the EEG data analysis, based on visual inspection of the monolingual data only, a time window ranging from 100 to 200 ms was selected. Further, a time window ranging from 350 to 550 ms was chosen based on visual inspection and on previous ERP studies (Friederici et al., 2001, 1998; Mecklinger et al., 1995; Roncaglia-Denissen et al., 2013; Steinhauer et al., 1997). In these studies a positivity with an earlier latency than the classical P600 was elicited during the processing of case ambiguous subject-object relative clauses. This early latency would result from the ease with which case ambiguous sentence would be reanalyzed (Friederici & Mecklinger, 1996), due to structural reasons (Gorrell, 1996, 2000) and lower processing costs (Friederici & Mecklinger, 1996; Friederici et al., 2001).

For each time window (100-200 ms and 350-550 ms) an ANCOVA was conducted for the mean amplitude response wave, with *argument position* (subject-first *vs.* object-first relative clause) and *rhythm* (regular *vs.* irregular rhythm) as within-participants factors. Together with the experimental factors, two topographical factors, i.e., *region* (anterior *vs.* posterior region) and *hemisphere* (left *vs.* right hemisphere) were used as within-participants factors. *Region* and *hemisphere* comprised four regions of interest (ROIs), constituted by 6 electrodes each: *left anterior* (F1, F3, F5, FC1, FC3, FC5), *right anterior* (F2, F4. F6, FC2, FC4, FC6), *left posterior* (CP1, CP3, CP5, P1, P3, P5) and *right posterior* (CP2, CP4, CP6, P2, P4, P6). Additionally, *group* (German monolinguals, early and late L2 learners) was entered as a between-participants factor while participants' score in the cognitive measures and self-reported German reading and listening skills were used as covariates. Only significant main effects and interactions of critical factors are reported.

Results

Cognitive pre-test session

Descriptive statistics. No difference between groups were found for participants' cognitive abilities, i.e. phonological and working memory capacities; *p*s > 0.1. Participants' scores and results of statistical comparison between groups for the Mottier test and the reading span are shown in Table 7.1.

Tasks	German monolingual controls (GMC)		Turkish-German early L2 learners (TELG)		Turkish-German late L2 learners (TLLG)	
	M	SD	M	SD	M	SD
Mottier test	27.33	2.63	26.53	4.29	26.86	5.80
Reading span	3.89	1.15	3.29	0.65	3.28	1.05

Table 7.1: Participants' scores for the Mottier test and for the reading span.

Turkish early and late learners of German differed statistically regarding their German listening ($U = 157.50$, $p < 0.001$) as well as reading skills ($U = 135.00$, $p < 0.001$), with early learners showing higher self-reported scores than late learners. Early and late learners' scores for L2 reading and listening skills are presented in Table 7.2.

L2 skill	Turkish early L2 learners of German		Turkish L2 late learners of German	
	M	*SD*	*M*	*SD*
Reading (%)	98.00	4.14	83.34	8.89
Listening (%)	100.00	0	88.00	8.61

Table 7.2: L2 language skills for Turkish early and late L2 learners of German.

EEG session

Accuracy rates. Overall mean correct response rates were above 75% in all conditions (M_{SFI} = 83.87%, *SD* = 36.78, M_{SFR} = 84.07%, *SD* = 36.60, M_{OFI} = 76.38%, *SD* = 42.48, M_{OFR} = 76.22%, *SD* = 42.58). The conducted ANCOVA revealed a significant interaction of *argument position* and *group*, $F(2, 39) = 6.02$, $p < 0.01$. When groups were analyzed separately, a significant main effect of *argument position* was found for German monolinguals, $F(1, 14) = 8.58$, $p < 0.05$, with participants making less errors in response to subject-first (*M* = 91.24%, *SD* = 28.27) than to object-first sentences (*M* = 87.04%, *SD* = 33.59). Similarly, a significant main effect of *argument position* was found for early L2 learners, $F(1, 14) = 22.70$, $p < 0.001$, with higher accuracy rates for subject-first (*M* = 90.12%, *SD* = 29.84) than for object-first sentences (*M* = 74.31%, *SD* = 43.70). No significant main effect of *argument position* was found for late L2 learners ($p > 0.10$). Accuracy rates for each group are depicted in Figure 7.2.

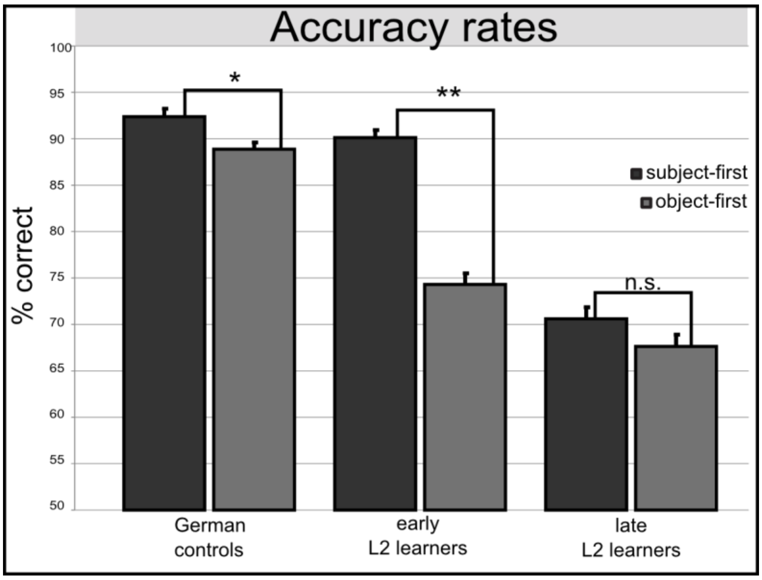

Figure 7.2: Participants' accuracy rates for argument position. Error bars indicate standard error.

Reaction times. No main effect or interactions were found for reaction times (all p > 0.1).

ERP data. Despite our first impression of a possible significant effect in the 100-200 ms time window based on visual inspection of the monolingual data, no significant effect or interactions were found (all $p > .05$).

For the 350-550 ms time window, the repeated-measures ANCOVA revealed a five-way interaction *argument position*rhythm*hemisphere*region*group*, $F(2, 39) = 4.27$, $p = 0.021$. Follow-up analysis revealed a four-way interaction of *argument position*rhythm*hemisphere*region* in monolingual controls, $F(1, 14) = 12.63$, $p < 0.01$, as well as in early L2 learners, $F(1, 14) = 10.43$, $p < 0.01$. No four-way interaction was found in late L2 learners, $p > 0.10$. ERP responses for late learners are illustrated in Figure 7.3.

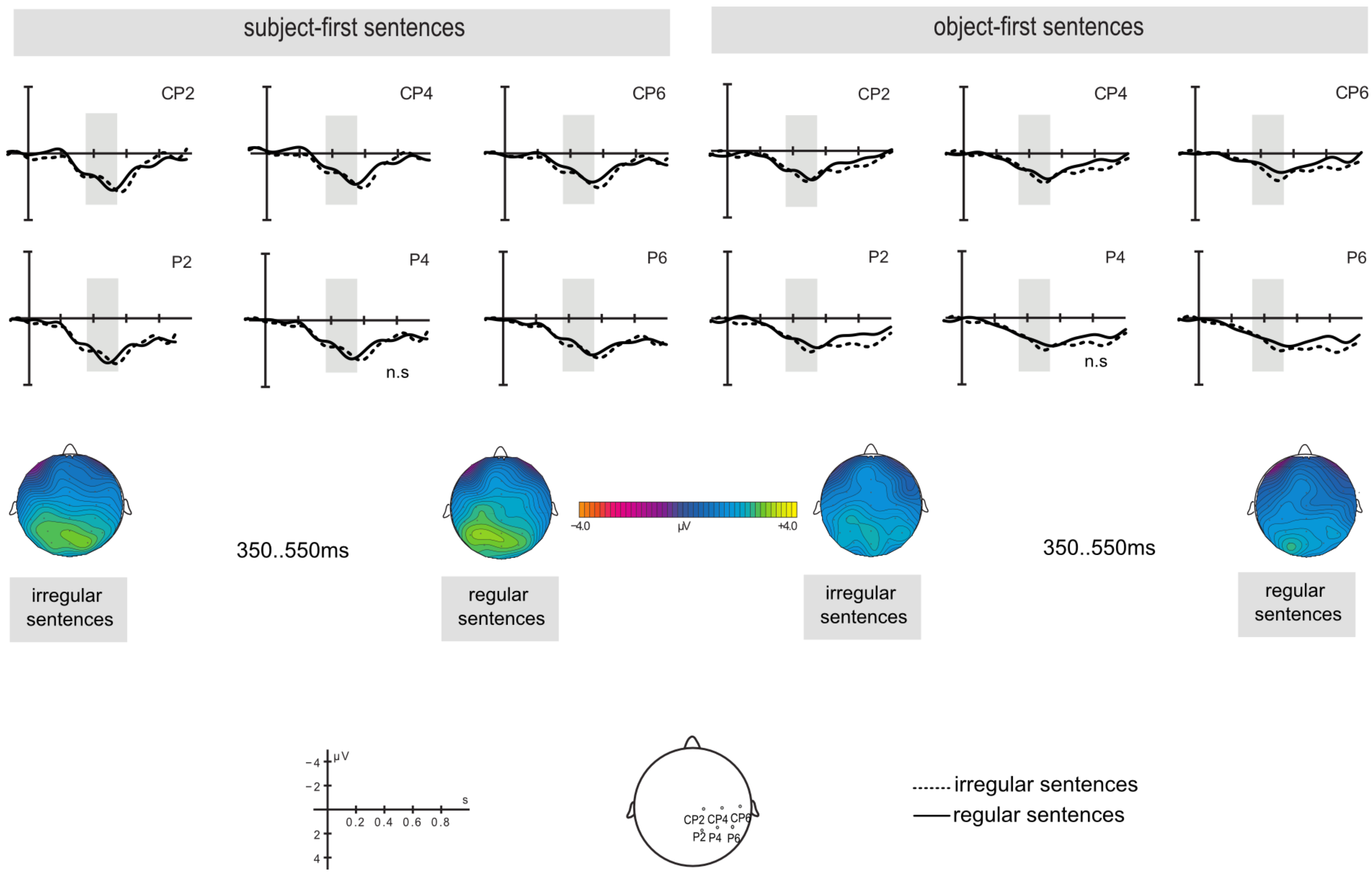

Figure 7.3: Event-related potentials elicited by the critical item for argument position in rhythmically regular and irregular contexts in Turkish late L2 learners of German. Gray bars indicate the significant time window (350 – 550 ms).

Pursuing this interaction, data from monolinguals confirmed a reduced P600 mean amplitude response over right posterior electrode-sites for object-first rhythmically regular sentences (*M* = 1.91 µV, *SD* = 2.89) compared to rhythmically irregular ones (*M* = 3.04 µV, *SD* = 2.13). Figure 7.4 illustrates ERP responses and topographical maps for German monolingual controls. Adopting similar procedure for the early L2 learners, a reduced P600 mean amplitude was found over right posterior electrode-sites for object-first sentences with regular rhythm (*M* = 2.06 µV, *SD* = 3.00) in comparison to rhythmically irregular context (*M* = 2.97 µV, *SD* = 2.76). Based on visual inspection of the scalp distributions in the early learners, subject-first sentences seemed to present lower amplitude (*M* = 2.87µV, *SD* = 2.61) than object-first sentences (*M* = 2.51µV, *SD* = 2.93), differently than German monolingual controls. To further investigate this possibility, the mean amplitude responses for these two syntactic orders were compared, yielding no statistically significant differences between them ($p > 0.1$). No further significant interaction or main effects were found. Figure 7.5 illustrates ERP responses and topographical maps for Turkish early L2 learners of German.

In summary, behavioral results reveal a main effect of *argument position* in monolingual controls and early L2 learners. Further a reduction of the P600 mean amplitude was found for object-first sentences embedded in rhythmically regular context in Turkish early L2 learners and in the German monolingual controls only.

