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Experimental investigations on the prosodic realization of restrictive and appositive relative clauses in German

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Abstract

This study reports on experimental investigations on the prosodic patterns of restrictive and appositive relative clauses (RRCs and ARCs) in German. RRCs and ARCs are associated with distinct prosodic patterns: While RRCs involve prosodic integration with their antecedent and may involve an accent shift from the antecedent to the determiner, ARCs are prosodically separated from their host clause. In the framework of two production experiments and one perception experiment, RRC and ARC constructions were tested in regard to F0 scaling, segment duration, silent pauses, and accent placement under different conditions. The results support the intuitive prosodic patterns described in the literature: ARC constructions were realized with higher F0 scaling and longer word duration preceding the relative clause, which indicates the presence of a prosodic phrase boundary, and accentuation of the determiner occurred only with RRC constructions. In perception, silent pauses were taken as cues to ARCs and accent shift as a cue to RRCs. These results suggest a difference in prosodic phrase structure reflecting the different syntactic structures. However, the production experiments also revealed that the prosodic differences are absent when the communicative situation does not require the disambiguation of the relative clause types.

Keywords: Prosody; Intonation; Phrasing; Disambiguation; Relative clauses; Syntax-prosody mapping; German

1. Introduction

This study deals with the prosodic correlates of adnominal relative clauses in German. Like most languages, German distinguishes between restrictive relative clauses, which contribute to the identification of their antecedent, and appositive relative clauses, which provide additional information on their (clearly identified) antecedent. It is commonly assumed that the two types are realized with different prosodic patterns: while restrictive relative clauses (henceforth, RRCs) are prosodically integrated with their antecedent, appositive relative clauses (henceforth, ARCs) are obligatorily separated from their host clause by prosodic breaks (Downing, 1970; Garro and Parker, 1982 for English; Lehmann, 1984; Brandt, 1990; Holler, 2005 for German). However, prior empirical studies on the prosody of relative clauses in German observed that both types were realized with both prosodic patterns (Schaffranietz, 1999; Birkner, 2008) and that listeners could not reliably discriminate the two types by means of prosodic cues (Kaland and van Heuven, 2010). As a result, at least for German and although intuitions are rather strong as to the presence of such prosodic cues, there is no clear empirical evidence for the association of different prosodic patterns with different types of relative clauses.

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The present study reports on a series of experiments that tested for the prosodic correlates of RRCs and ARCs in production and perception with innovative methods. Two production experiments elicited relative clauses in read and semi-spontaneous speech under different conditions and a perception experiment tested for silent pauses and accentuation as cues for differentiating the two types of relative clauses. The results provide empirical evidence for prosodic phrase boundaries, silent pauses and accent shift as indicators for the respective types of relative clauses, thus supporting the prosodic patterns described in the literature on the basis of native speaker intuitions (Lehmann, 1984; Brandt, 1990): RRCs are prosodically integrated with their antecedent and may involve accentuation of the determiner (see also Lenerz 1977:35; Altmann 1981; Wiltschko 1997:387 for this property) and ARCs are prosodically separated from their host clause by boundary tones and silent pauses. These clear associations of prosodic patterns suggest that the different syntactic structures of RRCs and ARCs are represented as different prosodic structures respectively. The absence of (most) prosodic correlates in the data from one of the production experiments however shows that the prosodic realization of the two types of relative clauses is not only an outcome of the mapping between syntax and prosody, but that it also depends on the communicative situation: If there is no contextual relevance to express the respective type of relative clause, both types are realized with a default prosodic pattern: antecedent and relative clause are integrated and the head noun is accented. This reflects the observation that disambiguating prosodic cues are more likely to be realized when they are relevant to the situation. The results are compared with those of Kraljic and Brennan (2005), Schafer et al. (2000) and Snedeker and Trueswell (2003), who investigated audience design with different data for English.

The paper is structured as follows: section 2 presents the theoretical background on relative clauses and the prosodic system of German. It also contains an introduction to the methodological background for the studies. Section 3 presents the two production experiments and section 4 the perception experiment. Finally, section 5 provides a general discussion and some concluding remarks.

2. Background

2.1. Restrictive and appositive relative clauses

RRCs contribute to the identification of their antecedent by providing at-issue information for the interpretation of their matrix clause. ARCs, on the other hand, provide additional information on their (clearly identified) antecedent, which is not directly relevant for the proposition expressed by the matrix clause. This is illustrated by the examples given in (1). The sentence in (1a) comprises an RRC, providing at-issue information relevant for the identification of the referent (i.e., those countries with a warm climate). The sentence in (1b) comprises an ARC, which is not needed for the identification of the antecedent: *Mutter* 'mother' is unambiguously determined, since we usually can assume that the speaker has only one mother. It should be noted that, in German orthography, all relative clauses, restrictive and appositive alike, are separated from the main clause by means of commas.

(1) a. *Richard mag alle Länder, die ein warmes Klima haben.*
Richard likes all counties that a warm climate have
'Richard likes all countries that have a warm climate.'

b. *Meine Mutter, die Lehrerin war, mochte einen organisierten Zeitplan.*
my mother who teacher was liked a organized schedule
'My mother, who was a school teacher, liked to have an organized schedule.'

The two types are distinguished by a series of properties, such as syntactic structure (e.g. Lehmann, 1984), rhetorical roles (Brandt, 1990; Potts, 2005), focus structure (see Holler, 2005), and discourse functions like continuity and subjectivity (Lehmann, 1984; Holler, 2005; Loock, 2010). ARCs are sometimes treated on a par with parenthetical clauses, and are attributed a separate predicative role (see Potts, 2005, 2007; Nouwen, 2014; Fabricius-Hansen, in press). In 'bidimensional' analyses, they have wide scope and are attached in their surface position. In regard to syntax, it is commonly assumed that the two types differ in height of attachment: Following Lehmann (1984), an RRC is attached to the antecedent NP and is thus in the scope of the determiner: $_{DP}$[Det $_{NP}$[N [RC]]]; an ARC, on the other hand, is sister of the higher DP and is thus outside of the scope of the determiner: $_{DP}$[$_{DP}$[Det $_{NP}$[N]] [RC]].

2.2. German prosody

This section sums up the main aspects of German prosody needed for a distinction between the two types of relative clauses. German is an intonation language, which strongly resembles the prosodic system of English. The model assumed in this study is couched in an autosegmental-metrical framework (Pierrehumbert, 1980), using different tones

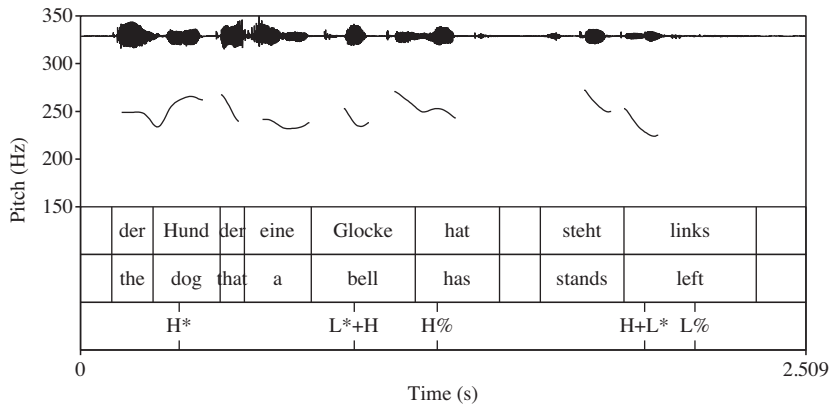

Fig. 1. Pitchtrack and tonal annotations of the RRC construction *Der Hund, der eine Glocke hat, steht links* 'The dog that has a bell is on the left', produced by a female speaker from experiment 2.

ordered in a sequence and two levels of prosodic phrasing. Prominence is signaled by means of pitch accents (such as H*, L*, and L*+H) and prosodic phrase boundaries are tonally marked by boundary tones (H- and L- for the lower 'intermediate phrase' and H% and L% for the higher 'intonation phrase') (Grice and Baumann, 2001; Féry, 2011). In the default case, the last pitch accent (henceforth, accent) of an intonation phrase is the nuclear accent, which is more prominent than the pre-nuclear ones. The nuclear accent may be realized with a higher F0 peak (nuclear upstep), thus interrupting the successive lowering sequence of H-tones (downstep) within the intonation phrase (Truckenbrodt, 2002; Féry and Kügler, 2008). Besides alterations in F0, the end of a prosodic phrase may also lead to pre-boundary lengthening, i.e., segments preceding a prosodic phrase boundary are realized with increased duration (Peters et al., 2005). A non-final prosodic domain typically ends with a high boundary tone (H- or H%), where the F0 height and the lengthening at the boundary are proportional to the strength of the boundary. Thus, a higher prosodic phrase has a corresponding higher boundary tone, which may also be accompanied by stronger pre-boundary lengthening and/or a silent pause. The boundary tone of a declarative sentence is usually low.

The intonational properties outlined above are illustrated in Figs. 1 and 2, with an RRC and an ARC taken from the production experiment reported in section 3.3 (experiment 2). Both utterances were produced by the same speaker with the same wording, as shown in (2). The RRC construction in Fig. 1 has no intonation phrase break after the antecedent noun whereas the ARC construction in Fig. 2 shows a high boundary tone (H%) and a period of silence in that position. Both utterances comprise an intonation phrase break after the relative clause, also realized by an H% boundary tone and a silent pause.

(2) *Der Hund, der eine Glocke hat, steht links.*
the dog that/which a bell has stands left
'The dog that has a bell is on the left.'
'The dog, which has a bell, is on the left.'

