Incremental processing in head-final child language: online comprehension of relative clauses in Turkish-speaking children and adults

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The present study investigates the parsing of pre-nominal relative clauses (RCs) in children for the first time with a real-time methodology that reveals moment-to-moment processing patterns as the sentence unfolds. A self-paced listening experiment with Turkish-speaking children (aged 5–8) and adults showed that both groups display a sign of processing cost both in subject and object RCs at different points through the flow of the utterance when integrating the cues that are uninformative (i.e., ambiguous in function) and that are structurally and probabilistically unexpected. Both groups show a processing facilitation as soon as the morphosyntactic dependencies are completed and parse the unbounded dependencies rapidly using the morphosyntactic cues rather than waiting for the clause-final filler. These findings show that five-year-old children show similar patterns to adults in processing the morphosyntactic cues incrementally and in forming expectations about the rest of the utterance on the basis of the probabilistic model of their language.

Keywords: pre-nominal relative clauses; Turkish; child language processing; head-final languages; filler-gap dependencies; morphosyntactic processing; expectation-based parsing

Relative clauses (henceforth: RCs) are embedded clauses that modify a DP, as shown in (1).

(1) 'The lion [that pushed the gorilla] kissed the elephant'.
(2) 'The lion [that the gorilla pushed] kissed the elephant'.

If the noun it modifies (henceforth: head noun) is the subject of the embedded verb *push* (henceforth: relativised verb), as in (1), the RC is referred to as subject RC (henceforth: SRC); if it is the object of the relativised verb, as in (2), it is referred to as object RC (henceforth: ORC).

The comprehension and production of RCs is one of the most commonly studied phenomena in the field of language acquisition. Although a number of cross-linguistic studies have revealed better comprehension and production performance in SRCs compared to ORCs (for reviews, see Diessel, 2004; Kidd, 2011), very few studies have investigated the acquisition of prenominal RCs (i.e., the cases where the RC precedes the head noun) and the results have been conflicting. While some studies report a subject preference (Turkish: Hermon, Öztürk, & Kornfilt, 2007; Hermon, Kornfilt, & Öztürk, 2010; Özge, 2010; Özge, Marinis, & Zeyrek, 2009, 2010; Slobin, 1986; Mandarin: Hsu, Hermon, & Zukowski, 2009), others report no asymmetry (Japanese: Ozeki & Shirai, 2010) or a better performance in ORCs (Turkish: Ekmekçi,

1990; Basque: Gutierrez-Mangado, 2011; Cantonese: Chan, Matthews, & Yip, 2011; Yip & Matthews, 2007). The conflicting data may be the consequence of language-specific constraints, which possibly mask universal constraints, or they could be due to varying methodologies reflecting different abilities.

The findings on the acquisition of prenominal RCs are the result of longitudinal observations, elicitation tasks or sentence-picture matching tasks that are based on offline measures, which reflect the overall cost incurred at the end of the sentence. These measures shed light onto the general processing pattern, but they are not as informative as online studies concerning the underlying causes of the processing asymmetries or the time-course of interpretation. To date, no study has investigated the real-time processing of prenominal RCs in children, which might be crucial in understanding the processing patterns in structures where the modifier appears prior to the modified head and in structures where the gap precedes the filler. Our study aims to fill this gap with a phrase-by-phrase self-paced listening experiment investigating how children and adults process Turkish pre-nominal RCs.

On the acquisition side, we address how the processing pattern between SRCs and ORCs changes as the sentence unfolds and whether child processing is qualitatively different from adult processing with respect to incremental integration of available syntactic and morphosyntactic

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cues. On the sentence processing side, we explore how filler-gap accounts and expectation-based models explain the processing patterns in prenominal RCs. In the remainder of this introduction, we will review the questions our study addresses regarding the nature of child language processing and the accounts about parsing. We will provide information about Turkish, Turkish RCs and why we investigate Turkish. The predictions of each account will be presented after the section 'Method'.

How does online processing of Turkish RCs inform us about child language processing?

The present study enables us to investigate several crucial issues in the development of parsing abilities. The first is concerned with the underlying causes of the processing difficulties in RCs. A number of hypotheses have been proposed to explain why RCs are acquired relatively late and why they pose processing difficulty for young children. While some attribute this to immature syntactic representations (e.g., Friedmann, Beletti, & Rizzi, 2009; Friedmann & Novogrodsky, 2004) or non-adult-like processing mechanisms (e.g., Sheldon, 1974; Tavakolian, 1981), others propose that child processing is constrained (perhaps more heavily) by the same factors guiding adult parsing (e.g., Arnon, 2010). Thus, while the former approach predicts that child parsing should be different from adult parsing, the latter predicts intrinsically similar patterns.

The present study enables us to determine whether child parsing is similar to adult parsing. Real-time studies on child processing have shown that children use early available information incrementally while interpreting spoken utterances (Choi & Trueswell, 2010; Snedeker & Trueswell, 2004; Trueswell, Sekerina, Hill, & Logrip, 1999). Most of these studies have focused on how children parse syntactically ambiguous structures such as 'Put the frog on the napkin in the box' and have revealed that children use early cues in an utterance to arrive at an interpretation that satisfies the structural expectations of the available verb/lexical item in the most probable manner (i.e., assigning the destination interpretation to 'on the napkin' rather than interpreting it as a modifier as the former is likelier). This pattern may result from adult-like incremental processing routines. Yet, these studies also stress that children cannot revise their initial parsing choices and fall into a garden path in these structures.

In Korean, morpheme (-ey) on a sentence-initial noun is ambiguous between a locative case and a locative relativiser. Korean-speaking children treat this morpheme merely as a locative case and fail to revise their initial parse even when the sentence-final verb requires the reanalysis of the -ey morpheme as a relativiser (Choi & Trueswell, 2010). This study points to a crucial aspect of child parsing that diverges from adult-like sentence interpretation. Children are not as adept as adults at

reanalysis. This is compatible with an approach suggesting that children have adult-like parsing mechanisms, rapidly integrating available cues into structure building. The study on Korean also indicates that children are incremental in terms of morphosyntactic processing; yet, the pattern attested could also be due to children's familiarity with the -ey morpheme only as a locative marker rather than a difficulty to revise an initial parse. Alternatively, children may be radically different from adults in that they may be unable to activate multiple interpretations (i.e., various functions) of a lexical item. If this is the case, they should not show processing slow-down upon encountering an ambiguous cue, as they would entertain only one interpretation of that cue. Similarly, they would also fail to reanalyse their initial parse even if the information that requires revision appears relatively early in an utterance. The structure of Turkish RCs involves morphosyntactic cues of varying reliability which are disambiguated relatively early in the sentence. This allows us to address how morphosyntactic cues are integrated and whether children deviate from adult-like incremental parsing.