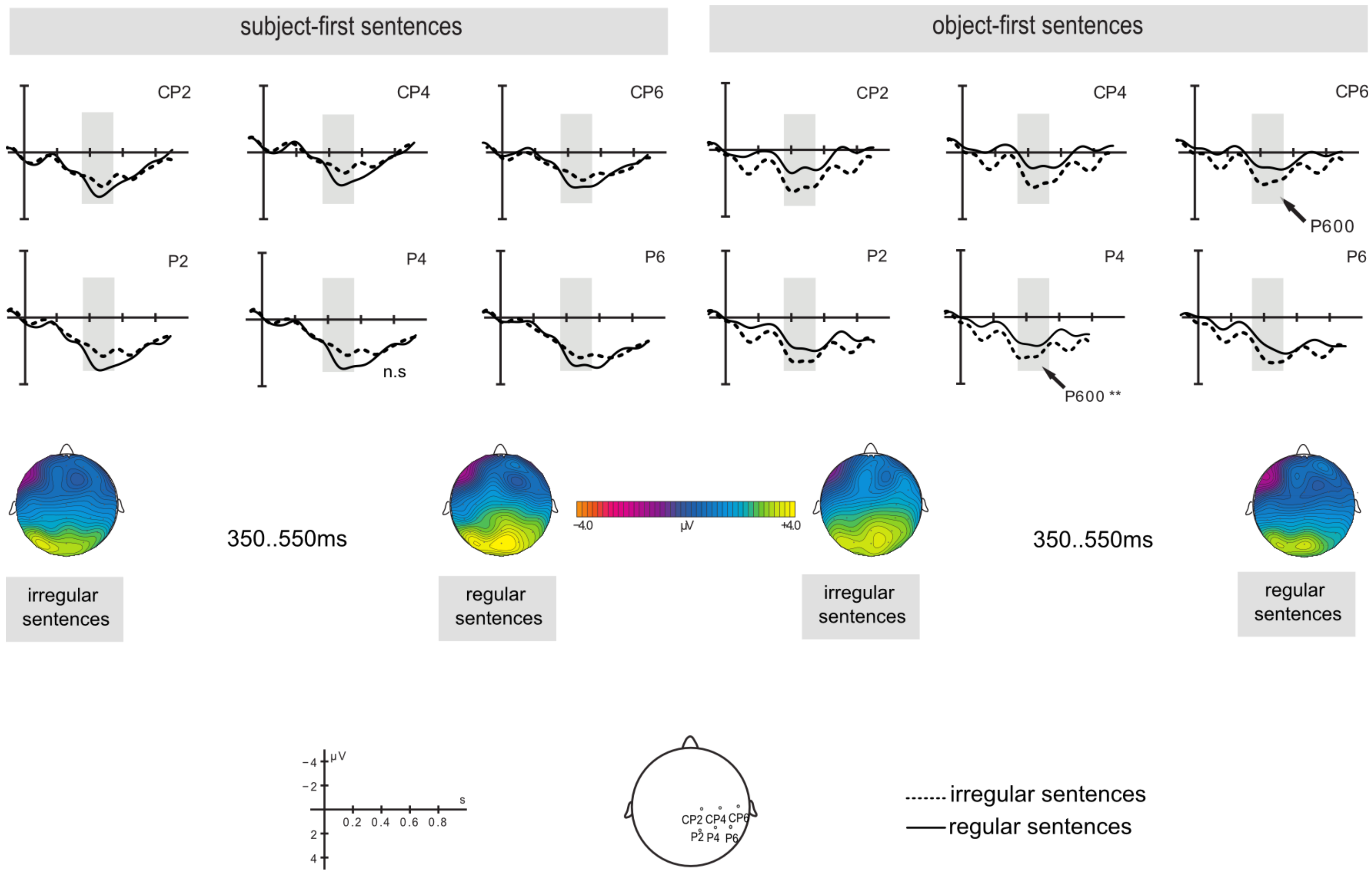

Figure 7.4: Event-related potentials elicited by the critical item for argument position in rhythmically regular and irregular contexts in German monolingual controls. Gray bars indicate the significant time window (350 – 550 ms).

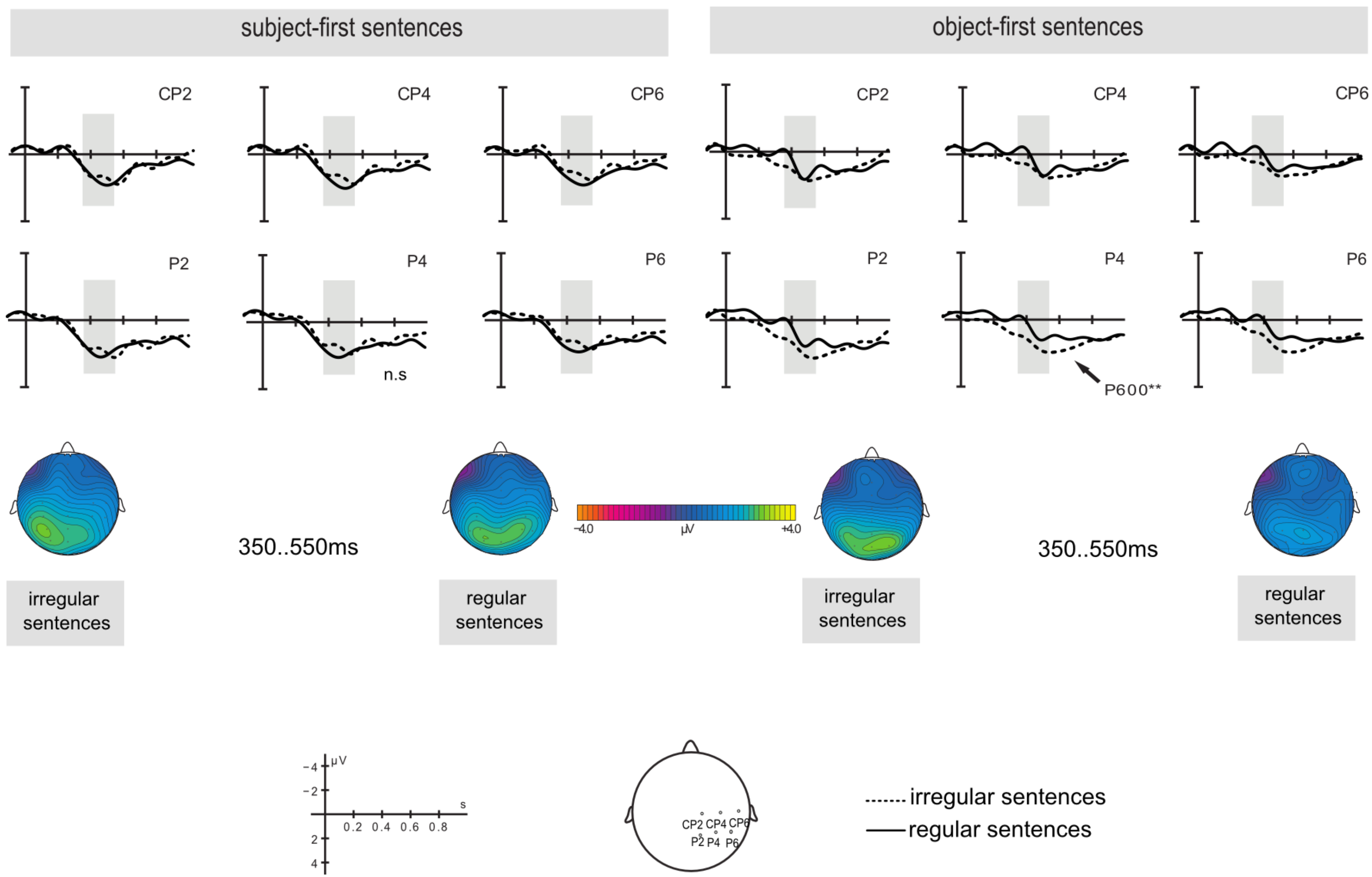

Figure 7.5: Event-related potentials elicited by the critical item for argument position in rhythmically regular and irregular contexts in Turkish early L2 learners of German. Gray bars indicate the significant time window (350 – 550 ms).

Discussion

In the current study we investigated Turkish early and late L2 learners of German and German monolingual controls regarding their ability to perceive and use speech rhythm as a sentence segmentation cue to facilitate the resolution of syntactically ambiguous sentences. Rhythmic regularity was ensured by a constant metric pattern of one stressed syllable followed by 3 unstressed ones. Participants performed a comprehension task while their brain responses were recorded by means of EEG. To control for individual differences in terms of cognitive abilities, participants' phonological and working memory capacities were tested and no significant statistical differences across groups were found.

Higher accuracy rates were found for subject-first in comparison to object-first relative clauses in monolingual controls and early L2 learners, indicating a preference for this syntactic order and corroborating previous findings in the literature (Demiral, Schlesewsky, & Bornkessel-Schlesewsky, 2008; Friederici et al., 2001). However, no such preference was found for late L2 learners, which could result from the competition between morphosyntactic differences in the two languages (MacWhinney & Bates, 1989; Tokowicz & MacWhinney, 2005).

German is a language with separate (i.e., overt) lexical forms (i.e., grammatical words) for relative pronouns, as shown in sentences a) and b). Turkish, on the other hand, is an agglutinative language (Oflazer, 1994), i.e., adding morphemes to word stems to produce different meaning and syntax. Turkish presents no independent (overt) lexical forms designating a relative pronoun in relative clauses (Kornfilt, 2000), as shown in example c).

a) Bernhard trifft die Gehilfen, die Nicole mal gestört haben.

   Bernhard meets the helpers who$_{(NOM.\ PL.)}$ *Nicole once bothered*$_{(PL.)}$

b) Paula trifft die Gehilfen, die Joel mal gestört hat.

Paula meets the helpers who$_{(ACC.PL.)}$ Joel once bothered$_{(SING.)}$

c) e_i geçen yas ada-da ben-I gö-ren kişi-ler$_i$. (Kornfilt, 2000)

last summer island-LOC I-ACC see- REL person-PL.

The people who saw me on the island last summer.

These differences may have induced competition between L1 and L2 morphosyntax, increasing error rates in the responses of late learners, overshadowing the syntactic preference effect. In this case, this reasoning is in line with the Competition Model first proposed by MacWhinney & Bates (1989), suggesting that syntactic information from L1 will compete with L2. This could contribute to a non-native manner to process complex syntactic structures, despite participants' high proficiency level (Clahsen & Felser, 2006; Felser & Roberts, 2007; Love et al., 2003; Marinis et al., 2005; Papadopoulou & Clahsen, 2003; Scherag, Demuth, Rösler, Neville, & Röder, 2004).

Similar reasoning can be drawn based on early and late learners' ERP responses in terms of syntactic processing, as both groups present different response patterns from monolingual controls. Neither L2 learner groups show significant differences in the P600 mean amplitude between subject-first and object-first sentences, indicating comparable processing costs for these two syntactic orders. These results are in line with previous literature suggesting that complex syntactic processing is constrained by AoA (Birdsong, 2006; Clahsen & Felser, 2006; Felser & Roberts, 2007; Hernandez & Li, 2007; J. S. Johnson & Newport, 1989; Love et al., 2003; Marinis et al., 2005; Mueller, 2005; Papadopoulou & Clahsen, 2003; Wartenburger et al., 2003; Weber-Fox & Neville, 1996).

Despite differences in syntactic processing, some similarities can be observed between monolingual controls and early learners in terms of their use of rhythmic information. Likewise monolingual controls, early L2 learners also showed a rhythmic facilitation effect in form of a reduced P600 response to object-first sentences. These results are in accordance with the existence of a prosodic hierarchy in speech distinct and independent from its syntactic structure, which, however, interacts with it, promoting speech organization (Hayes, 1989; Nespor & Vogel, 1986).

Furthermore, because no such rhythmic effect was found among late L2 learners, this could suggest that the use of rhythmic information during language processing may be subject to AoA to a lesser degree than the processing of complex syntactic structures. In this sense, late learners' ERP results may corroborate previous L2 research investigating the role of rhythm in word segmentation (Cutler, 2000, 2002; Cutler et al., 1992; Pallier, Christophe, & Mehler, 1997).

As participants were listening to rhythmic properties of their L2 (German), the data from the L2 late leaner group indicates that late learners may not benefit from these properties in a similar fashion as monolingual German speakers and early L2 speakers. Rather, late learners may still rely on the rhythmic properties of their L1 (Turkish), such as the use of the syllable, instead of the metric foot, as their unit for speech segmentation and processing.

Nevertheless, our study provides new evidence for the impact of speech rhythm in L2 sentence processing on two accounts. First, no other study has investigated the role of rhythm during L2 sentence processing using ERPs. ERPs are a powerful tool to capture ongoing linguistic processes, which are too fast to be depicted by behavioral measures, as it seems to be the case of the encountered rhythmic effect in monolinguals and early L2 learners. Second, so far, studies investigating the use of rhythm in L2 have mainly addressed its effect in the word level, namely language specific metric preferences in word segmentation (Cutler, 2002; Cutler et al., 1992; Otake et al., 1993; Pallier et al., 1997).

In the current study, rhythm in L2 was addressed as a sentence organization and segmentation cue at a higher level of the prosodic hierarchy (Hayes, 1989; Nespor & Vogel, 1986), i.e., at the level of the intonational phrase and the utterance. At this level, operating phonological rules become less language-specific and more universal (Nespor & Vogel, 1986). As such, they would be less subject to language specificity and therefore to L2 AoA. However, one should not forget that language-specific phonological rules operating in lower prosodic domains may interact with rules from higher domains (Nespor & Vogel, 1986). These interactions may bring language-specificity into domains where otherwise language universal rules were to be found. This may explain the fact that late learners do not seem to benefit from rhythmic information present in higher prosodic domains, where our experimental manipulation is to be found.

In view of these results, some limitations and caveats need to be addressed. Despite the fact that all participants have reported German to be their second language, it could still be the case that German is the dominant language for early learners. If this were the case, than it could be that early learners use rhythmic properties only in their dominant language, paralleling results with L2 research on word segmentation (Cutler et al., 1986; Otake et al., 1993). Alternatively, it could also be that early learners perceive and use rhythmic properties in their L1 and L2, according to the language context in use (Goetry & Kolinsky, 2000). Because L2 learners were tested only in one language, none of these two possibilities can be ruled out. Therefore, further research with L2 early learners concerning their use of rhythm as a sentence segmentation cue in both languages should be conducted. By doing so, a more conclusive interpretation can be drawn regarding monolingual and bilingual sentence processing and the use of speech rhythm beyond word segmentation.