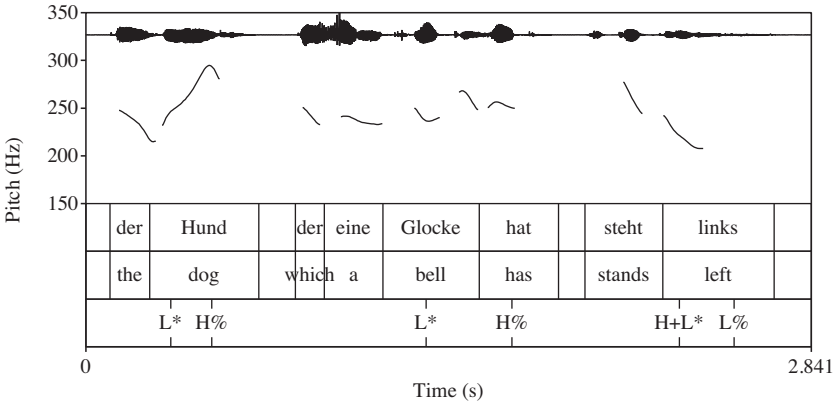

Fig. 2. Pitchtrack and tonal annotations of the ARC construction *Der Hund, der eine Glocke hat, steht links* 'The dog, which has a bell, is on the left', produced by a female speaker from experiment 2.

2.3. The prosody of relative clauses

It has often been claimed that the two types of relative clauses are realized with different prosodic patterns (Downing, 1970; Garro and Parker, 1982 for English; Lehmann, 1984; Brandt, 1990; Holler, 2005 for German; among others). Based on native speaker intuitions, Lehmann (1984) and Brandt (1990) argued that, in German, RRCs and ARCs differ as to the formation of prosodic phrases, the insertion of pauses, and the location of accents: first, while RRCs form an intonation phrase together with their antecedent, ARCs are phrased separately[2]; second, while RRCs are only followed by a pause, ARCs are also preceded by a pause; and, third, Brandt remarked that RRCs, but not ARCs, can be realized with an accent on the antecedent determiner instead of the antecedent noun, which is interpreted contrastively.

More recent studies, like Schaffranietz (1999), Birkner (2008) and Kaland and van Heuven (2010) took an empirical approach toward the prosody of relative clauses in German. Schaffranietz (1999) studied the pragmatics and prosody of relative clauses in semi-spontaneous speech elicited by means of task-oriented dialogs. She used 145 sentences with relative clauses from altogether 44 speakers and conversing in pairs while performing a construction task (the task was to build a model plane). Her production data showed that the aforementioned prosodic patterns only hold for RRCs: while most of the RRCs showed prosodic integration, only one third of the ARCs were realized with prosodic separation, i.e., the prosodic pattern associated with RRCs was found with two thirds of the ARCs in her corpus. Furthermore, Schaffranietz explored the accentuation patterns on the respective type of relative clause. She found that, by tendency, ARC constructions are more likely to be realized without an accent on the relative clause than RRC constructions. In regard to the discrimination of the two types of relative clauses, her perception data showed that accentuation patterns are more important than pause patterns: the combination of the respective pause and accentuation patterns lead to the same discrimination effects as the accentuation patterns alone.

The study by Birkner (2008) explored German relative clause constructions in a corpus of spontaneous speech. Her corpus consisted of 801 sentences that were taken from a German television reality show as well as from dialogs recorded at training programs for job interviews. Her prosodic analysis, which is based on the audio-visual impression of prosodic boundary signals (boundary tones, pre-boundary lengthening, and silent pauses), confirmed the associated prosodic patterns by tendency: two thirds of the ARCs were separated from the antecedent by a prosodic break and four fifths of the RRCs were prosodically integrated. Note that there was still a considerable amount of RRCs and ARCs that deviated from the expected patterns. Pauses and accent shift were not found to be relevant characteristics in Birkner's corpus.

Kaland and van Heuven (2010) conducted a perception study on the prosodic cues associated with relative clauses in German and Dutch. They used 16 simple sentences containing a relative clause, produced in 5 synthesized contours, and let 20 participants judge the prosodic wellformedness of sentences on a scale from one to ten. The sentences were rendered unambiguously restrictive or appositive by means of quantifiers or sentence adverbs such as 'by the way' respectively. They found that German speakers could not clearly discriminate RRCs from ARCs based on accentuation, boundary tones, and pauses. Thus, they conclude that there is a ''fixed'' prosodic pattern that holds for both types of relative clauses. They also remark that this could explain the inconsistency in the data of Schaffranietz (1999) and Birkner (2008) in regard to the frequency of prosodic (dis-)integration of the two types of relative clauses (because the restrictiveness status of the relative clause may not be responsible for the prosodic patterns).

In sum, prior studies do not provide a coherent picture of the prosody of relative clauses. While those studies that drew on native speaker intuitions offered a clear separation of prosodic patterns, the empirical studies revealed that these patterns hold only by tendency or not at all. As for the prosodic correlates, an impact of phrasing was observed to some extent in almost all studies. Pauses and accentuation, on the other hand, appeared to be less stable.

2.4. Methodological issues: awareness and audience design

In the experiments presented in this article, we rely on a distinction made in the literature between naïve and trained speakers. Watt and Murray (1996) and Allbritton et al. (1996) suggested that the utterances used in experiments are often atypical since trained speakers and listeners use prosodic correlates for the disambiguation of syntactic structure that untrained speakers do not use. These suggestions were tested in the literature, with different results.

Snedeker and Trueswell (2003) confirmed these suggestions. They found that speakers only produce prosodic cues to syntactic structure when they are aware that they need to disambiguate structures for the audience. The authors used sentences like in (3a), in which the listener is instructed by another person to either tap a frog that carries a flower, or to tap a frog with an instrument in form of a flower. Thus 'with a flower' can be an instrument or a modifier.

(3) a. Tap the frog with the flower.
b. Put the dog in the basket on the star.

[2] Similarly, parentheticals are phrased separately in German (Döring, 2011).

According to Snedeker and Trueswell (2003), speakers' awareness in regard to ambiguity – be it due to instructions or to a clear context – influences the productions of prosodic contrasts. This view implies that the speaker must be aware of the listener's need and must be able to meet this need.

The alternative view defended by Schafer et al. (2000) and Kraljic and Brennan (2005) considers that speakers do not change their prosody to adapt to the need of an audience. In this line of explanation, prosodic correlates like prosodic boundaries, prominence, tonal scaling and the like are by-products of the syntax and the phonetics. The prosodic structure is not a disambiguating device for the listeners, but rather prosody arises automatically as a by-product of the syntax-prosody interface. Schafer et al. (2000) elicited quasi-spontaneous speech from speakers involved in a cooperative board game. The players had to use pre-formulated sentences, but were allowed to use them whenever they wanted. The authors found that the players consistently used prosodic boundaries to mark syntactic boundaries. Moreover listeners were sensitive to prosodic disambiguation of syntactic structure. Schafer et al. interpreted their results as a confirmation that prosody is an important source of information for sentence comprehension. Kraljic and Brennan (2005) also used dialogs in form of instructions between participants to investigate audience design. They used sentences as given in (3b) above, in which the listener is instructed to put the dog into a basket located on top of a star, or to take the basket containing the dog and put it on the star. In this case, there is disambiguation between a goal and a modifier.

Both Snedeker & Trueswell and Kraljic and Brennan's studies used the visual world paradigm, and found that prosody plays an early role for comprehension, as early as lexical and phonological information. Visual-world eye-tracking is well-suited for psycholinguistics. This is because eye-movements are very closely time-locked to the speech stream, and thus follow participants' reaction in an efficient way. However, as far as audience design is concerned, they found diametrically opposed results: Snedeker & Trueswell found that speakers only used prosody to disambiguate when they were aware of an ambiguity, whereas Kraljic and Brennan found that speakers always disambiguated. A possible reason for the different results obtained may lie in the number of constituents and thus the complexity of the prosodic structure involved in each case.

Another reason may be that Kraljic and Brennan's design induced more ambiguities than they assumed when they started their study, as they observe themselves (see 2005:215), so that the structures that they called unambiguous may have been ambiguous for the participants. This is because the targeted object (dog) was displayed several times in the conditions they used, even though only one dog fulfilled all properties described by the PPs (in the basket on the star).

The discrepancy between the strong intuitions of German speakers that there are prosodic differences between RRCs and ARCs and the lack of such prosodic differences in the data of previous production experiments motivated the form of the experiments described in the following section. Moreover we were interested in testing the predictions of audience design to the German relative clauses.

3. Production experiments

3.1. Objective and hypotheses

In order to investigate the prosodic patterns described in the literature, we conducted two consecutive production experiments, testing for prosodic phrasing, pause insertion, and accent shift as prosodic correlates of adnominal (non-extraposed) relative clauses. Their aim was to reveal whether German speakers mark RRCs and ARCs by means of these prosodic correlates in a systematic way.

Based on the observations outlined in section 2, we state the hypotheses given in (4) below. Hypotheses (4a) and (4b) concern the prosodic phrasing patterns of RRCs and ARCs. Since the boundary of a higher prosodic phrase, such as an intonation phrase or intermediate phrase, inserts a high boundary tone (H% or H-), we expect that the F0 contour preceding the relative clause reaches a higher maximum when a boundary is present (4a). Furthermore, since a prosodic phrase may be realized by pre-boundary lengthening, we expect that segments preceding the relative clause are longer in duration when a boundary is present (4b). Following the assumptions of prior studies (see section 2.3), we expect a boundary to be present with ARCs, but not with RRCs. With adnominal (non-extraposed) relative clauses, as investigated here, these boundary cues are realized on the last syllable preceding the antecedent, as this is the one immediately preceding the boundary.