We have limited information on how children process filler-gap dependencies in RCs. With respect to the processing of filler-gap dependencies within RC structures, school-aged children show priming effects at the gap site, indicating that children establish filler-gap dependencies in a similar manner to adults (Love & Swinney, 1996; Roberts, Marinis, Felser, & Clahsen, 2007). Similarly, Omaki, Davidson-White, Goro, Lidz, and Phillips (2014) used a series of question-after-story tasks with English- and Japanese-speaking children to test the interpretations of ambiguous questions, such as *Where did Lizzie tell someone that she was gonna catch butterflies?* This could be asking about the location of the *telling* or the location of the *butterfly-catching* event, depending on which verb the sentence-initial wh-word is associated with. Both groups of children fit the pattern of active-gap filling by relating the sentence-initial wh-word to the first available verb phrase, which is the main verb in English and the embedded verb in Japanese. This study suggests that five-year-old children acquiring head-final languages are already adult-like with regard to eagerly forming filler-gap dependencies. However, the findings are based on offline measures; therefore, the exact nature and the time-course of dependency formation still needs to be uncovered. Moreover, both child and adult studies investigating filler-gap processing have focused on structures where the filler precedes the gap. There are few studies on filler-gap dependency processing with gaps preceding the filler but there are still many open questions such as how does the parser detect a gap in head-final structures, how does it posit the upcoming filler, and how does it form the filler-gap dependency without violating the incrementality assumption? Being prenominal, Turkish

RCs host the filler at the end of the clause. If the gap-search is initiated by the filler, the interpretation should be postponed until the head noun. In line with previous studies with adults (Kamide & Mitchell, 1999), we predict that other morphosyntactic cues that appear early in the sentence (e.g., case marking) may be guiding incremental interpretation of long distance dependencies in these languages. The present study will thus inform us about whether children form the dependencies by interpreting the morphosyntactic cues in a rapid and predictive manner.

How could online processing of Turkish relative clauses inform us about language processing accounts?

A large number of studies on real-time sentence processing has revealed that structures that involve filler-gap dependencies incur a processing cost. In these structures, processing cost is realised as slowdown at the point where the parser detects a gap and forms a structural dependency between the filler and the gap. Two hypotheses, namely the Linear Distance Hypothesis (LDH) and the Structural Distance Hypothesis (SDH), base their explanation of subject–object asymmetry on the existence of filler-gap dependencies in these structures. Both hypotheses assume that the processor works harder while establishing a dependency between the filler and its gap than if the item appears in its canonical position. According to the LDH, the processing difficulty increases with the number of lexical items between the filler and the gap (Gibson, 1998; Wanner & Maratsos, 1978), whereas the SDH proposes that the deeper a gap is located in the syntactic tree relative to its filler, the more difficult it is to assign it a correct interpretation (O'Grady, 1997). However, a crucial issue to address is to understand how the gap is detected and how the filler-gap dependency is established during the course of real-time processing (for a review, see Aoshima, Phillips, & Weinberg, 2004). Several strategies have been put forth to account for this. Early studies have suggested that the parser assumes a gap only when it identifies an empty argument position (*gap-driven parsing*) (Jakendoff & Culicover, 1971; Wanner & Maratsos, 1978). Another hypothesis states that the parser analyses the structure as if it involves no displaced items and it generates a filler-gap dependency only as a last resort (*gap-as-a-last-resort* or *minimal chain principle*) (De Vincenzi, 1991). According to one of the most widely accepted hypotheses, the *filler-driven parsing* or *active-filler hypothesis*, the search for a gap starts immediately after the parser encounters the filler (Crain & Fodor, 1985; Frazier & Flores d'Arcais, 1989; Kaan, 1997; Stowe, 1986).

Studies from head-final languages have demonstrated that sentence-initial displaced items (e.g., a wh-word) trigger an active and successive search for a gap in every available position until the semantic and syntactic constraints of this displaced item are satisfied (*successive search-for-a-gap hypothesis*) (Aoshima et al., 2004). In contrast, the lexicalist perspectives suggest that the structural requirement of any lexical item, be it a filler, some other category, initiates a search for a dependency formation as soon as it is encountered in the utterance (Garnsey, Tanenhaus, & Chapman, 1989; MacDonald, Pearlmutter, & Seidenberg, 1994; Pickering & Barry, 1991; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Trueswell, Tanenhaus, & Garnsey, 1994).

Expectation-based accounts propose that lexical, syntactic or semantic features of each available lexical item are immediately integrated into the existing structure to trigger anticipations about the structural and semantic feature of the rest of the utterance (e.g., Altmann & Kamide, 1999; Boston, Hale, Kliegl, Patil, & Vasishth, 2008; Demberg & Keller, 2008; Frank & Bod, 2011; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Hale, 2001; Hare, McRae, & Elman, 2003; Kamide & Mitchell, 1999; Levy, 2008; MacDonald et al., 1994; Staub & Clifton, 2006; Trueswell, Tanenhaus, & Kello, 1993). According to these models, highly predictable continuations of a string in a left-to-right parsing are processed faster compared to the less predictable ones. Processing difficulty results when the upcoming structure conflicts with the predictions. It is implied in these accounts that filler-gap dependency formation is not a special form of dependency, the structural and lexical features of each lexical item trigger a search for its dependent structures regardless of whether it is the filler. In this perspective, a combination of multiple factors simultaneously constrain parsing decisions such as the string-based probabilities (i.e., likelihood of a lexical/structural item in a particular location), cue ambiguity (i.e., reliability/informativity of a cue), selectional properties of lexical items and predictive strength of an item (i.e., predictability of a string in a left-to-right parsing).

Several studies have investigated the processing of filler-gap dependencies in prenominal RCs in adults. Studies on Japanese (Ishizuka, 2005; Ishizuka, Nakatani, & Gibson, 2003; Ueno & Garnsey, 2008) and Korean (Kwon, Gordon, Lee, Kluender, & Polinsky, 2010; Kwon, Polinsky, & Kluender, 2006) have shown that ORCs take longer to process than SRCs at the relativised verb and/or at the modified NP. For Chinese, some studies found longer reading times in SRCs compared to ORCs at the modified NP (Gibson & Wu, 2013; Hsiao & Gibson, 2003; Lin & Garnsey, 2011), while others showed the opposite pattern (Lin & Bever, 2006; also see Vasishth, Chen, Li, & Guo, 2013). For Turkish, a self-paced reading study with adults reported longer reading times only at the relativised verb in ORCs compared to SRCs (Kahraman, Sato, Ono, & Sakai, 2010).