Finally, additional studies with late L2 learners, whose L2 and L1 partly share rhythmic overlap, should be undertaken. Then one can better understand which rhythmic properties can be transferred, which ones can be learned, and which ones cannot.

Conclusions

In the current study we investigated the role of age of acquisition in using rhythmic properties during second language sentence processing. Syntactically ambiguous sentences embedded in rhythmically regular and irregular contexts were presented to Turkish early and late learners of German, and to German monolingual controls. ERP results reveal that, similarly to monolingual controls, Turkish early learners of German show a rhythmic facilitation effect during syntactic processing. No such rhythmic facilitation effect was found for Turkish late L2 learners of German. These findings suggest that similarly to the segment level, i.e. phonology, there may be a sensitive period to acquire and use rhythm, i.e. as a segmentation cue to organize linguistic information into larger processing units facilitating sentence processing. Therefore, future research investigating the role of speech rhythm in L2 processing using ERP should be undertaken, to understand its role not only in segmenting words, but also as a temporal organization device during sentence processing.

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Chapter 8

Enhanced Musical Rhythmic Perception in Turkish Early and Late Learners of German

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Abstract

As language rhythm relies partly on general acoustic properties, such as intensity and duration, mastering two languages with distinct rhythmic properties (i.e., stress position) may enhance musical rhythm perception. We investigated whether competence in a second language (L2) with different rhythmic properties than a L1 affects musical rhythm aptitude. Turkish early (TELG) and late learners (TLLG) of German were compared to German late L2 learners of English (GLE) regarding their musical rhythmic aptitude. While Turkish and German present distinct linguistic rhythm and metric properties, German and English are rather similar in this regard. To account for inter-individual differences, we measured participants' short-term and working memory (WM) capacity, melodic aptitude, and time they spent listening to music. Both groups of Turkish L2 learners of German perceived rhythmic variations significantly better than German L2 learners of English. No differences were found between early and late learners' performance. Our findings suggest that mastering two languages with different rhythmic properties enhances musical rhythm perception, providing further evidence of shared cognitive resources between language and music.

Keyword: speech rhythm, L2, musical rhythm, rhythmic aptitude

Introduction

Over the last few decades the impact of bilingualism and second language learning (L2) on cognitive processes has been the objective of many studies. Previous research reported a positive association between bilingualism and verbal and non-verbal intelligence (Peal & Lambert, 1962), problem-solving skills (Bialystok, 1999; Bialystok & Shapero, 2005), phonological memory (Cheung, 1996; Service, 1992), and working memory capacity in attention-impeding tasks (Yang, Yang, Ceci, & Wang, 2005).

Similarly, musical aptitude has been related to enhanced cognitive abilities (Draper & Gayle, 1987; Milovanov et al., 2008), such as general intelligence (Schellenberg, 2004), verbal memory (Brandler & Rammsayer, 2003), and to the enhanced processing of acoustic features embedded in complex musical contexts (Garza Villarreal, Brattico, Vase, Østergaard, & Vuust, 2012; Kraus & Chandrasekaran, 2010; Vuust, Brattico, Seppänen, Näätänen, & Tervaniemi, 2012).

More recently, attention has been drawn to the association between musical aptitude and L2 learning (Milovanov & Tervaniemi, 2011). Studies report a positive effect of musical aptitude on second language skills, such as pronunciation (Milovanov et al., 2008) and phonological perception (Slevc & Miyake, 2006). In addition, it has been shown that a second language may enhance musical aptitude with respect to of tone perception (D. Deutsch et al., 2006; Elmer et al., 2011). Nevertheless, as far as this study is concerned, the impact of second language learning on musical rhythm aptitude has not been investigated.

Similarly to rhythm in music, speech rhythm relies on acoustic prominence to create perceptual units that support the structuring and the organizing of the speech flow (Hayes, 1989; Jackendoff, 1989; Lerdahl & Jackendoff, 1983; Nespor & Vogel, 1986). These perceptual units may constitute the basis of rhythmic language classifications as stress-timed, syllable-timed, and mora-timed languages (Abercrombie, 1967; Ladefoged, 1975; Pike, 1945). In stress-timed languages, such as German and English, the unit of speech organization is the metric foot, i.e., a stressed syllable dominates at least one relatively weaker syllable (Hayes, 1985; Nespor & Vogel, 1986). In syllable-timed languages, such as Turkish and French, the syllable, regardless of stress, organizes and structures speech (Cutler, 1994b; Grabe & Low, 2002; Ladefoged, 1975; Nazzi & Ramus, 2003; Pike, 1945). Finally, in mora-timed language (e.g., Japanese), the mora, a subunit of the syllable, is regarded as the speech organization unit (Itô, 1989; Otake et al., 1993; Warner & Arai, 2001)[14].

At the word level, rhythm operates by means of stress assignment, determining a language's metric preference. In terms of their metric preference, languages rely on the trochee or the iamb as their default metric pattern (Hayes, 1985; Hay & Diehl, 2007). The trochee is characterized by one stressed syllable followed by, at least one relatively weaker syllable, while the iamb displays the opposite metric pattern, namely at least one unstressed syllable followed by one stressed one (Hayes, 1985). German and English provide examples of trochaic languages, while Turkish and French are iambic (Eisenberg, 1991; Inkelas & Orgun, 2003).

Implicit knowledge and the use of rhythmic properties, such as the organization, perceptual units, and metric preference, constitute part of a speaker's competence in a language (Patel, 2008). Therefore, to master a second language, its rhythmic properties must be learned as part of the linguistic inventory of this language.

Despite speech rhythm being a language-specific ability, it is based on acoustic properties, such as intensity and duration that are found in other auditory domains such as music (Bispham, 2006; Lerdahl & Jackendoff, 1983; Patel, 2003, 2008; Tincoff et al., 2005). Properties of speech rhythm can therefore be considered domain-general properties (Hay & Diehl, 2007; Jackendoff, 1989). Mastering two languages with different rhythmic properties

[14]Even though several studies refuted the idea of an objective isochrony (Beckman, 1982; Lea, 1974; Wenk & Wioland, 1982), on which the traditional rhythmic classification of languages is based (Abercrombie, 1967; Ladefoged, 1975; Pike, 1945) the terms "stress-timed", "syllable-timed" and "mora-timed" are still in use in the literature. For review and further discussion on this matter, see (Patel, 2008).

may thus enhance the sensitivity to these general acoustic properties when used in a specific language context.

This should be the case as speech rhythm may support language discrimination (Beckman, 1996; Patel, 2008; Ramus, Dupoux, et al., 2000; Ramus et al., 1999). Thus, if sensitivity to rhythmic speech properties enhances the perception of rhythmic properties in music, such evidence would support the notion of shared resources in these two domains. It would also suggest that a domain-specific skill may be transferred to another cognitive domain, e.g., music (Perkins & Salomon, 1989).

Furthermore, if mastering languages with different rhythmic properties positively impacts musical rhythm perception, this effect could be modulated by L2 age of acquisition. As some studies suggest, L2 learners must make use of rhythmic information in an L2 to some extent to acquire this language (Goetry & Kolinsky, 2000). In addition, studies reveal that highly proficient late learners are sensitive to L2 rhythmic properties (Field, 2003; Goetry & Kolinsky, 2000; Trofimovich & Baker, 2006). However, one cannot disregard previous findings that revealed that early L2 learners make use of rhythmic strategies in their dominant language only to segment words (Cutler et al., 1986, 1992; Otake et al., 1993). This would imply that, similarly to phonology (Flege et al., 1999; Piske, MacKay, & Flege, 2001b) the use of rhythmic strategies in speech segmentation would be constrained by age of acquisition (AoA). As contradictory as these findings may appear, the fact that L2 learners superimpose rhythmic segmentation strategies of their dominant language onto an L2 does not exclude the possibility that they are sensitive to general acoustic properties underlying rhythm in both languages.

In the current research, we addressed two main issues. First, we investigated the impact of mastering languages with different rhythmic properties, such as metric preference and rhythmic classification, on musical rhythmic aptitude. This is motivated by the commonalities in temporal organization (rhythm) of music and language. In both domains rhythm organizes acoustic events in terms of timing and grouping, structuring the acoustic input in a hierarchical fashion by means of perceptual units (Hayes, 1989; Jackendoff, 1989; Lerdahl & Jackendoff, 1983; Nespor & Vogel, 1986).

Second, we investigated whether musical rhythm can be modulated by L2 age of acquisition (AoA). Even though much is known about the impact of age of acquisition on different L2 skills, such as phonology, semantics, and syntax (Clahsen & Felser, 2006; Flege et al., 1999; Hernandez & Li, 2007; J. S. Johnson & Newport, 1989; Ojima et al., 2005; Piske et al., 2001b; Wartenburger et al., 2003; Weber-Fox & Neville, 1996), the same does not hold true for L2 rhythm (Chun, 2002; Trofimovich & Baker, 2006). It could be that either the attainment of L2 rhythm is constrained by AoA as suggested by some research on rhythmic strategies in word segmentation (Cutler et al., 1986; Guion et al., 2004; Otake et al., 1993), or that it may be acquired with increased L2 exposure and proficiency (Field, 2003; Goetry & Kolinsky, 2000; Trofimovich & Baker, 2006).

In order to address these issues, we tested Turkish early (TELG) and late L2 learners of German (TLLG) and German late L2 learners of English (GLE) with respect to their musical rhythmic aptitude. Whereas German and English share rhythmic classification and metric preferences (Pike, 1945; Eisenberg, 1991; Cummins and Port, 1998), Turkish and German represent rather an interesting contrast when considering their respective rhythmic properties. While German is a stress-timed language with a metric preference for the trochee, Turkish is syllable-timed and uses the iamb as its default metric pattern (Eisenberg, 1991; Grabe & Low, 2002; Höhle et al., 2009; Inkelas & Orgun, 2003; Nazzi & Ramus, 2003; Topbas, 2006).

In order to control for individual differences that may influence participants' performance, such as cognitive and musical ability, participants were tested in terms of their short-term memory and working memory capacities. Short-term memory regards the ability to store given, and relatively unprocessed, information for a short period of time (Baddeley, 2003; Conway et al., 2005). Working memory (WM) characterizes the ability to maintain information actively while cognitive processes are being executed (Baddeley, 2003; Conway et al., 2005). Previous research suggests that STM and WM capacity correlate with general intelligence, thus providing an indicator of cognitive resources (Conway et al., 2005; Daneman & Carpenter, 1980; Engle et al., 1999; Oberauer et al., 2000; Unsworth & Engle, 2007).

In addition, participants were asked about their musical background, weekly exposure to music, and were tested for their musical aptitude, by means of a melody aptitude test. Next to rhythm, the perception of pitch variation, as in melody and harmony, is considered one of the two fundamental aspects of music (Lerdahl & Jackendoff, 1983) and is extensively used as an indicator of musical aptitude (Gordon, 1969, 2007; Seashore, Lewis, & Saetveit, 1960; Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010).

Therefore, by controlling for differences in the participants' cognitive ability, musical aptitude, and weekly exposure to music, we expected differences in rhythmic aptitude to be explained by the mastery of languages with distinct rhythmic properties.

Methods

Participants

Eighty-five right-handed participants, non-musicians, were assigned to three experimental groups, i.e., 27 Turkish late L2 learners of German (13 females, M_{age} = 29.11, *SD* = 3.85, mean age of L2 first exposure, AoL2FE = 20.03, *SD* = 6.40), 26 Turkish early L2 learners of German (12 females, M_{age} = 26.80, *SD* = 4.48, M_{AoL2FE} = 1.03, *SD* = 0.19) and 32 German monolingual controls (16 females, M_{age} = 25.71, *SD* = 2.55). Participants reported having no formal musical training and were either university students or recent graduates.

They were paid for their participation. None of the participants reported any neurological impairment or hearing deficit, and all had normal or corrected-to-normal vision. This study was approved by the ethics committee of the University of Leipzig and all participants gave their written informed consent for data collection, use and publication.

Materials

Second language assessment and language history questionnaire. All participants were given a language history questionnaire concerning both their L1 and L2. With this questionnaire, we assessed language competence, such as listening, writing, reading and speaking skills, age of first exposure to the languages, situations in which each language was acquired, and current language use. Self-reported language questionnaires have been successfully used to assess L1 and L2 acquisition, history and competence skills (Elston-Güttler et al., 2005; Marian et al., 2007; Schmidt-Kassow, Roncaglia-Denissen, et al., 2011) Based on the results of the assessment and on the participants' own perception of their language preference, English and German were regarded as the second language among German and in both Turkish L2 learner groups, respectively.

The musical ear test. As a rhythmic aptitude measure, we used the rhythmic subset of the Musical Ear test (MET; (Wallentin et al., 2010). The MET rhythmic subset consists of 52 rhythmic pairs, which are formed by either two identical or two different rhythmic phrases. All rhythmic phrases were recorded using wood blocks and were 4–11 beats long. Rhythmic phrases have a duration of one measure and were played at 100 bpm. Trials constituted two distinct rhythmic phrases and differed only by one rhythmic change. Rhythmic complexity was achieved by including triplets in 21 trials, while the other 31 trials presented even beat subdivisions. Thirty-seven trials begin on the downbeat while the remaining trials begin on the beat removed. The order, in which these features occurred, was randomized.