Although pauses were found to be less important for the prosodic realization and discrimination of relative clauses, we follow the assumption from the literature that they occur preceding ARCs, but not preceding RRCs, as stated in Hypothesis (4c). This coincides with the commonly assumed patterns of prosodic phrasing.

Hypothesis (4d) states that the accentuation of the determiner instead of the head noun is only possible with the antecedents of RRCs. Unlike our expectations for phrasing and pauses, this strategy is expected to be optional.

(4) Hypotheses on the prosodic realization of RRCs and ARCs
   a. The F0 contour reaches a **higher** maximum on the syllable immediately preceding ARCs than on the syllable immediately preceding RRCs.
   b. The segment immediately preceding an ARC is **longer** than the segment immediately preceding an RRC.
   c. **Pauses** are inserted preceding ARCs, but not preceding RRCs.
   d. Accents may **shift** to the determiners of RRC-antecedents, but not to the determiners of ARC-antecedents.

We also tested whether speaker awareness (of the functions of relative clauses) and the communicative need to disambiguate have an influence on the implementation of prosodic correlates. A speaker who produces a relative clause in an experimental situation might not be aware of its function as an RRC or an ARC and thus not use the appropriate prosodic pattern. Hence, we compared relative clause constructions produced by naïve speakers with those produced by speakers who were informed about the functions of the two types of relative clauses. The latter might lead to a more consistent use of the disambiguating prosodic patterns. We also tested the use of prosody in contexts where informed speakers were required to first disambiguate relative clauses and then communicate the respective type to another person. Since it was found that speakers are more likely to implement disambiguating prosodic cues when they are relevant to the situation (see section 2.4), the use of the respective prosodic pattern might be even more consistent in this case.

3.2. Experiment 1

3.2.1. Experimental design

In the first production experiment, a localization task was used in which participants had to localize three toy animals or other toy objects, such as cars or trees, standing in a row. One of the toy animals – the target animal – was marked with a smaller toy object, which distinguished it from other animals of the same kind (e.g., a bear with a bucket). For each target animal we designed two layouts, one that elicits an RRC and one that elicits an ARC. As illustrated in Fig. 3, RRC layouts involved two animals of the same kind, of which one was the (marked) target animal. ARC layouts, as illustrated in Fig. 4, involved three different toy objects, i.e., the (marked) target animal was the only one of its kind. The participants' task was to orally localize the toy objects from left to right in respect to the surrounding ones. They were asked to use their own words. The marker of the target animal (here, the bucket) was supposed to be included in the localization description of the target animal. A relative clause referring to the marker in an RRC layout would distinguish the target animal from the other animal of its kind by establishing a contrastive focus and thus inevitably have a restrictive interpretation. In contrast, a relative clause elicited by an ARC layout would provide additional information about the target animal and thus be appositive.

Experiment 1 was run in two consecutive rounds. In the first round, the participants remained naïve about the different functions of RRCs and ARCs. In the second round, they were made aware of the different functions by means of written examples and instructions.

Fig. 3. RRC layout, target animal: the bear that carries a bucket.

Fig. 4. ARC layout, target animal: the bear, which carries a bucket.

3.2.1.1. Round 1: naïve participants. In the first round, 15 pairs of RRC and ARC layouts were used, which were presented one by one to the participants in a pseudo-randomized order (see Appendix A for the list of targeted productions). Thereby, the respective RRC and ARC layouts of one layout pair never appeared adjacently. In order to elicit semi-spontaneous speech, the participants were instructed to perform the localization task in their own wording. Instructions were given to them in written form. To point them toward producing relative clauses, the written instructions contained examples that involved adnominal (non-extraposed) relative clauses describing the marking object of the target sentences. In a second session with the same speakers, read speech was elicited.[3] In this session, the layouts were presented in combination with written localization descriptions containing relative clauses (see Appendix A). The participants were instructed to read the stimuli in such a way that they appropriately described the given layouts. The stimuli contained localization descriptions for the three toy objects from left to right or back to front. Both RRC- and ARC-target sentences contained an adnominal relative clause introduced by a relative pronoun and set off by commas on both sides (as is required in German punctuation). The examples in (5) illustrate an RRC and an ARC layout. The relative clauses and their antecedents are in bold.

(5) a. RRC layout

*Der Bär steht links**. Der Bär, der einen Eimer hat**, steht in der Mitte. Und das Krokodil steht rechts.*
'The bear is on the left hand side. **The bear that has a bucket** is in the middle. And the crocodile is on the right hand side.

b. ARC layout

*Die Kuh steht links. **Der Bär, der einen Eimer hat**, steht in der Mitte. Und das Krokodil steht rechts.*
'The cow is on the left hand side. **The bear, which has a bucket**, is in the middle. And the crocodile is on the right hand side.

We recorded 30 female speakers, aged between 20 and 30 years and students at the University of Frankfurt. They all were native speakers of Standard German. For our analysis we chose those five speakers that produced most relative clauses in semi-spontaneous speech (since the speakers were free to choose their own wording, the majority of descriptions contained prepositional phrases, like *Der Bär mit dem Eime*r 'The bear with the bucket'). Of these five speakers only those localization tokens that contained relative clauses entered the analysis. These were a total of 63 RRC tokens and 74 ARC tokens (out of 75 recorded tokens respectively). The remaining 13 tokens, which involved prepositional phrases to describe the marking object, were not taken into account.

[3] Read speech was elicited in a second session on a later day because the initial design only involved the elicitation of semi-spontaneous speech.

3.2.1.2. Round 2: aware participants. In the second round of experiment 1, twelve pairs of RRC and ARC layouts were used. Three of the toy objects from round 1 were not used and some of the words were changed in order to simplify the descriptions. As in the first round, the layouts containing the target toy objects were presented one by one in a pseudo-randomized order. Semi-spontaneous and read speech was elicited the same way as in the first round (see section 3.2.1.1). The second round differed from the first one in that the participants were informed about the different functions of RRCs and ARCs. Before the session, they received written explanations including examples that illustrated the use of the two types of relative clauses. They were also instructed to use relative clauses to describe the object marker of the target animal. In order to make the data comparable to the data obtained in round 1, we recorded the five participants from round 1 who entered our analysis (i.e., those five out of 30 recorded participants of round 1 that produced most relative clauses in total). The recordings were not made on the same day as those for round 1.

3.2.2. Recording and analysis

All recordings were made with a digital audio recorder (mono, 44.1 kHz) in a sound proof booth at the University of Frankfurt. The target sentences were extracted from the recorded material and analyzed with the acoustics analysis software Praat (Boersma and Weenink, 2012).

For each recorded target sentence, the syllable immediately preceding the relative clause was segmented manually based on auditory impression and visual inspection of the speech signal. The left hand boundary of the syllables was set at the point where the onset consonant was first perceivable and detectable in the signal. The right hand boundary was set immediately preceding the burst of the onset plosive of the relative pronoun (which was always [d]), or, in case of silence preceding the relative clause, immediately preceding the period of silence. A Praat script located the F0 maximum within the segmented syllables as well as the lowest F0 minimum of the utterance and collected the corresponding values. The assignment of the F0 measuring points was supervised and manually corrected in case of micro-prosodic distortions based on visual inspection of the speech signal. The collected F0 values were converted into semitones with the lowest F0 of each speaker as the reference.

Audio-visual inspection of the data revealed that the F0 contours on the material preceding the relative clause were consistent within and across subjects: only high boundary tones were realized preceding the relative clause and no creakiness or other phrase-final phenomena that could influence the voicing of the segments in the target syllables were present. The production of utterances appeared natural with the exception of four sentences in the data of round 2, where both the antecedent noun and the preceding determiner were accented.

For the analysis on pre-boundary lengthening, the duration of the last segment preceding the relative clause that was not an oral stop was measured. The collected duration values were speaker normalized by means of *z*-score transformation: The segments in the data set of each subject were divided into the following categories respectively: long vowels, short vowels, nasals, and liquids. Obstruents and glides were ignored because none of the target segments belonged to these categories. An automated alignment tool (Prosodylab-Aligner, Gorman et al., 2011) was applied, which localized the boundaries of all segments in the target sentences. The alignments of all vowels, liquids and nasals were manually checked and corrected in case of misalignments by the first and the third author. A Praat script collected the duration values of the segments belonging to the four categories for each subject. The *z*-scores of the duration values were then calculated on the basis of the subject's mean and standard deviation of the categories the duration values belonged to: $z = (x - \mu)/\sigma$, where x is the absolute value, μ is the mean, and σ is the standard deviation.

Silent pauses with a minimum of 0.1 s immediately preceding the relative clause and the location of the last pitch accent preceding the relative clause (noun vs. determiner) were annotated by the first author. The presence of a pitch accent was determined by means of auditory impression of relative prominence in combination with visual inspection of the F0 contour. Cues for the presence of a pitch accent were stronger perceivable prominence of syllables in relation to surrounding syllables as well as the presence of rapid pitch movement. Accentuation patterns where the last accent preceding the relative clause was on the determiner were taken as instances of accent shift.

3.2.3. Results

3.2.3.1. F0. Fig. 5 illustrates the results from round 1, in which the participants were not informed about the different functions of RRCs and ARCs and were also not instructed to produce relative clauses. The columns show the average values of the F0 maxima within the antecedent across speakers. As shown on the left hand side, there is no significant difference between RRCs and ARCs in semi-spontaneous speech ($p = 0.1945$, $t = 1.3036$ in a two-tailed *t*-test). Read speech, in contrast, showed a significant effect: as illustrated on the right hand side, the average F0 maximum of the RRC condition is significantly higher than the one of the ARC condition ($p < 0.0001$, $t = 4.0935$ in a two-tailed *t*-test).

