Last-Acquired-First-Forgotten: Interpretation of Turkish Relative Clauses in Typically Developing Children and Adults with Broca's Aphasia

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ABSTRACT: The present study addresses whether adults with Broca's aphasia who have damage in their Posterior Left Inferior Frontal Gyrus (PLIFG) show similar performance to typically developing children in their processing of complex syntax. We tested comprehension of Turkish relative clauses using a sentence-picture matching task in Broca's patients and children with typical development (aged: 3;04-4;03). Both groups showed better performance in subject relative clauses compared to object relative clauses. Children's similar performance to Broca's patients might be due to the fact that PLIFG is a late-maturing neural region. Our participants had more errors in object relative clauses despite the first referent was the agent so there was no evidence for the agent-first strategy. Poor performance in object relative clauses was linked to the morphosyntactic complexity in these structures.

Key words: Turkish relative clauses, Broca's aphasia, child language, comprehension

Son Edinilen İlk Unutulur Prensibi: Tipik Gelişim Gösteren Çocuklar ve Broka Afazili Bireylerin Türkçe İlgi Tümcelerini Anlamlandırma Süreçleri

ÖZ: Bu çalışma, Broka afazisi olan bireyler ile tipik gelişim gösteren çocukların karmaşık tümce yapıları içeren ifadeleri anlama yetilerinde benzerlik olup olmadığını araştırmaktadır. Çalışmada, ifade-cümle eşleştirme testi kullanılarak Broka afazili bireylerin ve 3;04-4;03 yaşlarındaki çocukların Türkçe ilgi tümcelerini anlama yetileri test edilmiştir. Çocuklar da afazili

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bireyler de nesne ilgi tümcelerinde özne ilgi tümcelerine göre daha iyi bir anlama performansı sergilemişlerdir. Bu bulgular, Sol Posteriyor Inferiyor Prefrontal Girus'un sözdizimsel olarak daha karmaşık yapı sergileyen ifadeleri işlemede etkisi olduğunu varsayan kuramlarla uyum göstermektedir. Çocukların Broka afazili bireylerle benzer bir performans sergilemeleri bahsi geçen beyin bölgesinin geç gelişmesine bağlanabilmektedir. Çalışmaya katılan katılımcılar, nesne ilgi tümcelerinde tümcenin öznesi tümce başında yer almasına rağmen bu yapıları anlamakta güçlük çekmişlerdir. Bu bulgu alanyazında önerilmiş 'ilk öge özne olur' stratejisi ile uyumsuzluk göstermektedir. Bu çalışma, özne ilgi tümcelerindeki anlama güçlüğünü bu yapılardaki biçimbirimsel birimlerin karmaşıklığına bağlanmıştır.

Anahtar sözcükler: Türkçe ilgi tümceleri, Broka afazisi, dil edinimi, dil anlama

1 Introduction

The idea that the latest developing linguistic features or functions are likely to be lost first as a result of brain damage goes back to Jakobson's Regression Hypothesis (Jacobson, 1968; originally published in 1941). This idea is actually based on Ribot's Law (Ribot, 2012; originally published in 1881) suggesting that the latest acquired memories deteriorate first in cognitive degeneration. According to this, cognitive deterioration is reminiscent of biological decay in evolution, where structures formed more recently in evolution tend to degenerate earlier than the old ones, and structures that are more complex tend to perish earlier than the simpler ones. In other words, the rules last learnt are the first to lose as a result of brain damage.

Regression Hypothesis was originally proposed in the domain of phonology where individuals with aphasia tend to lose the latest acquired phonological features first. However, it also suggests that there is such a directed process in other domains of language as well. Thus, language loss is expected to follow a reversed order of language acquisition that moves from simple to complex. But what might be the reason for such a resemblance between aphasic language and child language? One possibility is fragile brain regions and networks in both individuals with aphasia and children. According to the *Retrogenesis Model* of neurodegenerative diseases, decay in the cortical myelination of the white matter (WM) reflects the inverse pattern of myelination of the WM pathways in normal development because the recently myelinated brain regions are thinner and more susceptible to decay than ontogenically older myelinated regions (Reisberg, Franssen, Hasan, Monteiro, Boksay, Souren, Kenowsky, Auer, Elahi, & Kluger, 1999; Braak & Braak, 1996). For instance, it is well documented that Posterior Left Inferior Frontal Gyrus (PLIFG) is one of the latest developing regions both in terms of synaptic connections and speed of neurotransmission (Huttenlocher & Dabholkar, 1997). Similarly, it has been shown that dorsal fiber tracts that connect the temporal cortex and the Broadman Area (BA) 44 in the PLIFG develop late in cerebral maturation (Pujol, Soriano-Mas, Ortiz, Sebastian-Galles, Losilla, and Deus, 2006; Perani, Saccuman, Scifo, Anwander, Spada, Baldoli, Poloniato, Lohmann, & Friederici, 2011). There is more or less a consensus on the idea that the increase in the white matter myelination is closely correlated with higher order cognitive abilities in human postnatal development. However, there has been no agreement on the function of these late developing neural regions.