In its original version, the MET involves an answer sheet to be filled out by the participants. Additionally, the test provides participants with auditory instructions in English prior to and during the test to introduce each trial. We created an adapted version, in which instructions in German were presented visually prior to the test, i.e., in the training phase, but not before each single trial.

Short term memory and working memory measures. In the current study, we used the Mottier test, MT (Mottier, 1951), a non-word repetition test, as a measure of short-term memory. The MT is composed of sets of 6 non-words, ranging from 2 to 6 syllables each. The stimulus material presented a constant syllabic structure of one consonant followed by one vowel, i.e., CV. The non-words were spoken by a female professional speaker and presented to participants via headphones. a non-word repetition test, as a measure of short-term memory. The MT is composed of sets of 6 non-words, ranging from 2 to 6 syllables each. The stimulus material presented a constant syllabic structure of one consonant followed by one vowel, i.e., CV. The non-words were spoken by a female professional speaker and presented to participants via headphones.

We used the backward digit span (BDS), a WM measure involving information storage and transformation (Oberauer et al., 2000; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002) The BDS version adopted in the current study is composed of 14 sets of 2 trials, ranging from 2 to 8 numbers. The numbers were spoken by a female German native speaker and recorded at a rate of one number per second. Numbers were presented via headphones and participants had to recall them in the reverse order of which they were presented.

Melodic aptitude test. To measure participants' melodic aptitude, the melodic subset from the MET was used (Wallentin et al., 2010). This subset consists of 52 melodic pairs, formed by two identical or two different melodic phrases. Melodic phrases consisted of 3–8 tones and had a duration of one measure and were played at 100 bpm. Different trials (26 pairs) contained pitch violation and in half of them the pitch violation also characterized a violation in the pitch contour. Twenty-five trials were constituted by non-diatonic tones, while

7 trials were in the Minor key and 20 in the Major. The order, in which these features occurred, was randomized.

Procedures

Participants were tested individually in a quiet room. The tests were administered in a pseudo-randomized order on a computer and each individual session lasted ~1 h. Participants received written instructions for each test, either on separate instruction sheets or presented on the computer screen. Before each test, practice trials were provided and participants were allowed to repeat them until the test was understood correctly. At the end of the session, participants were asked about the average time they spent listening to music in a week (number of hours). Furthermore, participants' information about their L1 and L2 was assessed.

The musical ear test. The MET rhythmic subset was presented via headphones using a computer. While participants listened to rhythmic phrases, a white star was presented in the center of a black screen, providing a visual cue to attend to during stimulus presentation. Participants judged if the presented rhythmic pair comprised identical or different phrases. At the end of a rhythm trial, the white star was replaced by the words “JA” (*yes*) and “NEIN” (*no*) placed at middle height and at opposite sides of the screen, matching the positions of the response keys. Participants had 1 s to press the corresponding answer key. The position of the correct-response key was counter-balanced across participants.

Mottier test and backward digit span. Participants self-initiated the Mottier Test by pressing the space key. With a visual cue placed in the center of the computer screen, participants heard the first non-word and were instructed to repeat it as accurately and as fast as possible, after which the next non-word was presented and the same procedure was repeated. At the end of each trial set, participants were given a short break and self-determined when the test should be re-initiated. Participants' responses were computed *ad-hoc* by the experimenter with the help of a response sheet, as well as being recorded via the computer. The test was terminated when participants failed to recall a minimum of 4 items of the same trial set correctly. Scoring was based on the total number of correctly recalled non-words.

In the BDS, participants listened to the sequences of numbers via headphones while facing away from the computer. At the end of the numerical trial, participants were asked to repeat the numbers in the reversed order of their presentation. The test was terminated when participants failed to recall two trials of the same set. Scoring was given according to the total number of trials correctly recalled.

Melodic aptitude test. The MET melodic subset was presented via headphones using a computer. Participants listened to the melodic phrases while presented with a visual cue in the center of a black screen. Participants were to judge if the presented melodic pair consisted of identical or different phrases. With the end of the melodic trial, participants were presented with the words "JA" (*yes*) and "NEIN" (*no*), matching the positions of the response keys. Participants had 1 s to press the corresponding answer key. Correct-response key position was counter-balanced across participants.

Statistical analysis. German late L2 learners of English were divided into three groups according to their self-reported English proficiency level, i.e., having very good to excellent writing and speaking skills, having good writing and speaking skills and having good speaking, but not writing skills in English. An ANOVA was conducted with a between-subjects factor (proficiency) and their rhythmic performance as dependent variable. This allowed to explore whether their knowledge of another language (English) with similar rhythmic properties to German (Jusczyk et al., 1993; Pike, 1945) would affect their musical rhythmic performance. Furthermore, all participants were divided into three groups, creating a between-subjects factor *group* (German late L2 learners of English, Turkish early and late L2 learners of German). An analysis of covariance (ANCOVA) was computed with *group* as a between-subjects factor and participants' scores in the MET rhythmic subset as the dependent variable. Participants' scores in the cognitive tests, i.e., the MT and the BDS, their melodic aptitude as well as their weekly exposure to music (number of hours per week) were used as covariates. To ensure that the assumption of independence of the covariates (Miller & Chapman, 2001) was not violated, additional ANOVAs were conducted for each cognitive measure, i.e., BDS, MT, and melodic aptitude using *group* as a between-subjects factor. Along the same lines, a chi-square test was conducted to compare the three groups in terms of their weekly musical exposure.

Results

Descriptive results and reliability tests are summarized in Table 8.1. In Table 8.2 language skills of the three L2 learner groups are shown.

Tasks	Reliability (Cronbach's α)	German late L2 learners of English		Turkish early L2 learners of German		Turkish late L2 learners of German	
		M	*SD*	*M*	*SD*	*M*	*SD*
Rhythmic aptitude test (MET subset)	0.627	64.50	8.30	70.15	9.76	71.78	8.17
Mottier test	0.896	27.75	2.88	26.50	4.50	26.44	5.34
backward digit span	0.694	8.53	2.79	7.73	1.88	7.18	2.30
Melodic aptitude test (MET subset)	0.821	64.78	12.07	65.75	11.79	67.02	10.78

Table 8.1: Reliability tests and participants' score for each conducted task.

Language skill	German late learners of English		Turkish early learners of German		Turkish late learners of German	
	M	*SD*	*M*	*SD*	*M*	*SD*
L1 Listening	99.67	1.79	94.81	10.51	99.25	2.66
L2 Listening	76.78	13.62	99.61	1.96	85.92	11.52
L1 Reading	99.67	1.79	85.38	20.63	99.25	2.66
L2 Reading	81.42	10.78	97.77	4.23	82.22	11.87
L1 Language independence	100	-	94.44	10.50	99.62	1.92
L2 Language independence	82.56	28.72	98.14	5.57	80.37	15.05

Table 8.2: Language skills of L2 learners.

Statistical analysis

Results of the ANOVA conducted with German L2 learners revealed no significant effect of the participants' English skills on their rhythmic performance, $F_{(2, 39)} = 0.88$, $p > 0.1$. An ANOVA investigating the independence of covariates as well as the chi-square test revealed that none of the covariates vary across *groups*, all *p*s > 0.05. For the rhythmic aptitude test, the conducted ANCOVA revealed a significant effect of *group*, $F_{(2, 78)} = 9.29$, $p < 0.001$, $\omega^2 = 0.32$.

Pairwise comparison of the adjusted means of participants' scores using the Holm's Sequential Bonferroni correction revealed a significant difference between German late L2 learners of English ($M = 64.60$, $SE = 1.46$) and Turkish late L2 learners of German ($M = 71.78$, $SE = 1.57$; $p = 0.0002$). In addition, German L2 learners' performance was significantly different from Turkish early L2 learners' ($M = 70.15$, $SE = 1.91$; $p = 0.0023$). A comparison between the two Turkish L2 learner groups did not yield significant differences ($p = 0.40$).

These findings are consistent with our initial hypothesis, namely despite controlling for individuals' cognitive abilities and melodic aptitude, group differences in rhythmic aptitude are confirmed.

Rhythmic performance of all participants (German late L2 learners of English, Turkish early and late L2 learners of German) in the MET rhythmic subset are depicted in Figure 8.1.

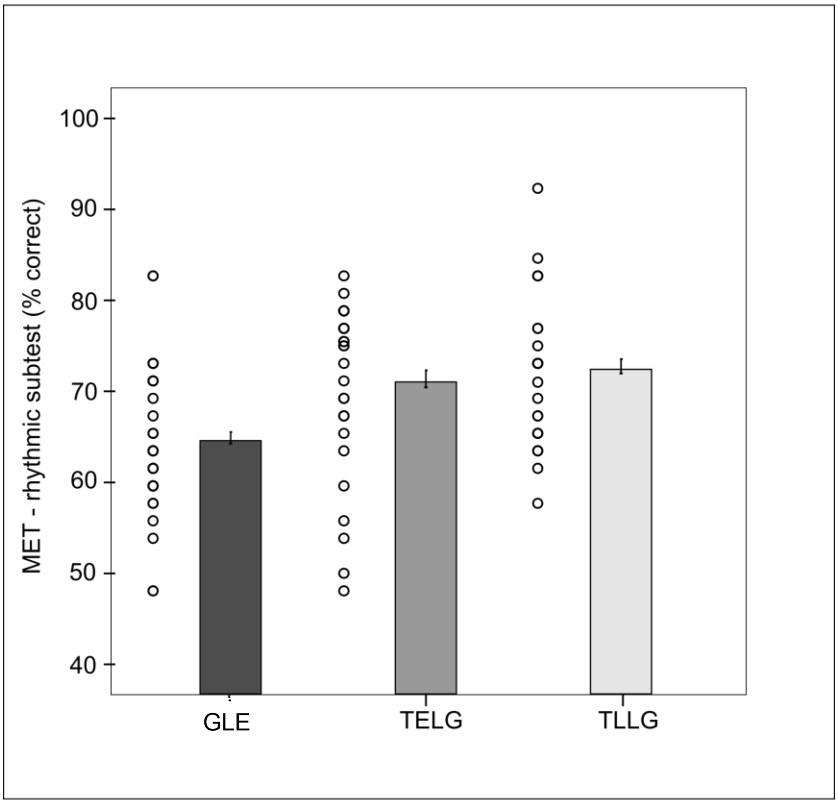

Figure 8.1: Participants' and group performance in the rhythmic aptitude test (MET rhythmic subset). Error bars indicade standard error.

Discussion

In the current study, we investigated the musical rhythm aptitude of Turkish early and late L2 learners of German and that of German late L2 learners of English to address two main issues. First, whether mastering languages with different rhythmic properties, such as Turkish and German, can enhance rhythm perception in music, and second, whether musical rhythm aptitude is modulated by L2 AoA.

Regarding the first question, results show that when controlling for participants' cognitive abilities i.e., STM and WM capacities, and for melodic aptitude, both Turkish L2 learner groups outperformed German L2 learners of English in terms of their rhythm aptitude. Our findings suggest that specific linguistic properties, i.e., rhythmic information, may be transferred to the musical domain. This could be the case as individuals may recognize acoustic similarities in music and language, e.g., stress (Hayes, 1989; Jackendoff, 1989; Lerdahl & Jackendoff, 1983; Patel, 2003). This, in turn, may transfer from one domain to the other (Magne, Schön, & Besson, 2003; Perkins & Salomon, 1989; Schön et al., 2004; Vuust, Wallentin, Mouridsen, Østergaard, & Roepstorff, 2011).

Thus, being sensitive to different rhythmic properties as a result of mastering two languages may constitute a domain-specific ability, which results from domain-general skills (Perkins & Salomon, 1989; Salomon & Perkins, 1989), namely the ability to structure and organize events in time, i.e., rhythm (Cummins & Port, 1998; Jackendoff, 1989). This would parallel with recent findings in music research that a domain-specific skill enhances an individual's acoustic perception (Kraus & Chandrasekaran, 2010; Pantev, Roberts, Schulz, Engelien, & Ross, 2001; Vuust et al., 2012)

In addition, as rhythm is a valuable cue to discriminate between languages (Nazzi & Ramus, 2003; Ramus, 2002), perhaps L2 learners whose L1 is fundamentally different from their L2 with respect to rhythmic properties are more attentive and sensitive to acoustic variations than monolinguals. This may lead to improved language recognition and selection. Given that Turkish and German are rather diverse concerning their rhythmic properties, rhythmic information may facilitate language selection and may allow cognitive resources to be allocated to other linguistic processes where they are most needed, such as speech segmentation.

Nevertheless, one may argue that our results could alternatively be explained by L2 learners' exposure to a different musical culture, namely Turkish music. In this sense, the higher level of rhythmic complexity found in Turkish music, such as the presence of a non-isochronous meter, so rare in Western music (Bates, 2010; Hannon, Soley, & Ullal, 2012), may contribute to higher rhythmic sensitivity among L2 learners. Thus, enhanced perception of rhythmic patterns could be influenced by the familiarity with a certain rhythm, and therefore, by a culture-specific listening experience (Hannon et al., 2012). Despite this reasoning, one should consider that the rhythmic variations participants were presented with can be found both in Western and Turkish music. Furthermore, rhythmic sentences varied with respect to one beat only, relativizing rhythmic complexity. As such, Turkish L2 learners of German should not start out with an advantage over German L2 learners of English in terms of musical rhythmic perception.