Fig. 6 illustrates the F0 results from round 2, in which the participants were informed about the differences between the two types of relative clauses. Again, the left hand columns show the results for semi-spontaneous speech and the right hand columns show the results for read speech. In both cases, there is no significant difference between the RRC and the ARC condition ($p = 0.1893$, $t = 1.3204$ for semi-spontaneous speech and $p = 0.0776$, $t = 1.7804$ for read speech,

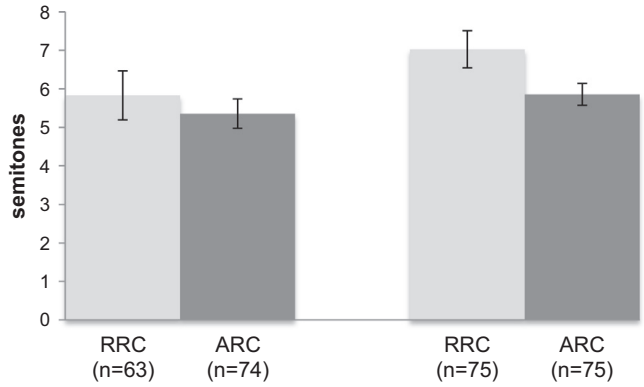

Fig. 5. F0 maxima from round 1: naïve speakers with semi-spontaneous speech (left) and read speech (right). Averages of the pooled semitone values from 5 speakers, plotted as 95% confidence intervals.

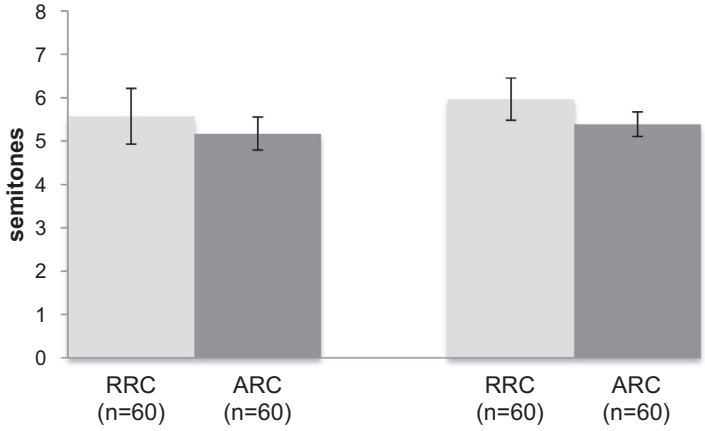

Fig. 6. F0 maxima from round 2: informed speakers with semi-spontaneous speech (left) and read speech (right). Averages of the pooled semitone values from 5 speakers, plotted as 95% confidence intervals.

in two-tailed *t*-tests). The values from the RRC condition tend to be slightly higher and to involve a broader variation than the respective values from the ARC condition.

3.2.3.2. Duration. Fig. 7 presents the duration results for experiment 1. The figure illustrates the average *z*-score values from round 1, where the participants remained naïve about the functions of the relative clause types. The results for

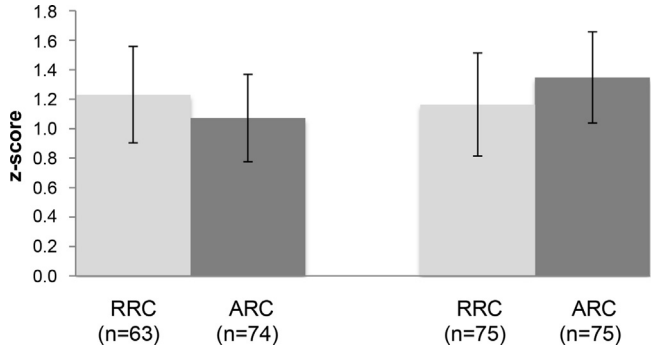

Fig. 7. Duration values from round 1: naïve speakers with semi-spontaneous speech (left) and read speech (right). Averages of the pooled values from 5 speakers, plotted as 95% confidence intervals.

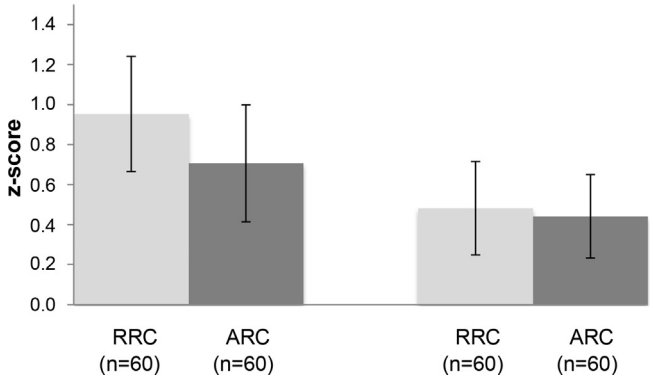

Fig. 8. Duration values from round 2: informed speakers with semi-spontaneous speech (left) and read speech (right). Averages of the pooled *z*-score values from 5 speakers, plotted as 95% confidence intervals.

semi-spontaneous speech are illustrated on the left hand side and those for read speech on the right hand side. As can be seen in Fig. 7, there is no significant effect ($p = 0.4828$, $t = 0.7039$ for semi-spontaneous speech and $p = 0.49$, $t = 0.7$ for read speech, in two-tailed *t*-tests).

Fig. 8 illustrates the duration results from round 2, where the participants were made aware of the functions of relative clauses. Semi-spontaneous speech did not lead to variation in wording, as a result from the instruction to use relative clauses, which was followed by all participants. All antecedent nouns in the produced sentences were identical. As can be seen in the plots, there is no significant difference between the two conditions, neither with semi-spontaneous speech (left columns, $p = 0.6661$, $t = 0.4340$ in a paired two-tailed *t*-test) nor with read speech (right columns, $p = 0.1328$, $t = 1.5254$ in a paired two-tailed *t*-test). Generally, the duration values from the second round are more balanced and show less variation than those from the first round.

3.2.3.3. Pauses. Table 1 shows the respective amounts of utterances that were realized with a silent pause between the antecedent noun and the following relative clause. In both rounds, pauses were rather rare: The amount of pauses produced by the naïve participants (round 1) lies between eight and 17 percent, with slightly more pauses in the RRC condition. Informed participants (round 2) produced only two pauses with each type of relative clause in semi-spontaneous speech. In read speech, no pauses were present.

3.2.3.4. Accent placement. Table 2 shows the respective amounts of utterances where speakers shifted the accent from the antecedent noun to the preceding determiner. In both rounds, participants never shifted the accent in the ARC condition. There are four sentences in the data from round 2 where a participant realized an accent on both the determiner

Table 1
Amount of tokens with a silent pause preceding the relative clause in experiment 1 (total numbers: RRC/ARC).

	Round 1 (naïve participants)		Round 2 (informed participants)	
	Semi-spont.	Read	Semi-spont.	Read
Total	63/74	75/75	60/60	60/600
RRC	11 (17%)	9 (12%)	2 (3%)	0
ARC	7 (10%)	6 (8%)	2 (3%)	0

Table 2
Amount of tokens with an accent on the antecedent determiner and no accent on the antecedent noun in experiment 1 (total numbers: RRC/ARC).

	Round 1 (naïve participants)		Round 2 (informed participants)	
	Semi-spont.	Read	Semi-spont.	Read
Total	63/74	75/75	60/60	60/60
RRC	0	0	26 (43%)	29 (48%)
ARC	0	0	0	0

and on the noun. Since these are not instances of accent shift, they are not included in Table 2. In the RRC condition, participants realized accent shift in the last two rounds, where they were made aware of the functions of relative clauses, but not in the first round, where they remained naïve. In the second round, almost half of the RRC sentences involved an accent shift, both in semi-spontaneous and in read speech.

3.2.4. Discussion of experiment 1

When participants remained naïve about the functions of the two types of relative clauses (round 1), they did not implement any of the expected prosodic means, neither in semi-spontaneous nor in read speech. In regard to F0 and duration, they even showed the opposite effects: in the RRC condition, the average values showed a higher F0 peak than in the ARC condition in read speech, but not in semi-spontaneous speech, and longer duration in both read and semi-spontaneous speech. This inconsistency shows that prosodic phrase boundaries can be present before RRCs and absent before ARCs, as observed in the data by Schaffranietz (1999) and Birkner (2008). The use of silent pauses did not meet the predictions either: the overall amount of pauses was low in the data of both conditions and slightly more pauses occurred with RRCs. The strategy of accent shift was not used at all in round one.

When participants were made aware of the functions of relative clauses (round 2), they did shift the accent from the antecedent noun to the determiner in order to mark RRC constructions (in nearly 50 percent of the data). This supports Hypothesis (4d), which states that accent shift is an optional strategy to mark RRCs. Yet, Hypotheses (4a-c) on F0, duration, and pauses were not supported: F0 did not show a significant effect, duration was slightly longer in the RRC condition, and pauses were completely absent. Thus, the differences between the prosodic patterns of naïve and informed speakers were rather limited. Besides accent shift, there was no clear prosodic effect that would mark the respective types of relative clauses.

In short, Hypotheses (4a-c) were not supported at all and Hypothesis (4d) was only supported in round 2 (informed participants). Due to the lack of support for the hypotheses (despite intuitions to the contrary), a second experiment was conducted, in which the speakers were not only made aware of the two types of relative clauses, but also had to implement differences between them in order to meet communicative needs.