In all these studies the subject–object asymmetry was observed either at the relativised verb or at the modified

NP rather than at the gap site. In all these languages, there is ambiguity between a RC and a declarative sentence at the position of the gap and the ambiguity is resolved later in the sentence. It is possible that these studies reported no asymmetry at the gap site because these structural ambiguities prevented the parser from positing a gap and leading it to assign the available string in a simple canonical sentence interpretation prior to the disambiguating regions. This would be in line with the *minimal chain principle*, where the parser does not posit a gap until there is enough information about the existence of a gap.

Several studies have shown that the processing difficulty in pre-nominal RCs arises because the parser's expectation for a canonical matrix clause is not fulfilled. This might be the case for Korean (Kwon et al., 2010; Yun, Whitman, & Hale, 2010) and Chinese (Chen, Grove, & Hale, 2012), where the processing cost increases at points where the parser is uncertain about the structural properties of the upcoming structure and at points where the utterance is disambiguated towards a less expected structure.

This study compares the predictions of the LDH, SDH and the expectation-based models. In Turkish RCs, the earliest time to posit a gap is the relativised verb. Between the two accounts, the LDH predicts faster processing in ORCs compared to SRCs, while the SDH predicts faster processing in SRCs at the relativised verb. However, expectation-based accounts predict an earlier asymmetry at the first NP, which bears an ambiguous genitive case in ORCs compared to an unambiguous accusative case in SRCs.

Turkish

Turkish, spoken by approximately 70 million people in Turkey, belongs to the Turkic branch of the Altaic language family. It is a head-final language with flexible but predominantly SOV word order and rich agglutinative morphology. It allows argument drop. Turkish RCs are pre-nominal and the RC precedes the modified NP. There is no overt relative pronoun but the verbal head (i.e., the embedded verb) is marked with a relativising suffix. In SRCs, the embedded verb is marked by the -An suffix (3). In ORCs, the -dIk suffix (which appears as '-tiğ' in (4) due to phonological reasons) is generally used as a relativiser. In addition, the subject of the ORC is marked with the genitive case, which always requires the possessive agreement marker after the object-relativising morpheme (4).

SRC:

[$_{NP}$ [$_{RC}$ *GAP$_i$* [$_{VP}$ Goril-i   it-en]]   **aslan$_i$**] fil-i öp-tü.
[$_{NP}$ [$_{RC}$ *GAP$_i$* [$_{VP}$ gorilla-Acc push-SRel]] **lion$_i$**] elephant-Acc kiss-Past.3sg
'The lion that pushed the gorilla kissed the elephant'.

ORC:

[$_{NP}$ [$_{RC}$ Goril-in   [$_{VP}$ *GAP$_i$* it-tiğ-i]]   **aslan$_i$**] fil-i öp-tü.
[$_{NP}$ [$_{RC}$ gorilla-Gen [$_{VP}$ *GAP$_i$* push-ORel-Poss.3sg]] **lion$_i$**] elephant-Acc kiss-Past.3sg
'The lion that the gorilla pushed kissed the elephant'.

The morphosyntax of ORCs is ambiguous, while -dIk could be an object-relativiser and a complementiser, subject-relativisation is always marked with -An. The genitive case may mark an embedded subject or a possessor of a possessive NP while the accusative reliably marks direct objects. Moreover, the genitive case always requires an agreement with its dependent head whereas an accusative-marked NP could directly attach to its subcategoriser.

Why Turkish?

As far as the acquisition of pre-nominal RCs is concerned, cross-linguistic studies have provided contrasting findings as to whether children show better performance in SRC compared to ORCs (e.g., Hsu et al., 2009; Kim, 1997; Ozeki & Shirai, 2010). For Turkish, although there is converging evidence for subject preference in child language, there is an ongoing debate regarding the underlying cause of this pattern. While some studies relate it to filler-gap dependencies (Hermon et al., 2010), others relate it to the reliability of the accusative case (Slobin, 1986) or to the interaction of multiple factors (Özge et al., 2009). Moreover, to date no studies have investigated how children process moment-to-moment interpretation of pre-nominal RCs. Turkish RCs allow us to explore how filler-gap dependencies are processed in structures where the gap precedes its filler and evaluate several sentence processing theories. Being a head-final language with rich morphosyntax, Turkish also allows us to explore whether children process morphosyntactic cues incrementally like adults (Kamide, Altmann, & Haywood, 2003).

Method
Participants

Thirty-five monolingual children at the age of 5– 8 (*M* = 6.7, SD = 1.09) and 37 undergraduates from Middle East Technical University participated in this study. The children attended kindergarten (*n* = 16) or primary school (*n* = 19). All participants were from lower middle-class families, and they were right-handed and did not have any behavioural or cognitive deficits. Adult participants were also from lower middle class as all attended a public university.

Materials

A self-paced listening experiment (Ferreira, Anes, & Horine, 1996) was developed that comprised 32 critical items, 32 fillers and 7 practice items. The critical items

were the sentences with RC-Type (SRC, ORC) × RC-Role (i.e., role of the head NP modified by the RC) (subject, object) and fully crossed (eight items per condition) (Table 1). The reason for manipulating the RC-Role was to check the effect of the grammatical role of the head noun within the matrix clause and to control for the parallel function hypothesis that predicts better perform-ance in structures where the RC has the same role in the embedded and the matrix clause (Sheldon, 1974). How-ever, due to space limitations, this study will only focus on the filler-gap and expectation-based accounts. The filler items consisted of simple sentences in various word orders (SOV, SVO, OVS and OSV).

The items were counterbalanced across four lists in a pseudo-randomised order. A comprehension question followed each item to ensure that participants were listening for comprehension.

All NPs were animal names and all verbs involved action. To ensure that each segment constituted a natural prosodic phrase, each NP was modified by an adjective and the relativised verb was preceded by an adverb.[1] All lexical items were controlled for imageability and age of acquisition of the lexical items using an English database (Bird, Franklin, & Howard, 2001) because there was no such database for Turkish at the time of testing. The test sentences were matched for the number of words.