In this paper we test a specific hypothesis, which asserts that PLIFG and the networks around Broca's area host complex syntactic knowledge and syntactic operations. It is not clear whether similarity is observed between adults with aphasia and typically-developing children in the domain of syntactic processing. Some studies highlight similar difficulties in syntactically complex structures both in individuals with brain damage and in children (Kolk, 2001; Grodzinksy, Wexler, Chien, Marakovitz, & Solomon, 1993). One issue with these studies is that they do not make direct experimental comparisons between patients and children. Instead, they either present a corpus analysis showing a developmental trajectory where certain complex structures appear relatively late in acquisition and argue that these linguistic structures are similarly impaired in aphasia (Kolk, 2001), or they combine different experimental studies that either focus on children (e.g., Wexler & Chien, 1985; Grodzinsky & Reinhart, 1993) or on adults with aphasia (e.g., Swinney, Nicol, & Zurif, 1989; Grodzinsky, 1986) to argue that both groups have similar 'deficits' (Grodzinksy, Wexler, Chien, Marakovitz, & Solomon, 1993). In this paper, we use the same measure for the first time both with Broca's patients and children with typical development to address whether they display similarities in their comprehension of relative clauses, syntactically complex structures that involve embedding. By doing that, we evaluate two complementary perspectives that attribute a purely syntactic function to these regions, namely *Trace Deletion Hypothesis (TDH)* and *Syntactic Maturation Hypothesis* (*SMH)*.

According to TDH, Broca's region hosts the so-called *movement operation* that transforms a canonical sentence into an embedded structure via *traces* that reveal the thematic structure of *who did what to whom* retaining the relation between the moved phrasal constituent and its extraction site (Grodzinsky, 1990; 2000). On this view, individuals with Broca's aphasia and young children with immature PLIFG cannot interpret traces and they fail to assign correct thematic roles to the dislocated referents in complex sentences. Instead, they rely on a *Default Universal Strategy* that automatically assigns the first referent the *agent* role.

According to SMH, the function of the late maturing PLIFG and the dorsal fibers connecting temporal cortex and Broca's area is to compute complex syntactic operations (Friederici, et al, 2006; Friederici, 2011; 2012). This is evidenced by neuroimaging studies with healthy adults that report activation in Broca's area during the processing of structures that involve non-adjacent lexical items and filler-gap dependencies (for a review, see Table 4 in Friederici, 2011). Similarly, language acquisition studies reporting late development of non-canonical structures, poor performance in syntactic tasks, inability to interpret the morphosyntactic markers in non-canonical structures, and high reliance on word order for thematic role assignment are also taken as evidence for the syntactic function of Broca's area (Brauer et al, 2013; Brauer et al. 2011; Knoll et al., 2012; Friederici, Oberecer, & Brauer, 2012; Skeide, Brauer, & Friederici, 2015). Poor parsing abilities of German-speaking children have especially been the strongest evidence for this hypothesis. It has been repeatedly shown that German-speaking children are unable to assign thematic roles in complex structures until late in acquisition (Knoll et al., 2013; Dittmar et al., 2013). In these studies, German-speaking 3-year-old children failed to interpret case marking cues for thematic interpretation when the verbal cues and the word order cues are not helpful, and they could not interpret case marking when they appear in conflict with canonical word order until age 6 or 7 (Knoll et al., 2013; Dittmar et al., 2013). The idea is that the object is dislocated from its original position to a position prior to the subject in noncanonical object-first sentences. According to SMH, 'the (re)computation of arguments that are moved from subordinate sentence parts recruit the posterior portion of BA 45 bordering BA 44' (Friederici, 2012; p. 264) and an 'increased activation of BA 44/45 is observed when the processing of dependency relationships in non-canonical sentences depends on movement operations' (Grodzinsky & Friederici, 2006; p. 244). Thus, Broca's patients and preschool children with immature Broca's area are expected to misinterpret displaced noun phrases and their case markers.