3.3. Experiment 2: presentation of layout pairs

3.3.1. Experimental design, recording and analysis

In experiment 2, a target sentence containing a relative clause and two pictures showing different layouts of toy animals were presented to the participants (see Fig. 9 below for illustration and Appendix B for the set of sentences). The target sentence could describe the target animal in either layout, which was marked with a smaller toy object (here again, the bear with a bucket). Thus, the relative clause could be read as an RRC or as an ARC construction, depending on whether the target animal was the only one of its type in the respective layout. One of the pictures was marked with a red frame. The participants were instructed to read the given sentences thereby describing the framed layout. They were told that another person, who was sitting in front of another computer in the room with their back turned to the participant, would see both layouts on the screen without the frame and would have to pick the correct one based on the way they read the respective target sentences. In so doing, we forced the participants to use prosody in order to communicate the difference between RRCs and ARCs. In total, twelve different layout pairs were used, similar to those of the second round of experiment 1, but with some changes in wording. Each pair was presented twice, once with marking of the RRC layout and once with

Fig. 9. Layout pair with target sentence (ARC layout framed). Target sentence: *Der Bär, der einen Eimer hat, steht in der Mitte* 'The bear that has a bucket is in the middle' or 'The bear, which has a bucket, is in the middle'.

marking of the ARC layout. The pictures and the respective target sentence were presented to the participants on a monitor screen, one by one in a pseudo-randomized order. Thereby, the two parts of one layout pair never occurred adjacently. As was done in round 2 of experiment 1, the participants were informed before the session about the different functions of RRCs and ARCs by means of written instructions and examples. Five female native speakers of German were recorded, aged between 20 and 35 years. None of them had participated in experiment 1.

Recording and data analysis was performed as in experiment 1. See section 3.2.2 for details.

3.3.2. Results

3.3.2.1. F0. The F0 results from experiment 2 are presented in Fig. 10. Across speakers, the F0 maxima of the ARC antecedents are significantly higher than those of the RRC antecedents ($p = 0.0005$, $t = 3.6073$ in a two-tailed t-test).

3.3.2.2. Duration. Fig. 11 shows the results for duration. Across speakers, the average duration of the antecedent is significantly longer in the ARC condition ($p = 0.0002$, $t = 3.9764$ in a paired two-tailed t-test).

3.3.2.3. Pauses. The speakers in experiment 2 produced considerably more pauses than those in experiment 1. As shown in the rightmost column in Table 3, 25 percent in the RRC condition and 42 percent in the ARC condition were realized with a pause in experiment 2. Twelve out of the fifteen instances of the RRC condition also involved an accent shift from the noun to the determiner (cf. section 3.3.2.4). Table 3 also reproduces the results of experiment 1 for comparison.

3.3.2.4. Accent placement. As shown in the rightmost column in Table 4, about one third of the RRC sentences and none of the ARC sentences of experiment 2 involved an accent shift from the antecedent noun to the preceding

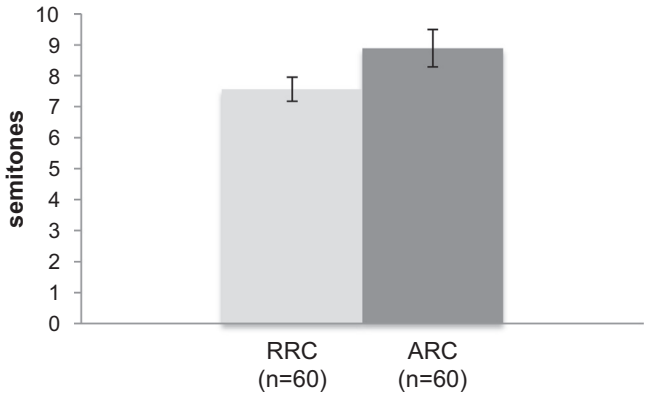

Fig. 10. F0 maxima from experiment 2: informed speakers with read speech and presentation of layout pairs. Averages of the pooled semitone values from 5 speakers, plotted as 95% confidence intervals.

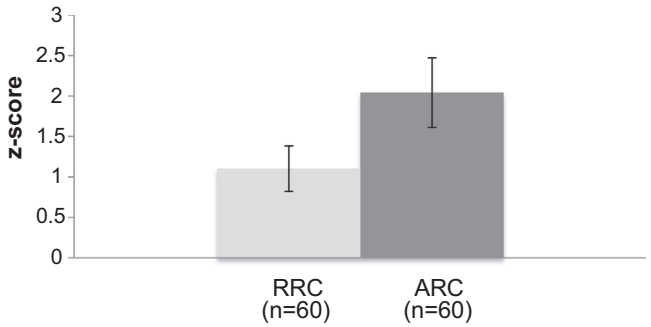

Fig. 11. Duration values from experiment 2: informed speakers with read speech and presentation of layout pairs. Averages of the pooled z-score values from 5 speakers, plotted as 95% confidence intervals.

Table 3
Amount of tokens with a silent pause preceding the relative clause from experiments 1 and 2 (total numbers: RRC/ARC).

	Exp. 1 – round 1 (naïve)		Exp. 1 – round 2 (informed)		Exp. 2 (layout pairs)
	Semi-spont.	Read	Semi-spont.	Read	Read
Total	63/74	75/75	60/60	60/60	60/60
RRC	11	9	2	0	15 (25%)
ARC	7	6	2	0	25 (42%)

Table 4
Amount of tokens with an accent on the antecedent determiner and no accent on the antecedent noun from experiments 1 and 2 (total numbers: RRC/ARC).

	Exp. 1 – round 1 (naïve)		Exp 1. – round 2 (informed)		Exp. 2 (layout pairs)
	Semi-spont.	Read	Semi-spont.	Read	Read
Total	63/74	75/75	60/60	60/60	60/60
RRC	0	0	26	29	21 (35%)
ARC	0	0	0	0	0

determiner. Twelve of the 21 instances from experiment 2 came along with a pause between antecedent noun and relative clause (cf. section 3.3.2.3). This is mainly due to one speaker, who realized RRC sentences with accent shift and coinciding pause in eleven out of twelve cases. Table 4 also reproduces the results of Table 2 for comparison.

3.3.3. Discussion of experiment 2

When informants had to read the relative clause constructions in such a way that another person could choose the correct layout, they implemented most of the expected prosodic means: As predicted by the hypotheses, F0 was significantly higher and duration was significantly longer in the ARC condition. This shows that speakers clearly used prosodic phrase boundaries to mark ARC constructions, but not RRC constructions. Pauses were inserted more often preceding ARCs (42 percent), but were still quite frequent with RRCs (25 percent). Thus, Hypothesis (4c), which stated a clear correlation between pauses and ARCs, was not supported. This is in line with Schaffranietz' (1999) conclusion that pauses alone are not reliable prosodic cues for ARC constructions. Accent shift was present with about one third of the RRC constructions, but not with ARC constructions, which supports Hypothesis (4d). Interestingly, one speaker consistently realized RRC constructions with a combination of pause and accent shift.

3.4. Discussion of production experiments

Comparing the two experiments, it can be observed that, in experiment 1, the participants made comparatively little effort to mark the respective type of relative clause by means of prosody. Rather, the patterns of F0 and duration showed a fair amount of variation, and accent shift as a strategy to mark RRC constructions was only present in the second round. The lack of prosodic cues clearly marking the difference between RRCs and ARCs may be due to the fact that the latter are pragmatically redundant: The localization of the target animal does not require the information provided by the ARC. This was also the case in the production experiment of Schaffranietz (1999), where participants had to describe the forms of objects by means of relative clauses, e.g., *der Kreis, der rund ist* 'the circle, which is round' as an ARC. As in experiment 1, her production data was inconsistent with regard to prosodic phrasing. In contrast, the data from experiment 2 showed a clear connection between the respective type of relative clause and the correlates of prosodic phrasing (F0 and duration). As the task required signaling the difference between RRCs and ARCs, no pragmatic redundancy was involved – and the participants used prosody in a more consistent way.

In sum, Hypothesis (4a) (on F0) and Hypothesis (4b) (on duration) were supported in the data from experiment 2, and Hypothesis (4d) (on accent shift) was supported in the data from experiment 1 (round two) and experiment 2. Hypothesis (4c) on pauses was not supported by the data. As expected, the more the participants were aware of the functions of the two types of relative clauses and the more they were required to signal the differences between the two types, the more prosodic effort they made.

The analyses presented in this section focused on boundary phenomena preceding the relative clause, but did not take into account a possible impact of the boundary after the relative clause. Since prior studies suggested that boundaries are relative (e.g. Carlson et al., 2001; Schafer et al., 2000), further research is needed that studies both locations for boundaries in

parallel. Also note that the results of the two experiments presented in this section involved only a limited number of subjects. Thus, further research on the prosodic realization of relative clauses is needed in order to verify the findings.

4. Perception experiment (experiment 3)

This section reports on a perception experiment, which tested whether listeners are able to disambiguate RRCs and ARCs based on prosodic differences.

4.1. Objective and hypotheses

As has been described in section 2.3, prior research suggested that RRCs and ARCs differ in regard to the use of silent pauses: ARCs, but not RRCs, are set off from the matrix clause by means of pauses (Lehmann, 1984; Brandt, 1990). Empirical studies however suggested that the use of pauses to mark the respective type of relative clause is not consistent in production (Schaffranietz, 1999; Birkner, 2008, production experiments of the present study) and not important for discrimination (Schaffranietz, 1999; Kaland and van Heuven, 2010). Similarly, the accentuation patterns of relative clauses were shown to be rather unreliable prosodic cues: Schaffranietz (1999) found that ARCs are more likely to be realized without an accent than RRCs, but accentuation is possible with both types. In contrast, the optional strategy to shift the accent from the antecedent noun to the preceding determiner is exclusively associated with RRCs (Brandt, 1990, experiment 2 of the present study).