Procedure

The test items were presented in a phrase-by-phrase self-paced listening experiment on a laptop using the E-Prime software and an E-Prime button-box to gather the responses. The E-Prime software recorded the time between each button-press, which provided the listening times (LTs) for each segment. The researcher coded the participants' responses for the comprehension questions into the programme.

The adults encountered one list each in a group design. For children we used a single-case design because there is generally large individual variation due to a still develop-ing system. Therefore, each child completed all four lists in four different sessions with at least a one-week interval between the sessions.

Predictions

Table 2 summarises the expectation of the filler-gap and the expectation-based accounts.

Filler-gap accounts predict processing differences only at the point where the gap is detected and the point where the filler-gap dependency is established. For Turkish, the earliest location to posit a gap is the relativised verb, and the filler (i.e., the head noun) appears after the relativised verb. The LDH predicts that SRCs should require longer LTs compared to ORCs in both locations, and the SDH predicts the opposite pattern. Expectation-based accounts predict that the subject–object asymmetry should be observed incrementally. It should start with the first NP and should continue until the end of the structure.

In the first segment (Table 1), expectation-based accounts predict longer processing times following the genitive-marked NP compared to the accusative-marked NP as the genitive NP is less likely to appear sentence initially, and it is not very informative about the role of the available NP because it is ambiguous between the possessor and the embedded subject. In the second

Table 1. Experimental stimuli divided into five segments/phrases (RC-Type × RC-Role).

Sentence type	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Subject RC with Subject matrix role (SRC-SubjMat)	NP-Acc Haylaz goril-i naughty gorilla-Acc	V-SRel hızlıca it-en hard push-SRel	NP-Nom güçlü aslan strong lion	NP-Acc yavaş fil-i slow elephant-Acc	V öp-tü. kiss-Past.3sg
	'The strong lion that pushed the naughty gorilla kissed the slow elephant'				
Object RC with Subject matrix role (ORC-SubjMat)	NP-Gen Haylaz goril-in naughty gorilla-Gen	V-ORel-PossAgr hızlıca it-tiğ-i hard push-ORel-Poss.3sg	NP-Nom güçlü aslan strong lion	NP-Acc yavaş fil-i slow elephant-Acc	V öp-tü. kiss-Past.3sg
	'The strong lion that the naughty gorilla pushed kissed the slow elephant'				
Subject RC with Object matrix role (SRC-ObjMat)	NP-Acc Haylaz goril-i naughty gorilla-Acc	V-SRel hızlıca it-en hard push-SRel	NP-Acc güçlü aslan-ı strong lion-Acc	NP-Nom yavaş fil slow elephant	V öp-tü. kiss-Past.3sg
	'The slow elephant kissed the strong lion that pushed the naughty gorilla'				
Object RC with Object matrix role (ORC-ObjMat)	NP-Gen Haylaz goril-in naughty gorilla-Gen	V-ORel-PossAgr hızlıca it-tiğ-i hard push-ORel-Poss.3sg	NP-Acc güçlü aslan-ı strong lion-Acc	NP-Nom yavaş fil slow elephant	V öp-tü. kiss-Past.3sg
	'The slow elephant kissed the strong lion that the naughty gorilla pushed'				

Table 2. Predictions of the filler-gap accounts and the expectation-based accounts.

	Filler-gap accounts		
	Linear Distance Hypothesis (LDH)	Structural Distance Hypothesis (SDH)	Expectation-based accounts
Segment 1	No effect of RC-Type or RC-Role	No effect of RC-Type or RC-Role	Effect of RC-Type: shorter LTs in SRC than in ORC Reason: genitive-marked NP in ORC is more ambiguous thanaccusative-marked NP in SRC. No effect of RC-Role
Segment 2	Effect of RC-Type: shorter LTs in ORC than in SRC Reason: greater number of lexical items intervening the gap and the verb in SRC than in ORC. No effect of RC-Role	Effect of RC-Type: shorter LTs in SRC than in ORC Reason: greater number of structural nodes intervening the gap and the verb in ORC than in SRC. No effect of RC-Role	Effect of RC-Type: shorter LTs in ORC than in SRC Reason: (1) Morphosyntactic dependency between genitive NP and the possessive agreement morpheme should facilitate processing in ORC. (2) Relativised verb is unexpected following accusative NP in SRC. No effect of RC-Role
Segment 3	Effect of RC-Type: shorter LTs in ORC than in SRC Reason: greater number of lexical items intervening the gap and the filler in SRC than in ORC. No effect of RC-Role	Effect of RC-Type: shorter LTs in SRC than in ORC Reason: greater number of structural nodes intervening the gap and the filler in ORC than in SRC. No effect of RC-Role	Effect of RC-Type: shorter LTs in SRC than in ORC Reason: relativiser is ambiguous in ORC but not in SRC. Effect of RC-Role: shorter LTs in RCs with object matrix role. Reason: if the previous relativised verb had been interpreted as the headless RC with the subject role, the parser would anticipate an accusative-marked NP (i.e., a matrix object) but not a nominative-marked NP. Encountering a nominative-marked NP requires reanalysis of the string as a full relativised NP (i.e., not a headless RC) with the subject matrix role
Segment 4	No effect of RC-Type or RC-Role But possible spill-over effects	No effect of RC-Type or RC-Role But possible spill-over effects	No effect of RC-Type or RC-Role But possible spill-over effects
Segment 5	No effect of RC-Type or RC-Role But possible spill-over effects	No effect of RC-Type or RC-Role But possible spill-over effects	No effect of RC-Type or RC-Role But possible spill-over effects

segment (Table 1), which hosts the relativised verb, they predict longer LTs after the subject-relativised verb compared to the object-relativised verb due to two main reasons. First, a sentence-initial accusative-marked NP is more likely to be followed by a matrix verb compared to an embedded verb. According to a corpus study, 70% of the simple transitive sentences in the METU Turkish Corpus start with an object followed by a matrix verb as they involve subject-drop (Çakıcı, 2005). Our fragment-completion study also showed that fragments starting with an accusative NP were more frequently completed to create simple matrix clauses than RCs (see Appendix).

Second, the genitive case in the previous segment requires an obligatory possessive agreement marker on its upcoming head.[2] As a result, the parser may generate an expectation to encounter this morphosyntactic dependency.

This is not the case for SRCs because the accusative case does not require a similar morphosyntactic agreement on the relativised verb. Considering these factors, we would predict an effect of facilitation in the form of shorter LTs after the embedded verb in ORCs (henceforth: object-relativised verb) compared to the embedded verb in SRCs (henceforth: subject-relativised verb).