Additionally, one may think that our findings result from the nature of the Turkish language. This should not be the case, because Turkish and German present the same fundamental features establishing acoustic prominence in speech, i.e., duration and intensity creating lexical stress. Hence, it is unlikely that Turkish controls should have a rhythmic advantage over German controls in terms of their ability to discriminate these rhythmic properties. In addition, in a recent study Schmidt-Kassow et al. (2011) reported that French native speakers detect stress variation in tonal sequences comparably to native speakers of German. Hence, their findings support the idea that no particular rhythmic class, i.e., stress-timing or syllable-timing, leads to an advantage in terms of rhythmic discrimination in a non-linguistic context. Nevertheless, in order to rule out the possibility that enhanced musical rhythmic perception may rely on the mastery of Turkish, Turkish monolingual controls should be further investigated.

Regarding the second issue addressed in this research, namely whether L2 AoA influences general rhythm perception, the current results indicate that musical rhythm perception does not seem to be subject to L2 AoA. The fact that both groups of Turkish L2 learners benefit from L1 and L2 rhythmic diversity seems to indicate that L2 speakers are sensitive and may learn, to some degree, L2 rhythmic properties beyond a sensitive period (Bailey, Plunkett, & Scarpa, 1999; Field, 2003; Goetry & Kolinsky, 2000; Trofimovich & Baker, 2006).

This could be the case because the prominence created by rhythm is based on temporal acoustic perception, which can be learned and improved later on in life (Alain, Snyder, He, & Reinke, 2007; Dahmen & King, 2007; Van Wassenhove & Nagarajan, 2007). Thus, speech rhythm could be less constrained by L2 AoA than other linguistic skills, such as complex syntactic processing and phonology (Clahsen & Felser, 2006; Flege et al., 1999; Hernandez & Li, 2007; J. S. Johnson & Newport, 1989; Papadopoulou, 2005; Piske et al., 2001b; Weber-Fox & Neville, 1996).

In view of the current results, some questions remain. If enhanced musical rhythm aptitude found among L2 learners results from the selection of languages with distinct rhythmic properties, this could suggest that these L2 learners are also better in discriminating languages based on rhythmic information. Therefore, further investigations regarding language discrimination based on rhythmic properties should be carried out with L2 learners, whose L1 and L2 have different rhythmic properties.

Moreover, L2 learners from languages sharing some of their rhythmic properties, such as metric preference (e.g., German and Italian) or rhythmic organization (e.g., Spanish and French), should be tested. This could provide a more complete understanding of which rhythmic properties contribute more or less to an enhancement in musical rhythmic aptitude.

Such investigations should shed more light on if and how mastering languages with different rhythmic properties (e.g., stress position) may affect the ability to discriminate between languages, facilitating the selection of the target language and, therefore, speech processing.

Conclusion

Our study is a first investigation on how distinct rhythmic properties in first and second languages may enhance musical rhythm aptitude. Results confirm an enhanced musical rhythm aptitude in Turkish early and late L2 learners of German compared to German late L2 learners of English. These findings should be taken as a starting point for future studies investigating the shared properties between language and music in the context of second language learning. Research into this specific topic will eventually provide a better understanding of how acoustic properties (e.g., sound duration and intensity) may be perceived and used across domains.

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General Discussion and Outlook

Part IV

Chapter 9

Summary and Conclusions

The present dissertation investigated speech rhythm as a sentence segmentation device in terms of its function (Experimental study 1) and possible limitations on its use during L2 processing (Experimental study 2). Additionally speech rhythm was addressed in terms of its transferability as a cognitive skill to the music domain (Experimental study 3).

Rhythm is the temporal and systematic organization of acoustic events in terms of prominence, timing and grouping (Patel, 2008), helping to structure our most basic experiences, such as body movement, music and speech (Cummins & Port, 1998; Guaïtella, 1999). In language, speech rhythm interacts with other linguistic domains, such as morphology, semantics and syntax, grouping linguistic elements into prosodic constituents in a hierarchical fashion. These constituents, in turn, constitute perceptual units, which may be used by the parser during sentence processing. Previous research has addressed the role of rhythm in speech organization focusing on the word level, while its use in the broader scope of the sentence has been neglected.

In addition, speech rhythm as a sentence segmentation device and possible constraints on its use, have not been considered from the L2 processing perspective. Similarly to any other linguistic domain, rhythm is part of an individual's competence in a certain language and must be, therefore, considered in terms of L2 attainment. If on the one hand, L2 literature provides plenty of evidence of L2 outcome in different linguistic domains, very little is known about the acquisition of L2 rhythmic properties. For this study Turkish L2 learners of German were chosen as a language pair due to the differences in metric preference and rhythmic organization between these two languages (Eisenberg, 1991; Inkelas & Orgun, 2003; Pike, 1945; Topbas, 2006).

Finally, the sensitivity to speech rhythm as a result of mastering languages with different rhythmic properties was addressed as a cognitive skill, which could be transferred to the music domain. This could be the case because rhythm in speech and in music rely on general acoustic properties, such as duration and intensity (Bispham, 2006; Lerdahl & Jackendoff, 1983; Tincoff et al., 2005). Because L2 learners may rely on speech rhythmic information to discriminate between languages to correctly select their target, they may present an enhanced sensitivity to rhythmic variation in speech. This sensitivity may, in turn, be applied to the music domain enhancing the ability to perceive rhythmic variation in music. As follows, each conducted study and its main findings will be briefly presented.

In Experimental study 1, German native speakers were tested regarding their ability to use speech rhythm as a sentence segmentation cue during syntactic ambiguity processing using the ERP method. Participants listened to case-ambiguous sentences, subject-first *vs*. object first order, embedded either in rhythmically regular or irregular context. Rhythmicity was created by a constant metric pattern of one stressed syllable followed by three unstressed ones. It was hypothesized that rhythmic regularity would provide a reliable and predictable segmentation cue, guiding the syntactic parser during sentence segmentation (Kjelgaard & Speer, 1999; Speer et al., 1996) and facilitating the processing of the less-preferred syntactic structure, i.e. object-first sentences (Bader & Meng, 1999; Gorrell, 2000).

Results confirmed the raised hypothesis and revealed that participants benefit from speech rhythmic regularity. Fewer errors were made and faster responses were obtained when participants were presented with rhythmically regular sentences in comparison to their rhythmically irregular counterparts. Additionally, a reduction in the P600 mean amplitude was found in response to object-first sentences when these were embedded in rhythmically regular context.

In Experimental study 2, Turkish early (TELG) and late L2 learners of German (TLLG) and German monolingual controls (GMC) were tested using the same experimental design and stimulus material as in Experimental study 1. Again, participants listened to syntactically ambiguous sentences embedded in rhythmically regular and irregular context. Here, was investigated if L2 rhythmic properties can be learned and used as a sentence segmentation cue to facilitate the processing and comprehension of syntactically ambiguous sentences. To control for individual differences in cognitive ability, which could have affected participants' performances, subjects were tested for their phonological memory and working memory capacities (Juffs & Harrington, 2011; Noort et al., 2006).

No behavioral evidence was found to indicate a rhythmic facilitation effect (i.e., no differences were found in accuracy rates or reaction times). ERP results, on the other hand, revealed a reduction in the P600 mean amplitude in TELG and GMC in response to object-first sentences when embedded in rhythmically regular context. No such reduction was found for TLLG.

In Experimental study 3, Turkish early and late L2 learners of German and German late learners of English were tested with respect to their musical rhythmic aptitude. As previously mentioned, Turkish and German were chosen for investigation because of the diversity in their rhythmic features, i.e., distinct metric preference as well as rhythmic organization (Eisenberg, 1991; Inkelas & Orgun, 2003; Pike, 1945; Topbas, 2006). Thus, being sensitive to such diversity in rhythmic properties may enhance L2 learners' attention to speech rhythmic variation, as it can provide relevant information for language discrimination and selection. In addition, participants' short-term memory and working memory capacities and melodic aptitude were measured and taken into consideration. Furthermore, participants were inquired regarding their weekly exposure to music and formal musical training.

Results reveal that Turkish early and late L2 learners of German perceived musical rhythmic variation significantly better than German late learners of English. No differences were found between early and late L2 learners.

The findings of the present dissertation can be summarized as follows:

- A rhythmically regular organization of speech may be used as cue during sentence segmentation in L1, facilitating the processing and comprehension of syntactically ambiguous sentences (**experimental study 1**);
- Rhythmically regular organization of speech may be used by early L2 learners as cue during L2 sentence processing, facilitating the parsing of syntactically ambiguous sentences (**experimental study 2**);
- Late L2 learners do not seem to profit from the rhythmically regular organization of speech during L2 sentence processing. Therefore, no facilitation effect was observed in this group (**experimental study 2**);
- Sensitivity to different rhythmic properties as a result of mastering two languages with different rhythmic organization seems to be transferable to the musical domain, enhancing musical rhythmic perception in L2 learners (**experimental study 3**).

With the current results, implications can be derived regarding the role of speech rhythm as a sentence segmentation device, its use in the context of L2, and in the music domain. These implications will be presented in the following.

Regarding experimental study 1, investigating speech rhythm and the processing of syntactically ambiguous sentences, findings are in line with language processing models predicting an interactive use of linguistic information, i.e., rhythm. Findings also support the idea of an existing prosodic representation as part of the ideal hearer's language competence (Nespor & Vogel, 1986; Patel, 2008). This mental representation is available in early stages of language processing, interacting with the parser and guiding it through the processing of syntactic constituents (Kennedy et al., 1989; Kjelgaard & Speer, 1999; Murray et al., 1998; Schafer, 1997; Speer et al., 1996). The current research provides further evidence of an interactive use of such early prosodic representation, but from a different perspective. While previous studies investigate speech organization in terms of pitch variation, the current research does so by addressing the role of rhythm, the other prosodic facet, in speech organization.

Moreover, results also suggest an incremental use of linguistic information, i.e., rhythmic and syntactic, during sentence processing (Carroll & Slowiaczek, 1987; Kennedy et al., 1989; Kjelgaard & Speer, 1999; Murray et al., 1998; Schafer, 1997; Slowiaczek, 1981; Speer et al., 1996). This may be the case because rhythmic regularity seems to be continuously incorporated as linguistic information into the ongoing language processing as it marks the boundaries of prosodic constituents. These prosodic constituents may be used as perceptual (Martin, 1967; Morgan, 1996; Tyler & Warren, 1987) and, therefore, processing units by the syntactic parser (Carroll & Slowiaczek, 1987; Slowiaczek, 1981), reducing memory load and facilitating language processing (Kennedy et al., 1989; Murray et al., 1998; Schafer, 1997). Thus, when predictable and reliable prosodic organization is created by rhythm, syntactic processing costs may be reduced.

In experimental study 2, where speech rhythm was addressed in the context of L2 processing, results suggest that the use of speech rhythm may be subject to age of acquisition (AoA). This may be the case because only Turkish early, but not late learners of German were comparable to German controls in terms of the rhythmic facilitation effect presented during syntactic ambiguity processing.

Regarding the non-native-like processing observed among late learners is consistent with, at least, three possible explanations. First, similarly to the attainment of L2 phonology (Flege et al., 1999; J. S. Johnson & Newport, 1989; Piske et al., 2001b), there could be a sensitive period in which L2 rhythmic information should be acquired to be used as relevant linguistic information during sentence processing. This may have constrained the acquisition of rhythmic properties in L2 by Turkish late L2 learners.

It has been suggested that phonological rules operating in the lower prosodic domains are language specific, while universal rules are found in the higher prosodic domains, where experimental rhythmic manipulation was performed. If there is a sensitive period to acquire L2 rhythmic information, this should have a greater impact in the organization of lower prosodic domains, i.e., affecting word segmentation, than in higher ones. Therefore, the detection and use of rhythmic regularity by late L2 learners in higher prosodic domains should not be severely affected by L2 AoA. Nevertheless, phonological rules operate across domains (Nespor & Vogel, 1986), which could have created a conflict between language specific and universal rules, neutralizing possible rhythmic benefits.

Second, perhaps the non-native processing showed by L2 late learners results from limitation in their cognitive resources (Ardila, 2003; Juffs & Harrington, 2011; Noort et al., 2006). In face of the high complexity found in syntactically ambiguous sentences, late learners allocated many cognitive resources to resolve syntactic ambiguity. Hence, their use of extra linguistic information available in the speech signal, i.e., rhythmic regularity, may be limited (Carpenter & Just, 1989; Daneman & Merikle, 1996; Just & Carpenter, 1992). One may argue that such an explanation should also hold true for early learners. However, it could be that early learners used cognitive resources more effectively than late learners as a result of higher language proficiency (Ardila, 2003; Noort et al., 2006).

Finally, the third possible explanation for the presented results is related to the processing of syntactic ambiguity. As rhythm interacts with syntax, organizing speech, perhaps what is affecting the outcome of this interaction is the difference in the syntactic processing showed by late learners. Research suggest that regardless of proficiency and L2 time of exposure late learners do not process complex syntactic structures native-like (Felser & Roberts, 2007; Love et al., 2003; Marinis et al., 2005; Papadopoulou & Clahsen, 2003). This could result from limited attainment in L2 grammar (Hawkins, 2001; Mueller, 2005; Papadopoulou, 2005; White & Genesee, 1996), or limited use of their procedural memory during syntactic processing (Ullman, 2004).