In the discrimination experiment reported on below, these rather unstable prosodic cues were examined in regard to their potential for disambiguating the restrictiveness status of adnominal relative clauses. The objective was to test whether listeners associate the presence of pauses with ARCs and the accentuation patterns (relative clause accentuation and accent shift) with RRCs. Although pauses and accentuation were found to be less important in the production experiments, it may well be that German listeners make use of these cues to discriminate the two types of relative clauses. Hence we posited the hypotheses in (6). Hypotheses (6a) and (6b) relate to hypotheses (4c) and (4d) of the production experiments respectively. In production, it was hypothesized that silent pauses between antecedent noun and relative clause would be produced only with ARC constructions and that accent shift to the determiner would be produced only with RRC constructions. Here we hypothesize that these cues are taken as disambiguating means in perception. Accentuation on the relative clause (6c) was not investigated in the production experiment.

(6) Hypotheses on the prosodic perception of RRCs and ARCs
- a. A relative clause that is set off by silent pauses from its matrix clause is interpreted as appositive.
- b. Accent shift from the antecedent noun to the preceding determiner leads to a restrictive interpretation of the relative clause.
- c. A relative clause that is accented is interpreted as restrictive.

The hypotheses in (6) follow the intuitive prosodic cues associated with the two types of relative clauses, although prior perception studies did not find clear discrimination effects for these cues (see section 2.3). The present study tests for an effect of these cues by means of a different method, which is presented in the following section.

4.2. Experimental design and procedure

The hypotheses were tested by means of a picture selection task in which participants heard a stimulus sentence and had to assign it to one out of two different pictures. As shown in (7), the stimuli involved copulative constructions with an adnominal relative clause modifying the subject. The subjects/antecedents were the geometric shapes *Dreieck* 'triangle', *Viereck* 'rectangle', *Kreis* 'circle', or *Stern* 'star', always followed by the relative clause *das/der gestreift ist* 'which is striped' or 'that is striped' and preceded by the definite article *das/der*. The predicative expressions were the color adjectives *rot* 'red', *blau* 'blue', *grün* 'green', or *gelb* 'yellow'. All combinations of geometrical shapes and colors were used, which makes a total of 16 test sentences (see Appendix C for the entire set of test sentences).

(7)

Das	Dreieck,	das	gestreift	ist,	ist	rot.
the	triangle	that/which	striped	is	is	red

'The triangle that is striped is red.'
'The triangle, which is striped, is red.'

All test sentences were recorded with a phonetically trained male native speaker of Standard German (aged 36) in four different prosodic patterns: first, with silent pauses of at least 0.2 s preceding and following the relative clause (8a);

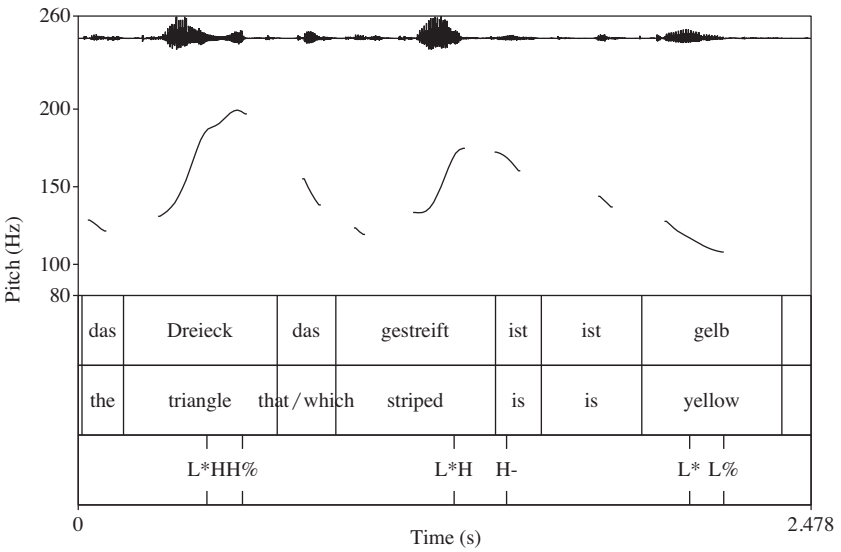

Fig. 12. Pitch track and tonal annotations of the sentence *Das Dreieck, das gestreift ist, ist gelb* 'The triangle that is striped is yellow' or 'The triangle, which is striped, is yellow', recorded with the fourth prosodic pattern. The right edge of the head noun *Dreieck* 'triangle' is marked with an H% boundary tone.

second, with accentuation on the determiner (8b); and, third, with accentuation on the relative clause (8c). A fourth prosodic pattern was recorded, which was intended to be realized without pauses and accentuation on the determiner and relative clause (unmarked prosody). A closer inspection of the test stimuli however revealed that the speaker realized H% boundary tones immediately preceding the relative clause (8d), as illustrated in the pitch track in Fig. 12. The recorded stimuli were not manipulated afterwards.

All four patterns were realized with three accents, one either on the antecedent noun (8a,c,d) or on the determiner (8b), one on the adjective in the relative clause, and one on the predicative expression. The first two accents always involved a peak (e.g. L*H), whereas the last accent was always low (L*), which is also visible from Fig. 12. In patterns (8a,b,d), successive F0 lowering applied from one accent to the next and the final L* is perceived as most prominent. In pattern (8c), the accent on the relative clause reaches a higher F0 peak and is perceived as more prominent than the preceding and the following one. All utterances ended with a low falling boundary tone (L%).

(8) a. Das Dreieck [pause] das gestreift ist [pause] ist rot.
b. DAS Dreieck, das gestreift ist, ist rot.
c. Das Dreieck, das geSTREIFT ist, ist rot.
d. Das Dreieck [H%] das gestreift ist ist rot.

For each of the 16 test sentences, two pictures were created that showed layouts of two geometrical shapes respectively (see Fig. 13). One of the layout images showed twice the shape of the item in the same color, once with and once without black stripes (RRC layout). In this case, the relative clause of the item elicits a restrictive reading, as the stripes distinguish the two otherwise identical shapes (e.g. the triangles in the left image of Fig. 13). The other image showed a layout of two different shapes: the one of the item, in the respective color and with stripes, and a different one in a different color and without stripes (ARC layout). In this case, the relative clause elicits an appositive reading, as it provides additional information on the clearly identified shape, viz. that it is striped (e.g. the triangle and the star in the right image of Fig. 13).

A total of 48 pairs of restrictive and appositive layout images were created on slides. Both layouts occurred equally often on the left and on the right hand side on the slides. In each layout pair, both striped shapes were either at the top or at the bottom of the layouts. They occurred equally often at the top and at the bottom throughout the experiment. The 48 slides were pseudo-randomized and presented to the participants in four blocks, each having the same order. Each of the layout pairs was randomly assigned one of the four prosodic patterns. Each prosodic pattern occurred twelve times per block and each layout pair was assigned a different prosodic pattern in each block. Thus, on the whole, each pair was presented once with each of the four prosodic patterns, which makes a total of 192 tokens (48 layout pairs $\times$ 4 prosodic patterns).

The forced-choice experiment was conducted with the following procedure: The participants were presented the slides on a computer screen, using the experimental control software Presentation (version 16.3). The sound stimuli were

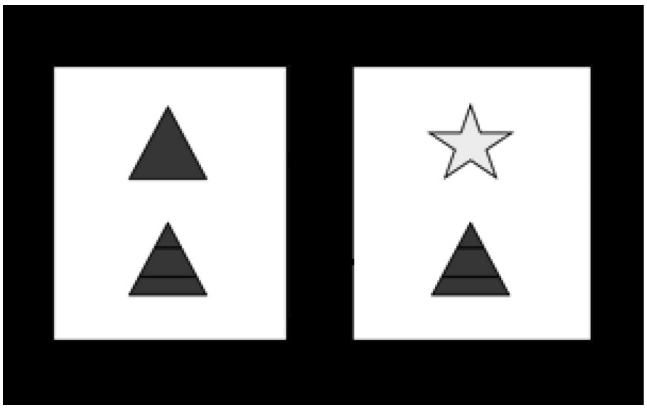

Fig. 13. Layout pair from the picture selection task: RRC layout (left) and ARC layout (right). Target item: *Das Dreieck, das gestreift ist, ist rot* 'The triangle that is striped is red' or 'The triangle, which is striped, is red'.

presented via headphones. The slides appeared first, followed by the respective sound stimulus after 1.9 s. The sound stimuli were only played once and could not be repeated. After that, the participants could assign the stimulus to the left or right layout by pressing a respective left or right button on a computer keyboard. The participants were given no time limit for entering their decision. After their entry, a red frame marked the chosen image for 1 s. Then, a black screen appeared for 1.2 s, followed by the presentation of the next layout pair. Between the blocks, the experiment was interrupted for a minimum of 2 min. Before starting the experiment, the participants were informed about the procedure: They were familiarized with the geometric shapes and instructed to assign the sentences they heard with one of the layouts by pressing the respective button. No awareness instructions, as in the production experiments (section 3), were provided. The procedure was practiced in a trial phase with six items. The entire procedure, including the breaks between the blocks, took 45–60 min.

A total of 20 German native speakers (ten males and ten females) aged between 22 and 35 years participated in the experiment.