For segment 3 (Table 1), the predictions are mixed, depending on several factors. If ambiguity leads to longer LTs and the object-relativised verb is interpreted as the verb of a complement clause (rather than the object-relativised verb), this would cause longer processing times at the head NP in ORCs compared to SRCs. If the relativising verb in the preceding segment is interpreted as a headless RC,[3] this could also lead to longer processing times in RCs with the subject matrix role compared to the

ones with the object matrix role. If the relativised verb in segment 2 is interpreted as a headless RC, it should receive a subject role because it is unmarked for the case; hence, the parser would anticipate a matrix object as the upcoming argument. In that case, encountering another unmarked NP would cause re-analysis of the structure as a full RC with an overt and unmarked modified NP. In contrast, encountering an accusative NP would still be in line with a headless RC interpretation as this would be interpreted as the matrix object rather than a modified NP with the object matrix role.

For segments 4 and 5, we may observe spillover effects from segment 3.

Data analyses

Segment-by-segment residual LT data[4] were analysed using repeated-measures ANOVAs with group (pre-schoolers and primary-school children) as a between-subject factor and RC-Type (SRC, ORC) and RC-Role (subject, object) as within-subject factors per subjects (F_1) and items (F_2). For adults, we used RC-Type (SRC, ORC) and RC-Role (subject, object) as within-subject factors. Interactions were followed up using Bonferroni correction and eta-rho-square ($\eta\rho^2$) was used as a measure of effect size (Cohen, 1988). We used ANOVAs with the same factors for each group to analyse the accuracy for the comprehension questions that appeared at the end of each sentence.[5]

Results
Children

Mean percentage of accuracy for each RC-Type for pre-schoolers and primary schoolers is displayed in Table 3. There was an overall high accuracy, but the effect of the group was significant, $F(1, 33) = 22.51, p = .000, \eta\rho^2 = .40$. Primary-school children showed a higher accuracy ($M = 83.5$; SE = .01) compared to pre-school children ($M = 93.1$; SE = .01). There was no effect of RC-Type, $F(1, 33) = 2.74, p = .10, \eta\rho^2 = .07$; RC-Role, $F(1, 33) = .43, p = .51, \eta\rho^2 = .01$ and no significant interaction between these factors.

Segment-by-segment LTs and standard errors for each RC-Type and RC-Role are displayed in Figures 1 and 2.

Table 3. Mean percentage of accuracy and standard deviation in each condition for children.

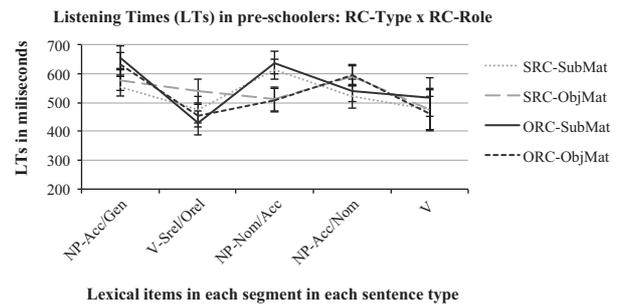| RC-Type, RC-Role	Pre-schoolers	Primary schoolers
SRC, subject	$M = 82$; SD = 14.0	$M = 94$; SD = 4.6
SRC, object	$M = 80$; SD = 11.2	$M = 91$; SD = 4.2
ORC, subject	$M = 85$; SD = 7.6	$M = 91$; SD = 4.4
ORCs, object	$M = 87$; SD = 11.3	$M = 96$; SD = 5.5

Figure 1. Listening times (LTs) in pre-schoolers: RC-Type × RC-Role.

The effect of the group was significant ($p < .003$) in all segments except for the final one. Pre-schoolers showed significantly longer LTs than primary-school children (Table 4).

For segment 1, the effect of RC-Type was significant, $F_1(1, 33) = 118.29, p = .000, \eta\rho^2 = .01; F_2(1, 62) = 30.32, p = .000, \eta\rho^2 = .32$. In both groups, the first segment in ORCs (NP-Gen) required longer LTs ($M = 549.60$; SE = 25.61) than the first segment in SRCs (NP-Acc) ($M = 458.78$; SE = 22.67). There were no other main effects or interactions.

For segment 2, there was a significant effect of RC-Type, $F_1(1, 33) = 18.33, p = .000, \eta\rho^2 = .35; F_2(1, 62) = 23.02, p = .000, \eta\rho^2 = .27$, due to longer LTs at the subject- ($M = 439.72$; SE = 28.85) compared to the object-relativised verb ($M = 366.79$; SE = 27.38). There were no other effects or interactions in this segment.

For segment 3, only the effect of RC-Role was significant, $F_1(1, 33) = 127.10, p = .000, \eta\rho^2 = .79; F_2(1, 62) = 44.20, p = .000, \eta\rho^2 = .41$. Children showed shorter LTs when the RC had the object matrix role ($M = 510.30$; SE = 40.50) compared to the ones with the subject matrix role ($M = 627.80$; SE = 37.64).

Segment 4 hosted the matrix object in the RCs with the subject matrix role, and the matrix subject in the RCs with the object matrix role. There was a significant effect of RC-Type, $F_1(1, 33) = 10.75, p = .002, \eta\rho^2 = .24;$
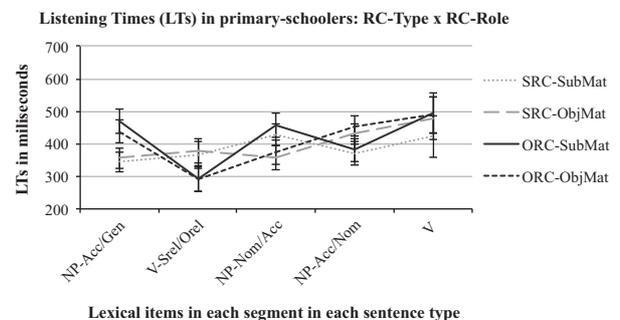

Figure 2. Listening times (LTs) in primary-school children: RC-Type × RC-Role.

Table 4. The effect of age group in each segment with the mean LTs and standard errors in pre-schoolers and primary schoolers.