Regarding experimental study 3, results provide further empirical evidence of shared underlying mechanisms and properties between rhythm in language and in music, paralleling with previous research (Jackendoff, 1989; Mithen, 2005; Patel, 2003, 2008). In both domains, rhythm relies on general acoustic properties, such as intensity and duration, to group events into perception units (Bispham, 2006; Lerdahl & Jackendoff, 1983; Nespor & Vogel, 1986; Patel & Daniele, 2003; Ramus, Hauser, Miller, Morris, & Mehler, 2000; Tincoff et al., 2005; Toro et al., 2003). These units, in turn, help to structure the acoustic signal, creating expectations regarding the upcoming events in the acoustic signal, being it linguistic or musical (Cummins & Port, 1998; Lerdahl & Jackendoff, 1983; Schmidt-Kassow & Kotz, 2008).

Previous research suggests that when a skill, such the use of rhythm in language, is highly practiced, it may be applied to perceptually similar situations (Salomon & Perkins, 1989), as in the perception of rhythm in music. In this sense, when individuals observe in music similar acoustic properties, e.g., stress, as in language, perhaps, procedural knowledge may be transferred from one domain to the other.

Nevertheless, even though L2 learners seem to detect musical rhythmic variation significantly better than German late learners of English, this advantage did not translate back into a superior processing of rhythmically regular sentences (experimental study 2). Only early learners seem to benefit from a rhythmically regular context during syntactic ambiguity processing, but they did so at similar levels to monolinguals instead of surpassing them. It could be that early but not late L2 learners can accurately select the target language during its processing, effectively suppressing the non-target language together with its rhythmic properties. In this sense, early learners would present a set of rhythmic properties only from one language to choose from while processing it.

Concerning late learners, as it was previously argued, the contrast between their sensitivity in musical rhythmic perception and lack of it during sentence processing could result from limitations on L2 grammar attainment or cognitive resources. During speech processing, rhythm interacts with other linguistic domains, such as syntax, organizing it into prosodic units. If any part of this interaction is affected, this may affect its end-product. Hence, limitations on L2 grammar or cognitive resources could have overshadowed their sensitivity to general acoustic properties, on which speech rhythm relies.

Chapter 10

Limitations and Future Directions

In this dissertation, speech rhythm was investigated as a sentence segmentation device in terms of its function, a possible limitation on its use (in L2 context) and as a cognitive skill transfer to the music domain. Results suggest that when rhythmic regularity is provided in higher prosodic domains, where it interacts with syntax, the processing and comprehension of syntactically ambiguous sentences is facilitated. Therefore, further empirical evidence was provided for the use of speech rhythm as an organization device at higher levels of the prosodic hierarchy.

In addition, the present findings indicate that second language AoA may constrain the use of speech rhythm as a sentence segmentation device, as only early, but not late L2 learners showed comparable rhythmic effect to monolinguals. Finally, results reveal that speech rhythm may be transferred as a cognitive skill to the music domain, enhancing musical rhythmic aptitude.

In face of the present results some limitations can be observed. In experimental study 1, speech rhythm was found to facilitate syntactic ambiguity resolution and comprehension. In this study, individual differences in cognitive capacities or musical rhythmic aptitude were not taken into consideration. It could be that rhythmic regularity may be used as a compensatory mechanism for working memory capacity. In this case, when presented with rhythmic regularity, individuals with high and low working memory spans could behave alike. Additionally, when considering musical rhythmic aptitude, perhaps individuals with higher sensitivity to musical rhythm would respond better to rhythmic regularity than individuals with lower rhythmic aptitude in music. Therefore, future studies investigating the use of speech rhythm should address individual cognitive ability and rhythmic aptitude.

With respect to experimental study 2, speech rhythm was investigated in L2 processing using syntactic complexity. Despite participants' high proficiency, they may still present a non-native-like processing in response to syntactically complex structures, such as in case-ambiguous sentences (Clahsen & Felser, 2006; Felser & Roberts, 2007; Love et al., 2003; Marinis et al., 2005; Papadopoulou & Clahsen, 2003). Future investigations with L2 learners should be carried out using other linguistic domains, such as semantics, where L2 attainment would be more comparable to native (Hernandez & Li, 2007; Ojima et al., 2005; Sanders & Neville, 2003).

Regarding experimental study 3, only Turkish L2 learners of German were tested their musical rhythmic perception. If speech rhythm accounts for an enhanced musical aptitude, then German L2 learners of Turkish should also present enhanced sensitivity to musical rhythm in comparison to German late learners of English. Additionally to rule out the possibility that musical rhythmic aptitude relies on the mastery of the Turkish language, Turkish monolinguals should also be tested regarding their musical rhythmic perception.

Moreover, L2 learners from languages sharing some of their rhythmic properties, such as metric preference or rhythmic organization, should be tested. This could provide a more complete understanding of which rhythmic properties contribute more or less to an enhancement in rhythmic aptitude in music.

If on the one hand, being sensitive to rhythmic properties from distinct languages may enhance rhythmic perception in music, perhaps similar reasoning applies to the other direction of effects. Namely, musical rhythmic training may enhance sensitivity in perceiving speech rhythm. Evidence provided by studies investigating pitch variation in music and in language supports such reasoning. One the one hand, studies report that melodic aptitude has a positive association with L2 skills, such as pronunciation (Milovanov et al., 2008) and phonological perception (Slevc & Miyake, 2006). On the other hand, language skills may enhance melodic aptitude (D. Deutsch et al., 2006; Elmer et al., 2011).

If skill transfer between language and music can be observed in terms of pitch variation in both directions, it is very likely that similar effect could be found for rhythm. Therefore, more studies addressing speech rhythm in terms of skill transfer from the musical to the language domain should be carried out.

Finally, one could investigate rhythm as a skill transfer phenomenon across other cognitive domains where temporal organization is also found. For instance, one could investigate the transferability of gestures in language to body movements in dance (Steven Brown, Martinez, & Parsons, 2006; Wachsmuth, 1999). Perhaps only then, a true understanding about cognitive transfer between different domains could be gained.

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Appendix

Stimulus material (experimental study 1 and 2)

Conditions:

SFI = subject-first rhythmically irregular
SFR = subject-first rhythmically regular
OFI = object-first rhythmically irregular
OFR = object-first rhythmically regular

Condition	Sentence
SFI	Bernhard trifft die Gehilfen, die Nicole mal gestört haben, im Park.
Filler SFI	Eckard trifft den Gehilfen, der Jana mal gestört hat, im Geschäft.
SFR	Roland trifft die Diener, die Antonio mal gestört haben, im Park.
Filler SFR	Arno trifft den Diener, der Riccardo mal gestört hat, im Geschäft.
OFI	Paula trifft die Gehilfen, die Joel mal gestört hat, im Geschäft.
Filler OFI	Ellen trifft den Gehilfen, den Karsten mal gestört hat, im Geschäft.
OFR	Dora trifft die Diener, die Charlotte mal gestört hat, im Geschäft.
Filler OFR	Maren trifft den Diener, den Lorena mal gestört hat, im Geschäft.
SFI	Paula trifft die Kollegen, die Karsten mal gedrückt haben, im Park.
Filler SFI	Ellen trifft den Kollegen, der Renée mal gedrückt hat, im Büro.
SFR	Dora trifft die Kumpel, die Bettina mal gedrückt haben, im Park.
Filler SFR	Maren trifft den Kumpel, der Charlotte mal gedrückt hat, im Büro.
OFI	Arno trifft die Kollegen, die Jana mal gedrückt hat, im Büro.
Filler OFI	Bernhard trifft den Kollegen, den Nicole mal gedrückt hat, im Büro.
OFR	Eckard trifft die Kumpel, die Andreas mal gedrückt hat, im Büro.
Filler OFR	Roland trifft den Kumpel, den Antonio mal gedrückt hat, im Büro.
SFI	Arno trifft die Matrosen, die Kathleen mal gegrüßt haben, im Park.
Filler SFI	Bernhard trifft den Matrosen, der Jana mal gegrüßt hat, im Café.
SFR	Eckard trifft die Schiffer, die Dimitri mal gegrüßt haben, im Park.
Filler SFR	Roland trifft den Schiffer, der Andreas mal gegrüßt hat, im Café.
OFI	Maren trifft die Matrosen, die Andrej mal gegrüßt hat, im Café.
Filler OFI	Paula trifft den Matrosen, den Karsten mal gegrüßt hat, im Café.
OFR	Ellen trifft die Schiffer, die Anita mal gegrüßt hat, im Café.
Filler OFR	Dora trifft den Schiffer, den Bettina mal gegrüßt hat, im Café.
SFI	Maren trifft die Praktikanten, die Andrej mal gemalt haben, im Park.

Filler SFI	Paula trifft den Praktikanten, der Karsten mal gemalt hat, im Park.
SFR	Ellen trifft die Lehrlinge, die Bettina mal gemalt haben, im Park.
Filler SFR	Dora trifft den Lehrling, der Anita mal gemalt hat, im Café.
OFI	Roland trifft die Praktikanten, die Kathleen mal gemalt hat, im Park.
Filler OFI	Arno trifft den Praktikanten, den Jana mal gemalt hat, im Park.
OFR	Bernhard trifft die Lehrlinge, die Andreas mal gemalt hat, im Café.
Filler OFR	Eckard trifft den Lehrling, den Dimitri mal gemalt hat, im Café.
SFI	Roland trifft die Vermittler, die Jana mal gewarnt haben, im Park.
Filler SFI	Arno trifft den Vermittler, der Nicole mal gewarnt hat, im Büro.
SFR	Bernhard trifft die Makler, die Elias mal gewarnt haben, im Park.
Filler SFR	Eckard trifft den Makler, der Andreas mal gewarnt hat, im Büro.
OFI	Dora trifft die Vermittler, die Karsten mal gewarnt hat, im Büro.
Filler OFI	Maren trifft den Vermittler, den Joel mal gewarnt hat, im Büro.
OFR	Paula trifft die Makler, die Brigitte mal gewarnt hat, im Büro.
Filler OFR	Ellen trifft den Makler, den Bettina mal gewarnt hat, im Büro.
SFI	Dora trifft die Akteure, die Kathleen mal geschult haben, im Park.
Filler SFI	Maren trifft den Akteur, der Jutta mal geschult hat, im Geschäft.
SFR	Paula trifft die Schauspieler, die Judith mal geschult haben, im Park.
Filler SFR	Ellen trifft den Schauspieler, der Karsten mal geschult hat, im Geschäft.
OFI	Eckard trifft die Akteure, die Andrej mal geschult hat, im Geschäft.
Filler OFI	Roland trifft den Akteur, den Konrad mal geschult hat, im Geschäft.
OFR	Arno trifft die Schauspieler, die Kasper mal geschult hat, im Geschäft.
Filler OFR	Bernhard trifft den Schauspieler, den Jana mal geschult hat, im Geschäft.
SFI	Eckard trifft die Regisseure, die Andrej mal gefoppt haben, im Park.
Filler SFI	Roland trifft den Regisseur, der Bettina mal gefoppt hat, im Park.
SFR	Arno trifft die Spielleiter, die Mona mal gefoppt haben, im Park.
Filler SFR	Bernhard trifft den Spielleiter, der Karsten mal gefoppt hat, im Geschäft.
OFI	Ellen trifft die Regisseure, die Kathleen mal gefoppt hat, im Park.
Filler OFI	Dora trifft den Regisseur, den Andreas mal gefoppt hat, im Park.
OFR	Maren trifft die Spielleiter, die Otto mal gefoppt hat, im Geschäft.
Filler OFR	Paula trifft den Spielleiter, den Jana mal gefoppt hat, im Geschäft.
SFI	Ellen trifft die Analysten, die Karsten mal gemocht haben, im Park.
Filler SFI	Dora trifft den Analysten, der Renée mal gemocht hat, im Park.
SFR	Maren trifft die Banker, die Roberto mal gemocht haben, im Park.
Filler SFR	Paula trifft den Banker, der Andreas mal gemocht hat, im Geschäft.
OFI	Bernhard trifft die Analysten, die Jana mal gemocht hat, im Park.
Filler OFI	Eckard trifft den Analysten, den Nicole mal gemocht hat, im Park.
OFR	Roland trifft die Banker, die Annette mal gemocht hat, im Geschäft.
Filler OFR	Arno trifft den Banker, den Bettina mal gemocht hat, im Geschäft.