4.3. Results

Seven out of the 20 participants were excluded from the analysis, as they exclusively chose the RRC layout. After the experiment, they reported that they had made their choice independently of the sound stimuli.

The pooled results of the remaining 13 participants (nine females and four males) are presented in Table 5. Altogether there were a total of 624 data points per prosodic condition. For the first prosodic pattern, where the relative clause was set off by pauses, the participants chose the ARC layout in 74 percent of cases. For the second prosodic pattern, which involved accentuation on the determiner instead of the antecedent noun, the participants chose the RRC layout in 87 percent of cases. For the third prosodic pattern, which involved accentuation of the relative clause, the participants chose the RRC layout in 63 percent of cases. For the fourth prosodic pattern, which was intended to involve unmarked prosody, the participants chose the ARC layout in 87 percent of cases. The missing data points (total numbers <624) are due to entries not accepted by the experimental control software.

A chi-square test (significance level: 0.05) showed a significant effect for all four prosodic conditions (pattern 1: χ^2-value = 139.799, $p < 0.001$, pattern 2: χ^2-value = 346.135; $p < 0.001$; pattern 3: χ^2-value = 41.876; $p < 0.001$; pattern 4: χ^2-value = 346.135; $p < 0.001$).

In order to check for a learning effect, the results for the first block only are presented in Table 6. It can be observed that the first, the second and the fourth prosodic pattern have a clear majority for the same layout as in the results for all four

Table 5
Amount of tokens assigned to the RRC and ARC layouts according to the four prosodic patterns from experiment 3.

	Pattern 1 (pauses)	Pattern 2 (Det accent)	Pattern 3 (RC accent)	Pattern 4 (boundary t.)
Total	623	622	619	622
RRC	164 (26%)	543 (87%)	390 (63%)	79 (13%)
ARC	459 (74%)	79 (13%)	229 (37%)	543 (87%)

Table 6
Amount of tokens from block 1 assigned to the RRC and ARC layouts according to the four prosodic patterns from experiment 3.

	Pattern 1 (pauses)	Pattern 2 (Det accent)	Pattern 3 (RC accent)	Pattern 4 (boundary t.)
Total	156	156	155	156
RRC	51 (33%)	115 (74%)	80 (52%)	29 (19%)
ARC	105 (67%)	41 (26%)	75 (48%)	127 (81%)

blocks. Only pattern 3 (RC accent) deviates from the results, having a nearly balanced distribution of assignments. A chi-square test (significance level: 0.05) showed a significant effect for the prosodic patterns 1, 2 and 4, but not for pattern 3 (pattern 1: χ^2-value = 18.692, $p < 0.001$; pattern 2: χ^2-value = 35.103, $p < 0.001$; pattern 3: χ^2-value = 0.161, $p > 0.05$; pattern 4: χ^2-value = 61.564, $p < 0.001$).

4.4. Discussion of experiment 3

The results of the picture selection task showed that pauses and accent shift were clearly taken as prosodic cues for one of the two types of adnominal relative clauses. Pauses setting off the relative clause were associated with ARC constructions in the majority of cases, showing a significant deviation from random distribution, both in the pooled data of all four blocks (74 percent) and in the data of only the first block (67 percent). Thus, the results are in line with Hypothesis (6a). This supports the intuitive assumptions that pauses are associated with ARCs (Lehmann, 1984; Brandt, 1990), but contrasts with the findings of Kaland and van Heuven (2010), whose discrimination experiment showed no effect for pauses in German, and Schaffranietz (1999), who attributes a minor role to pauses as cues for discrimination.

Accentuation of the determiner was interpreted as a cue for RRCs in 87 percent of cases, significantly deviating from random distribution, both in the pooled data of all four blocks and in the data of only the first block. This result can be taken as a support for Hypothesis (6b), strengthening the claim that this prosodic pattern is exclusively associated with RRCs (see also Brandt, 1990).

Accentuation of the relative clause was taken as an indicator for RRCs in 63 percent of cases across the four blocks, but only in 52 percent in the first block alone. This suggests that the participants developed the tendency to associate this accentuation pattern with RRC layouts in the course of the experiment. Thus, the results cannot be taken as supporting Hypothesis (6c). A possible explanation may be the overall distribution of assignments. Since two of the other prosodic patterns (Patterns 1 and 4) were primarily associated with ARC layouts and one other pattern with RRC layouts (Pattern 2), the participants may have developed the strategy to associate the remaining one (Pattern 3) with RRC layouts in order to balance the amount of assignments.

The fourth prosodic pattern, which was intended to be unmarked, but turned out to involve tonal boundary marking before the relative clause (see Fig. 12 above), was associated with ARC layouts in a significant majority of cases, both in the pooled data of all four blocks (87 percent) and in the data of only the first block (81 percent). This observation is in line with the claim that (tonally marked) prosodic phrase boundaries setting off the relative clause are associated with ARCs.

In sum, the perception experiment showed that pauses, which are considered to be a rather unstable prosodic marker, are nevertheless consistent cues for the discrimination of ARCs in German. Furthermore, the experiment showed that accentuation of the determiner and the presence of an H% boundary tone clearly points to a restrictive interpretation of the relative clause. An impact of accentuation on the relative clause could not be attested.

5. General discussion and conclusion

This paper reported on two production experiments and one perception experiment investigating the prosodic differences between RRC and ARC constructions in German. The second production experiment showed that speakers systematically use prosodic phrase boundaries to mark ARC constructions and accent shift to the determiner of the antecedent to mark RRC constructions. Silent pauses were not found to be a major prosodic means in production. The perception experiment however showed that listeners clearly perceived them as cues for ARCs. In the same way, the perception experiment showed that accent shift is taken as a cue for RRCs.

These results support the intuitive prosodic patterns for distinguishing RRCs and ARCs described in the literature (Lehmann, 1984; Brandt, 1990).

The differences between the prosodic patterns suggest that the two types of relative clause constructions are mapped onto different prosodic phrase structures, as illustrated in (9) and (10). Following Lehmann's (1984) syntactic analysis, where a RRC is attached to the antecedent NP and an ARC is sister of the higher DP (cf. section 2.1), we suggest that the

different prosodic patterns derive from a mapping of lexical XPs and clauses onto corresponding prosodic phrases, as posited in the framework of Match theory (Selkirk, 2009, 2011).

(9) RRC construction
a. $_{DP}$[der $_{NP}$[Hund $_{RC}$[der einen Eimer trägt]]]
the dog that a bucket carries
'the dog that is carrying a bucket'
b. (der Hund (der einen Eimer trägt)$_{I/\Phi}$)$_{\Phi/I}$

(10) ARC construction
a. $_{DP}$[$_{DP}$[der $_{NP}$[Hund]] $_{RC}$[der einen Eimer trägt]]
the dog which a bucket carries
'the dog, which is carrying a bucket'
b. (der Hund)$_{\Phi}$ (der einen Eimer trägt)$_{I}$

This theory assumes a straightforward matching relationship between syntactic phrases and corresponding higher prosodic domains: a clause is mapped onto an Intonation Phrase (I), and a lexical XP is mapped onto a Phonological Phrase (Φ), as required by the Match constraints given in (11). The theory furthermore assumes that functional elements, such as determiners, do not form their own prosodic phrases, but are integrated into the phrases mapped onto neighboring (lexical) elements. Thus, the DP comprising the RRC construction in (9a) forms a Φ and the relative clause forms a I. Since the latter is higher in the Prosodic Hierarchy, the resulting structure violates the principle Layeredness, which prohibits hierarchically lower prosodic domains to dominate higher ones. This problem could be resolved in several ways, such as promotion of the lower prosodic constituent to a I, demotion of the higher prosodic constituent to a Φ, or omission of one of the prosodic constituents. Either way, there is no right boundary present after the antecedent noun in the prosodic structure, as illustrated in (10b). The ARC construction in (10a), on the other hand, is mapped onto the prosodic structure in (10b), where the antecedent NP forms a Φ with the preceding determiner and the relative clause forms a separate I. In this case, there is a phrase boundary between antecedent noun and relative clause in prosodic structure. Assuming these prosodic representations explains the presence of higher F0 and increased duration on the antecedent of an ARC: Since a right prosodic phrase boundary follows, a high boundary tone and pre-boundary lengthening is realized. The antecedent of an RRC is not followed by a right phrase boundary and hence no such acoustic correlates are present.

(11) a. Match Clause
A clause in syntactic constituent structure must be matched by a corresponding prosodic constituent, call it I, in phonological representation.
b. Match Phrase
A phrase in syntactic constituent structure must be matched by a corresponding prosodic constituent, call it Φ, in phonological representation.

The analyses presented in (9) and (10) are also compatible with Alignment theory (Selkirk, 1995, 2000; Truckenbrodt, 1995, 1999). This theory of the syntax-prosody interface assumes the insertions of a left or right boundary of a specific prosodic constituent at the corresponding left or right edge of a specific syntactic constituent. Thus, the prosodic difference of the two types of relative clause constructions can be accounted for by the alignment constraint in (12), which inserts a Φ-boundary after the antecedent noun of the ARC construction in (10a), but not after the antecedent noun of the RRC construction in (9a).

(12) Align (XP, right; Φ, right)
The right edge of a lexical XP must be aligned with the right edge of a Φ-phrase.

Furthermore, since the prosodic structures in (9b) and (10b) directly reflect the respective syntactic structures, the given analyses are also compatible with a direct access account, which does not assume an independent representation of prosodic structure in phonology. It remains to be shown which of these approaches suits best for a theoretical account of the syntax-prosody interface.