Children	The effect of age group	Segment 1			Segment 2			Segment 3			Segment 4			Segment 5		
		M	SE	Sig.	M	SE	Sig.	M	SE	Sig.	M	SE	Sig.	M	SE	Sig.
Group	Pre-schoolers	606.60	35.10	.000	474.67	39.51	.012	569.05	38.58	.003	562.90	35.14	.002	483.20	64.85	.89
	Primary schoolers	401.78	32.21		331.84	36.25		404.00	35.41		406.47	32.25		471.20	59.51	
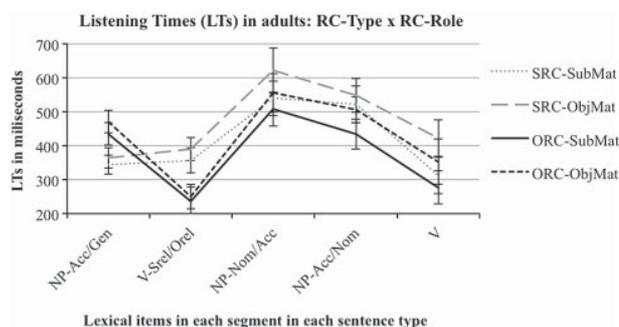
Figure 3.   Listening times (LTs) in adults: RC-Type × RC-Role.

$F_2(1, 62) = 60.15$, $p = .000$, $\eta\rho^2 = .49$, due to longer LTs in ORCs ($M = 494.03$; SE = 24.31) compared to SRCs ($M = 475.34$; SE = 23.96). There was also a significant effect of RC-Role, $F_1(1, 33) = 35.94$, $p = .000$, $\eta\rho^2 = .52$; $F_2(1, 62) = 19.68$, $p = .000$, $\eta\rho^2 = .24$, due to longer LTs in RCs with an object matrix role ($M = 515.14$; SE = 23.11) compared to the ones with subject matrix role ($M = 454.23$; SE = 25.58). There were no other effects or interactions.

For segment 5, there were no significant effects or interactions.

Finally, because the children saw all four experimental lists, we conducted another ANOVA with the data of the children's first session only to address possible long-term priming or list effects. The results in all segments were the same in this analysis (Table 5).

Adults

The mean percentage of accuracy for each RC-Type for adults is displayed in Table 6. There was overall high accuracy in all sentence types and there was no effect of RC-Type, $F(1, 36) = .01$, $p = .89$, $\eta\rho^2 = .001$; or RC-Role, $F(1, 36) = 1.12$, $p = .29$, $\eta\rho^2 = .03$.

Segment-by-segment LTs and standard errors for each RC-Type and RC-Role are displayed in Figure 3.

For segment 1, only the effect of RC-Type was significant, $F_1(1, 36) = 32.4$, $p = .000$, $\eta\rho^2 = .47$; $F_2(1, 29) = 16.85$, $p = .000$, $\eta\rho^2 = .36$. ORCs (NP-Gen) required longer LTs ($M = 549.60$; SE = 25.61) compared to the SRCs (NP-Acc) ($M = 458.78$; SE = 22.67). For segment 2, the effect of the RC-Type was also significant, $F_1(1, 36) = 26.67$, $p = .000$, $\eta\rho^2 = .42$; $F_2(1, 29) = 5.41$, $p = .02$, $\eta\rho^2 = .15$, which was due to longer LTs in SRCs (following the subject-relativised verb) ($M = 373.46$; SE = 32.07) compared to the ORCs (following the object-relativised verb) ($M = 242.64$; SE = 35.28). For segments 3, 4 and 5, there were no significant effects or interactions.

Table 5. Segment-by-segment processing effects only in List 1 for children.

Effects	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Group	$F(1, 33) = 5.21$, $p = .029$, $\eta\rho^2 = .13$	$F(1, 33) = 3.58$, $p = .067$, $\eta\rho^2 = .09$	$F(1, 33) = 4.70$, $p = .037$, $\eta\rho^2 = .12$	$F(1, 33) = 3.35$, $p = .076$, $\eta\rho^2 = .09$;	$F(1, 33) = .09$, $p = .75$, $\eta\rho^2 = .003$
RC-Type	$F(1, 33) = 36.73$, $p = .000$, $\eta\rho^2 = .052$	$F_1(1, 33) = 16.74$, $p = .000$, $\eta\rho^2 = .33$	$F_1(1, 33) = .26$, $p = .87$, $\eta\rho^2 = .00$	$F_1(1, 33) = 25.51$, $p = .000$, $\eta\rho^2 = .43$	$F_1(1, 33) = 1.37$, $p = .25$, $\eta\rho^2 = .04$
RC-Role	$F_1(1, 33) = .145$, $p = .23$, $\eta\rho^2 = .04$	$F_1(1, 33) = 9.76$, $p = .004$, $\eta\rho^2 = .22$	$F_1(1, 33) = 144.69$, $p = .000$, $\eta\rho^2 = .81$	$F_1(1, 33) = 49.40$, $p = .000$, $\eta\rho^2 = .60$	$F_1(1, 33) = .14$, $p = .71$, $\eta\rho^2 = .004$
Group × RC-Role	$F_1(1, 33) = .00$, $p = .98$, $\eta\rho^2 = .00$	$F_1(1, 33) = 4.36$, $p = .045$, $\eta\rho^2 = .11$	$F_1(1, 33) = 2.09$, $p = .15$, $\eta\rho^2 = .06$	$F_1(1, 33) = 2.34$, $p = .13$, $\eta\rho^2 = .06$	$F_1(1, 33) = .10$, $p = .75$, $\eta\rho^2 = .003$

Discussion

Our goal was to investigate real-time processing of pre-nominal Turkish RCs in children and adults. We conducted a self-paced listening experiment to address whether there are qualitative differences between child and adult parsing mechanisms, whether there is a processing asymmetry between SRCs and ORCs, and how the moment-by-moment processing patterns are captured by sentence processing accounts. Below we summarise the results and then discuss the implications for the development of parsing strategies in children and for the parsing accounts we compared.

In segment 1, both children and adults showed a significant slowdown at the genitive NP compared to the accusative NP at the sentence-initial position. Two factors might have contributed to this asymmetry. First, the genitive case is ambiguous between a possessor of a possessive NP and a subject of an embedded clause; therefore, the cue does not reliably signal the role of the NP. In the case of the accusative NP, the grammatical role it marks (i.e., the direct object) is straightforward from the start. Second, it is more likely to encounter to an accusative NP sentence initially compared to a genitive NP as Turkish frequently allows pro-drop of subjects.