Previous studies with Turkish-speaking patients with Broca's aphasia have shown that they have no problems in their production of simple canonical sentences while showing difficulty in non-canonical sentences (Duman, Aygen, Özgirgin, & Bastiaanse, 2007). As for the case marking cues, Turkish Broca's patients have problem-free production of the nominative and accusative cases (Duman, Aygen, Özgirgin, & Bastiaanse, 2007). Dutch- and German-speaking Broca's patients also correctly articulate case marking cues in simple and complex sentences (Ruigendijk & Bastiaanse, 2002). Studies from child language in Turkish have also shown correct production of case marking as early as 2 years of age (Ketrez 2004; Ketrez & Aksu-Koç, 2009). Turkish-speaking 4-year-olds can also interpret nominative and accusative case marking cues in their online processing of simple sentences (Özge, Küntay, & Snedeker, 2019). Findings reporting intact production of case marking in Turkish and German Broca's patients do not concur with the findings from German-speaking children who acquire case rather late (Knoll et al., 2013; Dittmar et al., 2013). We know, however, that comprehension of non-canonical sentences and their respective case marking is problematic in Broca's aphasia in languages like Turkish (Kükürt, 2004; Duman, Aygen, & Bastiaanse, 2008; Duman, Altınok, Özgirgin, & Bastiaanse, 2011), Serbo-Croatian (Smith, & Mimica, 1984), Russian (Friedmann, Reznick, Dolinski-Nuger, & Soboleva, 2010), Hebrew (Friedmann & Shapiro, 2003), and Japanese (Hagiwara & Caplan, 1990) despite the morphosyntactic cues on the nouns or verbs in these complex sentences. The same finding has repeatedly been reported for children in various languages (for a review see, Bates, MacWhinney, Caselli, Devescovi, Natale, & Venza, 1984; McCauley & Christiansen, 2019). Turkish-speaking children also show processing difficulty in their comprehension of non-canonical sentences (Slobin & Bever, 1982) and in their processing of the genitive case in object relative clauses (Özge, Marninis, & Zeyrek, 2015). Thus, it may be the case that both Broca's patients and children have similar problems of computing complex syntactic structures but they may be using reliable case marking cues in their comprehension while failing to use the other unreliable cues. Alternatively, aphasic patients and children may be using different strategies to accommodate similar syntactic comprehension problems. However, we do not have clear-cut answers for these questions and to date there is no study comparing the Broca's patients and children in their comprehension of complex syntax using the same task in the same language. Comparing language comprehension in Broca's patients and children is particularly important because the former has impaired PLIFG and the latter has a still maturing one. This would provide insight about the role of PLIFG, the type of processing strategies used in these groups, thereby allowing us to test the above-mentioned accounts, namely the TDH and SMH.

The present study aims to fill in this gap and address whether (i) 3-year-old children with typical development display a similar pattern to adults with Broca's aphasia in their comprehension of relative clauses, complex structures that involve dislocated referents, and (ii) whether their interpretation patterns conforms to the predictions of the TDH and SMH. We test this particular age group for two reasons. First, children at this age group still undergo brain maturation especially in their PLIFG regions. This provides us with a good opportunity to test the hypotheses of THD and SMH. Second, there are previous findings showing that children acquiring German, another language with rich case marking system, are unable to interpret case marking cues in non-canonical sentences at these ages (Knoll et al., 2013; Dittmar et al., 2013). This age group enables us to test whether these findings could be generalized to Turkish, a language with a more reliable case system than German. It might be the case that Turkish-speaking children can use case marking cues in their interpretation of relative clauses earlier than German-speaking children.