SFI	Bruno trifft die Betreuer, die Katrhin mal gesucht haben, im Park.
Filler SFI	Boris trifft den Betreuer, der Kathleen mal gesucht hat, im Café.
SFR	Axel trifft die Ausbilder, die Leo mal gesucht haben, im Park.
Filler SFR	Achim trifft den Ausbilder, der Kasper mal gesucht hat, im Café.
OFI	Carmen trifft die Betreuer, die Timo mal gesucht hat, im Café.
Filler OFI	Astrid trifft den Betreuer, den Andrej mal gesucht hat, im Café.
OFR	Anna trifft die Ausbilder, die Karen mal gesucht hat, im Café.
Filler OFR	Anke trifft den Ausbilder, den Judith mal gesucht hat, im Café.
SFI	Carmen trifft die Produzenten, die Mona mal geschützt haben, im Park.
Filler SFI	Astrid trifft den Produzenten, der Andrej mal geschützt hat, im Park.
SFR	Anna trifft die Hersteller, die Kerstin mal geschützt haben, im Park.
Filler SFR	Anke trifft den Hersteller, der Judith mal geschützt hat, im Büro.
OFI	Achim trifft die Produzenten, die Otto mal geschützt hat, im Park.
Filler OFI	Bruno trifft den Produzenten, den Kathleen mal geschützt hat, im Park.
OFR	Boris trifft die Hersteller, die Linos mal geschützt hat, im Büro.
Filler OFR	Axel trifft den Hersteller, den Kasper mal geschützt hat, im Büro.
SFI	Achim trifft die Direktoren, die Judith mal gestresst haben, im Park.
Filler SFI	Bruno trifft den Direktor, der Nicole mal gestresst hat, im Geschäft.
SFR	Boris trifft die Leiter, die Joachim mal gestresst haben, im Park.
Filler SFR	Axel trifft den Leiter, der Bettina mal gestresst hat, im Geschäft.
OFI	Anke trifft die Direktoren, die Renée mal gestresst hat, im Zug.
Filler OFI	Carmen trifft den Direktor, den Kasper mal gestresst hat, im Geschäft.
OFR	Astrid trifft die Leiter, die Corinna mal gestresst hat, im Geschäft.
Filler OFR	Anna trifft den Leiter, den Andreas mal gestresst hat, im Geschäft.
SFI	Anke trifft die Kanadier, die Kathleen mal geheilt haben, im Park.
Filler SFI	Carmen trifft den Kanadier, der Judith mal geheilt hat, im Café.
SFR	Astrid trifft die Dänen, die Dimitri mal geheilt haben, im Park.
Filler SFR	Anna trifft den Dänen, der Antonio mal geheilt hat, im Café.
OFI	Axel trifft die Kanadier, die Andrej mal geheilt hat, im Café.
Filler OFI	Achim trifft den Kanadier, den Kasper mal geheilt hat, im Café.
OFR	Bruno trifft die Dänen, die Anita mal geheilt hat, im Café.
Filler OFR	Boris trifft den Dänen, den Charlotte mal geheilt hat, im Café.
SFI	Anna trifft die Referenten, die Jacqueline mal gefilmt haben, im Park.
Filler SFI	Anke trifft den Referenten, der Judith mal gefilmt hat, im Park.
SFR	Carmen trifft die Redner, die Brigitte mal gefilmt haben, im Park.
Filler SFR	Astrid trifft den Redner, der Charlotte mal gefilmt hat, im Geschäft.
OFI	Boris trifft die Referenten, die Marcel mal gefilmt hat, im Park.
Filler OFI	Axel trifft den Referenten, den Kasper mal gefilmt hat, im Park.

OFR	Achim trifft die Redner, die Elias mal gefilmt hat, im Geschäft.
Filler OFR	Bruno trifft den Redner, den Antonio mal gefilmt hat, im Geschäft.
SFI	Boris trifft die Studenten, die Renée mal gewählt haben, im Park.
Filler SFI	Axel trifft den Studenten, der Kasper mal gewählt hat, im Café.
SFR	Achim trifft die Schüler, die Antonio mal gewählt haben, im Park.
Filler SFR	Bruno trifft den Schüler, der Elias mal gewählt hat, im Café.
OFI	Astrid trifft die Studenten, die Nicole mal gewählt hat, im Café.
Filler OFI	Anna trifft den Studenten, den Judith mal gewählt hat, im Café.
OFR	Anke trifft die Schüler, die Charlotte mal gewählt hat, im Café.
Filler OFR	Carmen trifft den Schüler, den Brigitte mal gewählt hat, im Café.
SFI	Astrid trifft die Beamten, die Marcel mal gehetzt haben, im Park.
Filler SFI	Anna trifft den Beamten, der Konrad mal gehetzt hat, im Geschäft.
SFR	Anke trifft die Zöllner, die Annette mal gehetzt haben, im Park.
Filler SFR	Carmen trifft den Zöllner, der Antonio mal gehetzt hat, im Geschäft.
OFI	Bruno trifft die Beamten, die Nadine mal gehetzt hat, im Geschäft.
Filler OFI	Boris trifft den Beamten, den Jutta mal gehetzt hat, im Geschäft.
OFR	Axel trifft die Zöllner, die Roberto mal gehetzt hat, im Geschäft.
Filler OFR	Achim trifft den Zöllner, den Charlotte mal gehetzt hat, im Geschäft.
SFI	Detlev trifft die Kuriere, die Linos mal gestoppt haben, im Park.
Filler SFI	Dennis trifft den Kurier, der Nicole mal gestoppt hat, im Büro.
SFR	David trifft die Briefträger, die Karen mal gestoppt haben, im Park.
Filler SFR	Christoph trifft den Briefträger, der Jutta mal gestoppt hat, im Büro.
OFI	Ellen trifft die Kuriere, die Kerstin mal gestoppt hat, im Büro.
Filler OFI	Ella trifft den Kurier, den Renée mal gestoppt hat, im Büro.
OFR	Elke trifft die Briefträger, die Leo mal gestoppt hat, im Büro.
Filler OFR	Conny trifft den Briefträger, den Konrad mal gestoppt hat, im Büro.
SFI	David trifft die Kandidaten, die Timo mal gemobbt haben, im Zug.
Filler SFI	Christoph trifft den Kandidaten, der Renée mal gemobbt hat, im Zug.
SFR	Detlev trifft die Prüflinge, die Konrad mal gemobbt haben, im Zug.
Filler SFR	Dennis trifft den Prüfling, der Dimitri mal gemobbt hat, im Café.
OFI	Elke trifft die Kandidaten, die Kathrin mal gemobbt hat, im Zug.
Filler OFI	Conny trifft den Kandidaten, den Nicole mal gemobbt hat, im Zug.
OFR	Ellen trifft die Prüflinge, die Jutta mal gemobbt hat, im Café.
Filler OFR	Ella trifft den Prüfling, den Anita mal gemobbt hat, im Café.
SFI	Elke trifft die Diplomaten, die Marcel mal geduzt haben, im Zug.
Filler SFI	Conny trifft den Diplomaten, der Jutta mal geduzt hat, im Zug.
SFR	Ellen trifft die Konsuln, die Anita mal geduzt haben, im Zug.
Filler SFR	Ella trifft den Konsul, der Annette mal geduzt hat, im Geschäft.

OFI	Dennis trifft die Diplomaten, die Nadine mal geduzt hat, im Zug.
Filler OFI	David trifft den Diplomaten, den Konrad mal geduzt hat, im Zug.
OFR	Christoph trifft die Konsuln, die Dimitri mal geduzt hat, im Gaschäft.
Filler OFR	Detlev trifft den Konsul, den Roberto mal geduzt hat, im Gechäft.
SFI	Dennis trifft die Präsidenten, die Konrad mal gelobt haben, im Zug.
Filler SFI	David trifft den Präsidenten, der Nadine mal gelobt hat, im Zug.
SFR	Christoph trifft die Kanzler, die Joachim mal gelobt haben, im Zug.
Filler SFR	Detlev trifft den Kanzler, der Elias mal gelobt hat, im Büro.
OFI	Ella trifft die Präsidenten, die Jutta mal gelobt hat, im Zug.
Filler OFI	Elke trifft den Präsidenten, den Marcel mal gelobt hat, im Zug.
OFR	Conny trifft die Kanzler, die Corinna mal gelobt hat, im Büro.
Filler OFR	Ellen trifft den Kanzler, den Brigitte mal gelobt hat, im Büro.
SFI	Ella trifft die Komponisten, die Marcel mal gekränkt haben, im Zug.
Filler SFI	Elke trifft den Komponisten, der Malte mal gekränkt hat, im Zug.
SFR	Conny trifft die Musiker, die Kirsten mal gekränkt haben, im Zug.
Filler SFR	Ellen trifft den Musiker, der Karen mal gekränkt hat, im Café.
OFI	Detlev trifft die Komponisten, die Nadine mal gekränkt hat, im Zug.
Filler OFI	Dennis trifft den Komponisten, den Laura mal gekränkt hat, im Zug.
OFR	David trifft die Musiker, die Lukas mal gekränkt hat, im Café.
Filler OFR	Christoph trifft den Musiker, den Leo mal gekränkt hat, im Café.
SFI	Gerhard trifft die Galeristen, die Mona mal gerühmt haben, im Zug.
Filler SFI	Georg trifft den Galeristen, der Annett mal gerühmt hat, im Zug.
SFR	Felix trifft die Kunsthändler die Nina mal gerühmt haben, im Zug.
Filler SFR	Erik trifft den Kunsthändler der Leo mal gerühmt hat, im Geschäft.
OFI	Flora trifft die Galeristen, die Otto mal gerühmt hat, im Zug.
Filler OFI	Eva trifft den Galeristen, den Pascal mal gerühmt hat, im Zug.
OFR	Esther trifft die Kunsthändler die Oskar mal gerühmt hat, im Geschäft.
Filler OFR	Elsa trifft den Kunsthändler den Karen mal gerühmt hat, im Geschäft.
SFI	Flora trifft die Konsumenten, die Pascal mal genervt haben, im Zug.
Filler SFI	Eva trifft den Konsumenten, der Karen mal genervt hat, im Zug.
SFR	Esther trifft die Käufer, die Elias mal genervt haben, im Zug.
Filler SFR	Elsa trifft den Käufer, der Corinna mal genervt hat, im Büro.
OFI	Erik trifft die Konsumenten, die Annett mal genervt hat, im Zug.
Filler OFI	Gerhard trifft den Konsumenten, den Leo mal genervt hat, im Zug.
OFR	Georg trifft die Käufer, die Brigitte mal genervt hat, im Büro.
Filler OFR	Felix trifft den Käufer, den Joachim mal genervt hat, im Büro.
SFI	Erik trifft die Instrukteure, die Annett mal geplagt haben, im Zug.
Filler SFI	Gerhard trifft den Instrukteur, der Brigitte mal geplagt hat, im Zug.

SFR	Georg trifft die Kursleiter, die Oskar mal geplagt haben, im Zug.
Filler SFR	Felix trifft den Kursleiter, der Leo mal geplagt hat, im Café.
OFI	Elsa trifft die Instrukteure, die Pascal mal geplagt hat, im Zug.
Filler OFI	Flora trifft den Instrukteur, den Elias mal geplagt hat, im Zug.
OFR	Eva trifft die Kursleiter, die Nina mal geplagt hat, im Café.
Filler OFR	Esther trifft den Kursleiter, den Karen mal geplagt hat, im Café.
SFI	Elsa trifft die Konditoren, die Yvonne mal getäuscht haben, im Park.
Filler SFI	Flora trifft den Konditor, der Pascal mal getäuscht hat, im Geschäft.
SFR	Eva trifft die Bäcker, die Joachim mal getäuscht haben, im Park.
Filler SFR	Esther trifft den Bäcker, der Roberto mal getäuscht hat, im Geschäft.
OFI	Felix trifft die Konditoren, die Timo mal getäuscht hat, im Park.
Filler OFI	Erik trifft den Konditor, den Annett mal getäuscht hat, im Geschäft.
OFR	Gerhard trifft die Bäcker, die Corinna mal getäuscht hat, im Geschäft.
Filler OFR	Georg trifft den Bäcker, den Annette mal getäuscht hat, im Geschäft.
SFI	Felix trifft die Cousins, die Karen mal gepflegt haben, im Park.
Filler SFI	Erik trifft den Cousin, der Annette mal gepflegt hat, im Büro.
SFR	Gerhard trifft die Vetter, die Johannes mal gepflegt haben, im Park.
Filler SFR	Georg trifft den Vetter, der Corinna mal gepflegt hat, im Büro.
OFI	Esther trifft die Cousins, die Leo mal gepflegt hat, im Büro.
Filler OFI	Elsa trifft den Cousin, den Roberto mal gepflegt hat, im Büro.
OFR	Flora trifft die Vetter, die Daniela mal gepflegt hat, im Büro.
Filler OFR	Eva trifft den Vetter, den Joachim mal gepflegt hat, im Büro.
SFI	Esther trifft die Franzosen, die Leander mal gesiezt haben, im Park.
Filler SFI	Elsa trifft den Franzosen, der Timo mal gesiezt hat, im Café.
SFR	Flora trifft die Briten, die Tobias mal gesiezt haben, im Park.
Filler SFR	Eva trifft den Briten, der Roberto mal gesiezt hat, im Café.
OFI	Georg trifft die Franzosen, die Darina mal gesiezt hat, im Café.
Filler OFI	Felix trifft den Franzosen, den Kathrin mal gesiezt hat, im Café.
OFR	Erik trifft die Briten, die Elisa mal gesiezt hat, im Café.
Filler OFR	Gerhard trifft den Briten, den Annette mal gesiezt hat, im Café.
SFI	Georg trifft die Verwandten, die Kathrin mal geschätzt haben, im Park.
Filler SFI	Felix trifft den Verwandten, der Pascal mal geschätzt hat, im Büro
SFR	Erik trifft die Opas, die Annette mal geschätzt haben, im Park.
Filler SFR	Gerhard trifft den Opa, der Daniela mal geschätzt hat, im Büro.
OFI	Eva trifft die Verwandten, die Timo mal geschätzt hat, im Büro
Filler OFI	Esther trifft den Verwandten, den Annett mal geschätzt hat, im Büro.
OFR	Elsa trifft die Opas, die Roberto mal geschätzt hat, im Büro.
Filler OFR	Flora trifft den Opa, den Johannes mal geschätzt hat, im Büro.