In segment 2, the object-relativised verb was processed faster than the subject-relativised verb in both children and adults. This segment is the point where the genitive NP in the previous segment attaches to its head (i.e., the object-relativised verb) and where the morphosyntactic dependency is established between the genitive case and the obligatory possessive agreement marker. We suggest that facilitation at the object-relativised verb is caused by the

possessive marker that has to agree with the genitive case in the previous segment and the verification of the morphosyntactic dependency that is already anticipated in the previous segment. In addition, the subject-relativised verb may have taken longer to integrate if the expectation of the parser had been to encounter a simple matrix verb rather than an embedded verb. This conforms to our sentence-completion study, where the accusative NP was more frequently followed by a matrix verb rather than an embedded verb. This also confirms the predictions of the expectation-based accounts suggesting that more predictable structural continuations are easier to process compared to the less predictable ones.

In segment 3, children showed longer LTs in RCs with the subject role compared to the object role.[6] They may have assigned a headless RC interpretation to the relativised verb. This is indeed possible because headless RCs are acquired earlier than full RCs in many languages (Hamburger, 1980; Hamburger & Crain, 1982). As we discussed earlier, this would have led to a slowdown upon encountering an unmarked modified NP, which would require a reanalysis of the structure as a full RC. Adults did not show such an effect, probably because they already favoured the full RC interpretation.

In segment 4, children showed longer LTs in ORCs compared to SRCs, and they showed an effect of RC-Role, which was due to longer LTs in RCs with the object matrix role compared to the ones with the subject role. In other words, they showed longer LTs when they encountered the matrix subject in this segment. This may be due to the interpretation of the sentence-initial modified NP with the accusative case (in the previous segment) as a sign for a subject-drop structure and showing an effect of reanalysis upon encountering the matrix subject in this segment. This is indeed possible given that subject-drop is a highly frequent phenomenon whereas the OSV order constitutes only 8% of the sentences in the child-directed corpus reported in Slobin and Bever (1982).

The processing patterns in this study have several implications for the development of parsing abilities and for the processing models under discussion.

Table 6. Mean percentage of accuracy and standard deviation in each condition for adults.

RC-Type, RC-Role	Adults
SRC, subject	$M = 91$; $SD = 9.6$
SRC, object	$M = 89$; $SD = 11.6$
ORC, subject	$M = 92$; $SD = 9.0$
ORCs, object	$M = 88$; $SD = 12.1$

First, if we take processing slowdown as an indication of difficulty, we cannot say that one RC-Type was more difficult to parse than the other, as there were moments within the flow of the sentence where SRCs incurred more processing cost than ORCs or vice versa. In other words, the real-time patterns do not reflect a consistent subject–object asymmetry, but both children and adults showed a dynamic change in their processing throughout each structure. How can this be reconciled with previous studies on the offline comprehension of Turkish RCs with children showing better performances in SRCs compared to ORCs? We propose that Turkish SRCs benefit from an early appearing reliable cue, the accusative case marking the object role (a la Choi & Trueswell, 2010). If children assign this sentence-initial NP the object role, their interpretation of the RC would automatically be correct. In contrast, in ORCs the grammatical role of the sentence-initial genitive NP is ambiguous, and it is not disambiguated until the relativised verb. Furthermore, the object-relativiser is also ambiguous between the complementiser and relativiser, and we predict that it is acquired later than subject relativiser (for an experimental evidence to support this prediction, see Özge, Özkan, Arslan-Uzundağ, Küntay, & Snedeker, 2014). In short the structure is disambiguated much later in ORCs compared to SRCs. Thus, we suggest that encountering two uninformative (i.e., ambiguous) cues consecutively might be leading to a low performance in ORCs in the previous offline comprehension studies.

The common pattern in the first two segments between children and adults crucially suggests that children are influenced by similar parsing constraints. This accords with processing accounts showing that factors such as frequency, the type of referential expression (Arnon, 2010) and animacy (Kidd, Brandt, Lieven, & Tomasello, 2007) guide both child and adult parsing. Our study further shows that children are also incrementally guided by morpheme ambiguities and structural expectations about the upcoming structure. Children, just like adults, were able to integrate the sentence-initial accusative and genitive case rapidly. This is consistent with the pattern reported in Choi and Trueswell (2010), where the Korean children assigned an incremental interpretation of a sentence-initial morpheme. The slowdown at the genitive case might be due to the activation of several plausible functions of this ambiguous morpheme. The slowdown at the subject-relativised verb following the accusative NP (i.e., because it was an unexpected structure) and the facilitation at the object-relativised verb following the genitive NP (i.e., because the morphosyntactic dependency is completed at this point) is evidence for the predictive parsing of morphosyntax. Furthermore, we interpret the slowdown at the ambiguous genitive case as indicative of the ability to activate multiple functions of a lexical item. We interpret the longer LTs at the subject-relativised verb as an indication of re-analysis of the sentence-initial accusative NP as part of an embedded structure rather than an object of a matrix clause. These are clear signs of incremental processing in children acquiring a head-final language, and they further indicate that children can revise their initial parsing choices if the revising information comes early enough in the structure.

The pattern in the first two segments has crucial implications for the processing of filler-gap dependencies and parsing models. Neither children nor adults waited until the clause-final filler to anticipate the upcoming structure. Above, we related the longer LTs after the sentence-genitive NP to the fact that (1) it is ambiguous, (2) it is a relatively unexpected structure at the sentence-initial position compared to an accusative NP and (3) it is morphosyntactically dependent on an upcoming head. However, one might also suggest that the sentence-initial genitive NP might be a better indication of an upcoming embedded structure than the sentence-initial accusative NP.[7] If the pattern in segment 1 was caused by this, it is crucial to underline that such early detection of the gap on the basis of morphosyntax is novel to the present study. Earlier online studies on prenominal RCs in adults (Ishizuka et al., 2003; Kwon et al., 2006, 2010; Ueno & Garnsey, 2008) did not report any asymmetry between subject- and object RCs until the relativised verb. Kahraman et al. (2010), which was a self-paced reading study, reported longer reading times for the object-relativised verb compared to the subject-relativised verb in Turkish-speaking adults. They did not find any processing differences prior to this point. In this study, they did not have adverbials prior to the embedded verb, which might have created an expectation for a possessed NP as the head following the genitive case rather than an object relativised verb. In addition, prosodic cues in our self-paced listening study might have created an expectation for a verbal head following the sentence-initial NPs in both structures. In short, the longer LTs at the object-relativised verb in Kahraman et al. (2010) might be due to reanalysis.