A crucial result of our investigation is that the respective prosodic patterns are not obligatory. The fact that the phrasing correlates may be absent suggests that the prosodic realization of adnominal relative clauses is not solely an outcome of the mapping between syntax and prosody, but that pragmatic conditions have an important role as well. Earlier studies (see e.g. Allbritton et al., 1996; Watt and Murray, 1996) found that it is important to distinguish between

naïve and trained speakers when investigating prosodic cues to syntactic ambiguities. However, the distinction between naïve and trained speakers is not sufficient to explain our results, as revealed by the two rounds of experiment 1. If there is no pragmatic and communicative relevance for disambiguation – as in experiment 1 – it is less likely that a relative clause is realized with a marked prosodic pattern. Rather, speakers use a default prosodic pattern with both types of relative clause constructions: antecedent and relative clause are integrated in one prosodic phrase and the head noun carries the accent,[4] reflecting Kaland and van Heuven's (2010) proposal that there is a ''fixed'' prosodic pattern for both types of relative clause constructions in German. The present study showed that there are systematic deviations from such a pattern in cases where prosodic marking is contextually relevant, i.e., when speakers feel that they have to mark the difference between the two types of relative clauses by means of prosody. These two opposite tendencies may explain the inconsistency found in parts of our data as well as in the production data of Schaffranietz (1999) and Birkner (2008).

Our experiments are in line with Snedeker and Trueswell (2003), who found that speakers only produce effective prosodic disambiguation when they are aware of an ambiguity. These authors concluded that speakers provide cues when needed, and that listeners use these cues. Similar studies by Schafer et al. (2000) and Kraljic and Brennan (2005) found that speakers always use disambiguating cues, as a by-product of planning and articulating utterances. Both studies reject the hypothesis that prosodic cues that resolve syntactic ambiguities are produced ''for'' themselves and not ''for'' their addressees (audience design hypothesis). We suggest that the different conclusions drawn by Schafer et al. (2000) and Kraljic and Brennan (2005) on the one hand, and Snedeker and Trueswell (2003) and our study on the other hand, have to do with several differences in the design of these experiments, as explained above in section 2.4.

The production experiments reported on in this study involved an innovative method in form of a localization task, which elicited the descriptions of object layouts comprising relative clauses. Since the production experiments involved only few participants, the conclusions drawn from this data need to be taken with caution. Future research should test a larger group of subjects in order to validate the present findings. Future research may also apply the method used here for the investigation of the prosody of other constructions that are potentially ambiguous, such as prepositional phrases. In doing so, more factors that have a potential influence on prosody, such as information structure, phonological weight, and speech rate should be taken into account. Moreover, the systematic measurement of phonetic correlates should be applied to data of naturally occurring speech.

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Appendix A. Target sentences of experiment 1

Round 1:
Die Kuh, die eine Glocke trägt, steht links vom Krokodil.
'The cow that/which is carrying a bell is left of the crocodile.'
Der Eisbär, der einen Rettungsring trägt, steht vor dem Gorilla.
'The polar bear that/which is carrying a lifesaver is in front of the gorilla'.
Das Zebra, das eine Melone trägt, steht hinter dem Löwen.
'The zebra that/which is carrying a melon is behind the lion.'
Das Pferd, das einen Sattel trägt, steht rechts vom Baum.
'The horse that/which is carrying a saddle is right of the tree.'
Der Tiger, der eine Gabel trägt, steht hinter dem Elefanten.
'The tiger that/which is carrying a fork is behind the elephant.'
Der Löwe, der eine Schleife trägt, steht vor dem Schwein.

[4] A reviewer points out that all the sentences may as well involve a strong boundary and not be integrated, since the production experiments did not involve control sentences. The auditory impression of the sentences however suggests that antecedent and relative clause are integrated in one prosodic phrase. This pattern was also observed in Truckenbrodt's (2005) data on the prosody of embedded clauses in German, which did not distinguish between restrictive and appositive readings of relative clauses.

‘The lion that/which is carrying a bow, is in front of the pig’
Das Nilpferd, das einen Blumenstrauß trägt, steht links vom Hund.
‘The hippopotamus that/which is carrying a bouquet of flowers is left of the dog.’
Der Bär, der einen Eimer trägt, steht hinter dem Seelöwen.
‘The bear that/which is carrying a bucket is behind the sea lion.’
Der Esel, der einen Wagen zieht, steht vor dem Tiger.
‘The donkey that/which is pulling a Wagen, is in front of the tiger.’
Der Pandabär, der ein Baby trägt, steht rechts vom Nilpferd.
‘The panda that/which is carrying a baby is right of the hippopotamus’
Der Elefant, der einen Schirm trägt, steht hinter der Giraffe.
‘The elephant that/which is carrying an umbrella is behind the giraffe.’
Der Hund, der eine Glocke trägt, steht vor dem Tiger.
‘The dog that/which is carrying a bell is in front of the tiger.’
Der Gorilla, der eine Orange trägt, steht links vom Pferd.
‘The gorilla that/which is carrying an orange is left of the horse.’
Das Schwein, das einen Pilz trägt, steht hinter dem Eisbären.
‘The pig that/which is carrying a mushroom is behind the polar bear.’
Der Seelöwe, der einen Ball trägt, steht hinter dem Zebra.
‘The sea lion that/which is carrying a ball is behind the zebra.’

Round 2:
Der Bär, der einen Eimer trägt, steht in der Mitte
‘The bear that/which is carrying a bucket is in the middle.’
Der Esel, der einen Karren zieht, steht in der Mitte.
‘The donkey that/which is pulling a carriage is in the middle.’
Der Gorilla, der eine Orange trägt, steht in der Mitte.
‘The gorilla that/which is carrying an orange is in the middle.’
Der Hund, der eine Glocke trägt, steht in der Mitte.
‘The dog that/which is carrying a bell is in the middle.’
Die Kuh, die eine Glocke trägt, steht in der Mitte.
‘The cow that/which is carrying a bell is n the middle.’
Der Löwe, der eine Schleife trägt, steht in der Mitte.
‘The lion that/which is carrying a Schleife is in the middle.’
Der Pandabär, der ein Baby trägt, steht in der Mitte.
‘The panda that/which is carrying a baby is in the middle.’
Das Pferd, das einen Reiter trägt, steht in der Mitte.
‘The horse that/which is carrying a rider is in the middle.’
Das Schwein, das einen Pilz trägt, steht in der Mitte.
‘The pig that/which is carrying a mushroom is in the middle.’
Der Tiger, der eine Gabel trägt, steht in der Mitte.
‘The tiger that/which is carrying a fork is in the middle’
Das Zebra, das eine Melone hat, steht in der Mitte.
‘The zebra that/which has a melon is in the middle.’

Appendix B. Target sentences of experiment 2

Das Nilpferd, das einen Blumenkranz hat, steht in der Mitte.
‘The hippopotamus that/which has a bouquet of flowers is in the middle.’
Der Löwe, der eine Schleife hat, steht links.
‘The lion that/which is has a bow is on the left.’
Das Schwein, das einen Pilz hat, steht links.
‘The pig that/which has a mushroom is on the left.’
Das Pferd, das einen Reiter trägt, steht links.
‘The horse that/which is carrying a rider is on the left.’
Die Kuh, die ein Halsband trägt, steht in der Mitte.
‘The cow that/which is carrying a collar is in the middle.’
Der Eisbär, der einen Ring trägt, steht rechts.

‘The polar bear that/which is carrying a ring is on the right.’
Der Hund, der eine Glocke hat, steht links.
‘The dog that/which has a bell is on the left.’
Das Zebra, das eine Melone frisst, steht rechts.
‘The zebra that/which is eating a melon is on the right.’
Der Bär, der einen Eimer hat, steht in der Mitte.
‘The bear that/which has a bucket is in the middle.’
Der Esel, der eine Schleife trägt, steht rechts.
‘The donkey that/which is carrying a bow, is on the right.’
Der Pandabär, der sein Junges trägt, steht in der Mitte.
‘The panda that/which is carrying its bear cub is in the middle.’
Der Gorilla, der eine Orange hat, steht rechts.
‘The gorilla that/which has an orange is on the right.’

Appendix C. Test sentences of experiment 3

Das Dreieck, das gestreift ist, ist gelb.	‘The triangle that/which is striped is yellow.’
Das Dreieck, das gestreift ist, ist rot.	‘The triangle that/which is striped is red.’
Das Dreieck, das gestreift ist, ist grün.	‘The triangle that/which is striped is green.’
Das Dreieck, das gestreift ist, ist blau.	‘The triangle that/which is striped is blue.’
Das Viereck, das gestreift ist, ist gelb.	‘The rectangle that/which is striped is yellow.’
Das Viereck, das gestreift ist, ist rot.	‘The rectangle that/which is striped is red.’
Das Viereck, das gestreift ist, ist grün.	‘The rectangle that/which is striped is green.’
Das Viereck, das gestreift ist, ist blau.	‘The rectangle that/which is striped is blue.’
Der Kreis, der gestreift ist, ist gelb.	‘The circle that/which is striped is yellow.’
Der Kreis, der gesteift ist, ist rot.	‘The circle that/which is striped is red.’
Der Kreis, der gestreift ist, ist grün.	‘The circle that/which is striped is green.’
Der Kreis, der gestreift ist, ist blau.	‘The circle that/which is striped is blue.’
Der Stern, der gestreift ist, ist gelb.	‘The star that/which is striped is yellow.’
Der Stern, der gestreift ist, ist rot.	‘The star that/which is striped is red.’
Der Stern, der gestreift ist, ist grün.	‘The star that/which is striped is green.’
Der Stern, der gestreift ist, ist blau.	‘The star that/which is striped is blue.’

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