SFI	Eva trifft die Kameraden, die Timo mal gequält haben, im Zug.
Filler SFI	Esther trifft den Kameraden, der Annett mal gequält hat, im Zug.
SFR	Elsa trifft die Brüder, die Joachim mal gequält haben, im Zug.
Filler SFR	Flora trifft den Bruder, der Darina mal gequält hat, im Café.
OFI	Gerhard trifft die Kameraden, die Kathrin mal gequält hat, im Zug.
Filler OFI	Georg trifft den Kameraden, den Pascal mal gequält hat, im Zug.
OFR	Felix trifft die Brüder, die Corinna mal gequält hat, im Café.
Filler OFR	Erik trifft den Bruder, den Leander mal gequält hat, im Café.
SFI	Hendrik trifft die Gelehrten, die Pascal mal gereizt haben, im Park.
Filler SFI	Heinrich trifft den Gelehrten, der Kathrin mal gereizt hat, im Geschäft.
SFR	Hellmut trifft die Forscher, die Leander mal gereizt haben, im Park.
Filler SFR	Heiko trifft den Forscher, der Corinna mal gereizt hat, im Geschäft.
OFI	Greta trifft die Gelehrten, die Marcel mal gereizt hat, im Geschäft.
Filler OFI	Gerda trifft den Gelehrten, den Timo mal gereizt hat, im Geschäft.
OFR	Frieda trifft die Forscher, die Darina mal gereizt hat, im Geschäft.
Filler OFR	Frauke trifft den Forscher, den Joachim mal gereizt hat, im Geschäft.
SFI	Greta trifft die Philosophen, die Timo mal gerügt haben, im Zug.
Filler SFI	Gerda trifft den Philosophen, der Annett mal gerügt hat, im Zug.
SFR	Frieda trifft die Denker, die Darina mal gerügt haben, im Zug.
Filler SFR	Frauke trifft den Denker, der Daniela mal gerügt hat, im Büro.
OFI	Heiko trifft die Philosophen, die Kathrin mal gerügt hat, im Zug.
Filler OFI	Hendrik trifft den Philosophen, den Pascal mal gerügt hat, im Zug.
OFR	Heinrich trifft die Denker, die Leander mal gerügt hat, im Büro.
Filler OFR	Hellmut trifft den Denker, den Johannes mal gerügt hat, im Büro.
SFI	Frauke trifft die Poeten, die Maurice mal geehrt haben, im Park.
Filler SFI	Greta trifft den Poeten, der Linos mal geehrt hat, im Café.
SFR	Gerda trifft die Dichter, die Elisa mal geehrt haben, im Park.
Filler SFR	Frieda trifft den Dichter, der Daniela mal geehrt hat, im Café.
OFI	Hellmut trifft die Poeten, die Yvonne mal geehrt hat, im Café.
Filler OFI	Heiko trifft den Poeten, den Kerstin mal geehrt hat, im Café.
OFR	Hendrik trifft die Dichter, die Tobias mal geehrt hat, im Café.
Filler OFR	Heinrich trifft den Dichter, den Johanes mal geehrt hat, im Café.
SFI	Frieda trifft die Theologen, die Maurice mal gesandt haben, im Zug.
Filler SFI	Frauke trifft den Theologen, der Judith mal gesandt hat, im Zug.
SFR	Greta trifft die Kleriker, die Oskar mal gesandt haben, im Zug.
Filler SFR	Gerda trifft den Kleriker, der Simon mal gesandt hat, im Büro.
OFI	Heinrich trifft die Theologen, die Yvonne mal gesandt hat, im Zug.
Filler OFI	Hellmut trifft den Theologen, den Leo mal gesandt hat, im Zug.
OFR	Heiko trifft die Kleriker, die Kathrin mal gesandt hat, im Büro.

Filler OFR	Hendrik trifft den Kleriker, den Nora mal gesandt hat, im Büro.
SFI	Gerda trifft die Dozenten, die Maurice mal geschockt haben, im Park.
Filler SFI	Frieda trifft den Dozenten, der Kerstin mal geschockt hat, im Geschäft.
SFR	Frauke trifft die Lehrer, die Elisa mal geschockt haben, im Park.
Filler SFR	Greta trifft den Lehrer, der Darina mal geschockt hat, im Geschäft.
OFI	Hendrik trifft die Dozenten, die Renée mal geschockt hat, im Geschäft.
Filler OFI	Heinrich trifft den Dozenten, den Linos mal geschockt hat, im Geschäft.
OFR	Hellmut trifft die Lehrer, die Tobias mal geschockt hat, im Geschäft.
Filler OFR	Heiko trifft den Lehrer, den Leander mal geschockt hat, im Geschäft.
SFI	Jacob trifft die Verwalter die Yvonne mal geküsst haben, im Park.
Filler SFI	Ingmar trifft den Verwalter der Annett mal geküsst hat, im Büro
SFR	Ingo trifft die Manager, die Nina mal geküsst haben, im Park.
Filler SFR	Henning trifft den Manager, der Laura mal geküsst hat, im Büro.
OFI	Greta trifft die Verwalter die Kathleen mal geküsst hat, im Büro.
Filler OFI	Hilde trifft den Verwalter den Jacqueline mal geküsst hat, im Büro.
OFR	Heike trifft die Manager, die Kerstin mal geküsst hat, im Büro.
Filler OFR	Heidi trifft den Manager, den Nora mal geküsst hat, im Büro.
SFI	Greta trifft die Passanten, die Otto mal gefragt haben, im Park.
Filler SFI	Hilde trifft den Passanten, der Oskar mal gefragt hat, im Café.
SFR	Heike trifft die Fußgänger, die Malte mal gefragt haben, im Park.
Filler SFR	Heidi trifft den Fußgänger, der Lukas mal gefragt hat, im Café.
OFI	Henning trifft die Passanten, die Mona mal gefragt hat, im Café.
Filler OFI	Jacob trifft den Passanten, den Nina mal gefragt hat, im Café.
OFR	Ingmar trifft die Fußgänger, die Laura mal gefragt hat, im Café.
Filler OFR	Ingo trifft den Fußgänger, den Kirsten mal gefragt hat, im Café.
SFI	Heike trifft die Athleten, die Marie mal geweckt haben, im Park.
Filler SFI	Heidi trifft den Athleten, der Lukas mal geweckt hat, im Geschäft.
SFR	Greta trifft die Sportler, die Mareike mal geweckt haben, im Park.
Filler SFR	Hilde trifft den Sportler, der Elisa mal geweckt hat, im Geschäft.
OFI	Ingmar trifft die Athleten, die Jerome mal geweckt hat, im Geschäft.
Filler OFI	Ingo trifft den Athleten, den Kirstin mal geweckt hat, im Geschäft.
OFR	Henning trifft die Sportler, die Mathäus mal geweckt hat, im Geschäft.
Filler OFR	Jacob trifft den Sportler, den Tobias mal geweckt hat, im Geschäft.
SFI	Ingmar trifft die Genossen, die Kirstin mal geprüft haben, im Park.
Filler SFI	Ingo trifft den Genossen, der Jerome mal geprüft hat, im Büro.
SFR	Henning trifft die Partner, die Mathäus mal geprüft haben, im Park.
Filler SFR	Jacob trifft den Partner, der Alexis mal geprüft hat, im Büro.
OFI	Hilde trifft die Genossen, die Lukas mal geprüft hat, im Büro.

Filler OFI	Heike trifft den Genossen, den Marie mal geprüft hat, im Büro.
OFR	Heidi trifft die Partner, die Mareike mal geprüft hat, im Büro.
Filler OFR	Greta trifft den Partner, den Kathrina mal geprüft hat, im Büro.
SFI	Iris trifft die Rebellen, die Marie mal gepackt haben, im Park.
Filler SFI	Ingrid trifft den Rebellen, der Lukas mal gepackt hat, im Café.
SFR	Ina trifft die Hetzer, die Kathrina mal gepackt haben, im Park.
Filler SFR	Ilka trifft den Hetzer, der Riccardo mal gepackt hat, im Café.
OFI	Jürgen trifft die Rebellen, die Jerome mal gepackt hat, im Café.
Filler OFI	Josef trifft den Rebellen, den Kirstin mal gepackt hat, im Café.
OFR	Jonas trifft die Hetzer, die Alexis mal gepackt hat, im Café.
Filler OFR	Jochen trifft den Hetzer, den Lorena mal gepackt hat, im Café.
SFI	Ilka trifft die Assistenten, die Marie mal geneckt haben, im Zug.
Filler SFI	Iris trifft den Assistenten, der Laura mal geneckt hat, im Zug.
SFR	Ingrid trifft die Helfer, die Kathrina mal geneckt haben, im Zug.
Filler SFR	Ina trifft den Helfer, der Mathäus mal geneckt hat, im Geschäft.
OFI	Jochen trifft die Assistenten, die Jerome mal geneckt hat, im Zug.
Filler OFI	Jürgen trifft den Assistenten, den Malte mal geneckt hat, im Zug.
OFR	Josef trifft die Helfer, die Alexis mal geneckt hat, im Geschäft.
Filler OFR	Jonas trifft den Helfer, den Mareike mal geneckt hat, im Geschäft.
SFI	Jochen trifft die Experten, die Malte mal gekürt haben, im Park.
Filler SFI	Jürgen trifft den Experten, der Jerome mal gekürt hat, im Büro.
SFR	Josef trifft die Meister, die Mathäus mal gekürt haben, im Park.
Filler SFR	Jonas trifft den Meister, der Lorena mal gekürt hat, im Büro.
OFI	Ina trifft die Experten, die Laura mal gekürt hat, im Büro.
Filler OFI	Ilka trifft den Experten, den Marie mal gekürt hat, im Büro.
OFR	Iris trifft die Meister, die Mareike mal gekürt hat, im Büro.
Filler OFR	Ingrid trifft den Meister, den Riccardo mal gekürt hat, im Büro.
SFI	Ina trifft die Emigranten, die Mona mal geschubst haben, im Zug.
Filler SFI	Ilka trifft den Emigranten, der Joel mal geschubst hat, im Zug.
SFR	Iris trifft die Flüchtlinge, die Laura mal geschubst haben, im Zug.
Filler SFR	Ingrid trifft den Flüchtling, der Enrico mal geschubst hat, im Café.
OFI	Jonas trifft die Emigranten, die Otto mal geschubst hat, im Zug.
Filler OFI	Jochen trifft den Emigranten, den Jacqueline mal geschubst hat, im Zug.
OFR	Jürgen trifft die Flüchtlinge, die Malte mal geschubst hat, im Café.
Filler OFR	Josef trifft den Flüchtling, den Patricia mal geschubst hat, im Café.
SFI	Jonas trifft die Humoristen, die Joel mal geschickt haben, im Zug.
Filler SFI	Jochen trifft den Humoristen, der Karen mal geschickt hat, im Zug.
SFR	Jürgen trifft die Komiker, die Otto mal geschickt haben, im Zug.

Filler SFR	Josef trifft den Komiker, der Malte mal geschickt hat, im Geschäft.
OFI	Ingrid trifft die Humoristen, die Jacqueline mal geschickt hat, im Zug.
Filler OFI	Ina trifft den Humoristen, den Leo mal geschickt hat, im Zug.
OFR	Ilka trifft die Komiker, die Mona mal geschickt hat, im Geschäft.
Filler OFR	Iris trifft den Komiker, den Laura mal geschickt hat, im Geschäft.
SFI	Josef trifft die Bekannten, die Joel mal geboxt haben, im Zug.
Filler SFI	Jonas trifft den Bekannten, der Jana mal geboxt hat, im Zug.
SFR	Jochen trifft die Nachbarn, die Mona mal geboxt haben, im Zug.
Filler SFR	Jürgen trifft den Nachbarn, der Oskar mal geboxt hat, im Geschäft.
OFI	Iris trifft die Bekannten, die Jacqueline mal geboxt hat, im Zug.
Filler OFI	Ingrid trifft den Bekannten, den Karsten mal geboxt hat, im Zug.
OFR	Ina trifft die Nachbarn, die Otto mal geboxt hat, im Geschäft.
Filler OFR	Ilka trifft den Nachbarn, den Nina mal geboxt hat, im Geschäft.
SFI	Peter trifft die Pensionäre, die Jacqueline mal geherzt haben, im Zug.
Filler SFI	Robert trifft den Pensionär, der Mareike mal geherzt hat, im Zug.
SFR	Rainer trifft die Rentner, die Riccardo, mal geherzt haben, im Zug.
Filler SFR	Philipp trifft den Rentner, der Enrico mal geherzt hat, im Büro.
OFI	Paula trifft die Pensionäre, die Joel mal geherzt hat, im Zug.
Filler OFI	Nora trifft den Pensionär, den Mathäus mal geherzt hat, im Zug.
OFR	Rita trifft die Rentner, die Lorena, mal geherzt hat, im Büro.
Filler OFR	Petra trifft den Rentner, den Patricia mal geherzt hat, im Büro.

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