The fact that we have processing differences between subject- and object RCs earlier than the clause-final filler has significant consequences for the filler-gap strategies in structures where the gap precedes the filler (for an extensive discussion of how SDH, but not LDH, accounts for offline data from Turkish children, see Hermon et al., 2010). The *active-filler strategy* (Frazier & Flores d'Arcais, 1989) cannot capture the pattern in such structures as the filler triggers the search for a gap in this model. Similarly, the *successive search-for-a-gap hypothesis* (Aoshima et al., 2004) needs to be modified because it is also based on the idea that the filler precedes the gap. The latter hypothesis suggests that the lexical and structural requirements of the filler trigger the successive search for a gap until the dependency is complete. In structures

where the gap precedes the filler, we suggest that the requirements of early appearing cues (e.g., morphosyntactic markers or other lexical/structural material), rather than the filler, constrain upcoming structure. This conforms to lexicalist perspectives that assume a provisional analysis in line with each incoming lexical item (e.g., Garnsey et al., 1989) and expectation-based models, where the interpretation of each linguistic item triggers structural expectations about the possible upcoming configurations (e.g., Levy, 2008). One may suggest that filler-prior-to gap structures may be evoking a filler-based strategy while gap-prior-to-filler structures may evoke a lexically based or gap-based strategy. Although this is a possibility, expectation-based accounts provide a more parsimonious account connecting each incoming item (be it a word, a filler or a morpheme) with its possible upcoming syntactic and morphosyntactic configurations and ranking them on the basis of the probabilities of each possible structural continuation.

It is crucial to highlight that we do not assume that the processing complexity arises merely as a result of conditional probability of string items. We suggest that the present data support an expectation-based accounts, where the parsing expectations are driven by the integration of multiple factors from cue ambiguity (i.e., multiple functions of the genitive case) and string-based probabilities (i.e., probability to encounter a genitive-marked NP sentence initially) to the need to license a particular grammatical feature (Abney, 1989; Aoshima et al., 2004; Pritchett, 1992) and selectional properties of lexical items (e.g., expectation of the possessive agreement morpheme upon encountering the genitive case).

As for the specific accounts of filler-gap processing in RC structures, the processing load may be increasing in line with the number of lexical items (as in the LDH) (Gibson, 1998) or in line with the number of structural nodes (as in the SDH) (O'Grady, 1997) between the filler and the gap. However, both of these accounts relate the processing asymmetry to a single cause (i.e., either the linear distance or the structural distance between the filler and the gap) and predict a single and consistent pattern. The present pattern does not support this prediction. It seems that morpheme ambiguities, probabilistic and structural expectations and morphosyntactic dependencies as well as filler-gap dependencies acted in combination and they led to a dynamic processing change between structures at multiple points during interpretation. Future studies with other languages in which the morphosyntax does not pose any ambiguity might dissociate morphosyntactic factors from the syntactic ones (e.g., Polinsky, Gallo, Graff, & Kravtchenko, 2012).

Finally, previous studies have shown that expectations constrain processing at the following levels: lexical (Tanenhaus et al., 1995), argument structural (Kamide et al., 2003) and phrase structural (Arai & Keller, 2013;

Garnsey et al. 1997; MacDonald et al., 1994; Trueswell et al., 1994). Our findings show that morpheme level ambiguities and morphosyntactic expectations also guide child and adult parsing. Thus, in head-final languages, a developing parser interprets the morphosyntactic cues as incrementally as an adult parser and forms expectations about the rest of the utterance based on structural and probabilistic model of their language.

Notes

1. Few studies have used the self-paced listening paradigm to evaluate the expectation-based models due mostly to the difficulty controlling for the naturalness of the prosodic structure of the sentences. Our study shows that the paradigm yields reliable results once the segments correspond to the natural prosodic breaks.
2. The genitive case creates an expectation for a head with a possessive agreement morphology. Structure-wise, it may be more likely to be followed by a possessed NP (see Appendix), but in our experiment, the adverbial prior to the embedded verb might be increasing the expectation for a verbal head. Regardless of the type of the head, we predict that the genitive case should create anticipation for an upcoming morphosyntactic dependency.
3. Headless RCs are formed via the omission of the modified NP and can be translated as 'the one that', as shown in (i).

   (i) Headless SRC
   [RC Goril-i it-en] fil-i öp-tü.
   [RC gorilla-Acc push-SRel] elephant-Acc kiss-Past.3sg
   'The one that pushed the gorilla kissed the elephant'.

4. Data trimming was done with a programme in Python, we thank Umut Özge for the programme.
5. Analysing the comprehension questions with these factors might be problematic if the means are outside of the range of proportions of .3 to .7, as detailed in Jaeger (2008). However, since the interpretation of the results does not rest on the performance in the comprehension questions, we do not conduct mixed-logit models here.

6. The pattern in this segment does not accord with the Parallel Function Hypothesis (Sheldon, 1974), which would predict an RC-Type by RC-Role interaction in this segment. We omit further discussion here due to space limitations.

7. We thank Matt Wagers for suggesting this possibility.

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Appendix. Fragment-completion study

We conducted a fragment-completion study to investigate the likelihood of the genitive-marked NPs and accusative-marked NPs to be followed by a relativised verb. Eighty Turkish-speaking adults participated in the study that was conducted on the internet using Qualtrics. The participants were provided with fragments composed of an NP followed by an adverbial and asked to complete these fragments in the most plausible way. There were 12 critical items and 20 fillers distributed in two lists. An independent *t*-test with the annotated responses for each case marking type showed that for the fragments marked with the accusative case, there were significantly more simple transitive sentences ($M = 55.41$; $SD = 5.23$) compared to SRCs ($M = 1.66$; $SD = .79$), $t(119) = 5.07$, $p = .000$. Other sentence types following the accusative NP involved structures with ditransitive, causative or coordination ($M = 44.58$; $SD = 6.05$). The fragments with the genitive case were more likely to be followed by the simple structures with NPs ($M = 51.66$; $SD = 5.02$) compared to structures with complement clauses ($M = 27.08$; $SD = 3.71$), $t(119) = 2.69$, $p = .008$ and with ORCs ($M = 9.58$; $SD = 2.48$), $t(119) = 6.58$, $p = .000$. The difference between the complement clauses and the RCs was also significant, $t(119) = 3.43$, $p = .001$. This shows that a sentence-initial accusative NP is more frequently followed by a matrix verb compared to a subject RC, and a sentence-initial genitive NP is more frequently followed by a possessive NP compared to a complement clause or an object RC.