We focus on Turkish for several reasons, which will especially inform us about (ii) above. First, Turkish is a head-final language so relative clauses are pre-nominal, which means that the relativizer (modifier) precedes the modified noun, as in (1). Relativization is carried by a verbal morpheme (i.e., relativizing morpheme) that attaches to the embedded verb (i.e., *chase*). There are two distinct relativizing morphemes: *–(y)An* for subject relativization and *–dIk* for object relativization. The type of the relativizing morpheme is informative about the thematic role of the upcoming modified noun (i.e., *the dog*). In other words, whether the modified noun is the agent or the patient of the embedded verb is cued by the relativizing morpheme before the modified noun appears clause finally. If the embedded verb is marked with *–(y)An,* it indicates that the upcoming noun is the agent of the action depicted in the embedded verb. If the embedded verb is marked with *–dIk*, the upcoming noun is the patient of the action depicted in the embedded verb. In English relative clauses, on the other hand, the modified noun precedes the relativizer so it is not clear until the embedded verb whether this clause-initial noun will be the subject or the object of the clause so the parser needs to keep the first noun in memory until it is integrated into its predicate. In addition to the relativizing morphemes, case marker on the non-head noun within the relative clause (i.e., *the cat*) is also informative about the role of the upcoming head noun. The arguments might change position within the relative clause in Turkish but in the most likely ordering of the arguments, which we followed in this study, the object noun is preceded by the embedded verb in a subject relative clause and it is marked with the accusative case if it is a definite noun, and the subject noun is preceded by the embedded verb in an object relative clause and it is has to be marked with the genitive case. In other words, the clause-initial noun is the object noun in subject relative clauses and it is the subject in object relative clauses, and the case marker on this clause-initial noun reveals its thematic role, which would in turn provide a predictive cue for the thematic role of the upcoming modified noun.

(1) a. *Subject Relative Clause*

Kedi-yi	kovala-yan	köpek	havla-dı.
cat-Acc	chase-SubRel	dog	bark-Past

“The dog that chased the cat barked.”

b. *Object Relative Clause*

Kedi-nin	kovala-dığ-ı	köpek	havla-dı.
cat-Gen	chase-ObjRel-Poss.3sg	dog	bark-Past

“The dog that the cat chased barked.”

These features might ease processing only if the parser is able to interpret them. Under both TDH and SMH, neither Broca’s patients nor children should be able to interpret the moved noun phrases and their case marker as they receive interpretation via *traces*, which go undetected in impaired or immature syntactic machinery. Both accounts posit a canonical order strategy that assigns the agent role to the first noun. In the case of Turkish relative clauses, both subject relative clauses and object relative clauses involve movement so Broca's patients and children should fail to assign correct thematic roles to the arguments in these structures but they should select the first noun as the agent by default. This predicts better performance in object relative clauses compared to subject relative clauses because the first argument (i.e., *kedi-nin, cat-Gen*) is already the subject of the embedded clause (1b), whereas it is the object (i.e., *kedi-yi, cat-Acc*) (1a). In this study, we test whether Turkish-speaking Broca's patients and 3-year-old children with typical development show any evidence of (i) inability to interpret dislocated arguments and their case markers in relative clauses and (ii) agent-first strategy.

2 Experiment

2.1 Method

2.1.1 Participants

Thirteen adults diagnosed with Broca's aphasia (4 female adults) and fifteen monolingual (7 female) children with typical development participated in this study.

Participants in the aphasia group were diagnosed both by a neurologist and a speech therapist (the second author in this paper) and they had minimum three months post-onset. Their age ranged between 30 and 71 years, and they had at least five years of education. The age and educational level in our patients showed a large variation. However, given the difficulty of finding individuals with similar brain impairments and similar backgrounds, this was inevitable. They were tested in a rehabilitation center in Ankara, where they were admitted for speech therapy (Table 1 for information on participants with aphasia). Three patients were excluded from the test for the following reasons: One could not follow the instructions, another dropped out due to severe depression, and the other could barely show %10 success in the comprehension of canonical sentences.

Child participants were all neurologically intact, their age ranged between 3;04 and 4;03 years, they attended a private nursery in Ankara, and their mother had at least 8 years of education. The reason why we included children at this age group is that their PLIFG is still maturing and this is the age group that clearly used the canonical word order strategy upon their failure to interpret the non-canonical sentences in the previous studies with German-speaking children (e.g., Knoll et al., 2012; Friederici, Oberecer, & Brauer, 2012). Thus, this would be an appropriate age to test in order to compare the present findings from Turkish-speaking children to those of German-speaking children in the previous studies. Relying on the findings of the previous studies, we did not conduct pilot test with the age group we tested.

Ten healthy adult participants, matched for age and education to the language impaired group served as a control group in the experiment.

Table 1. Information on Participants with Aphasia

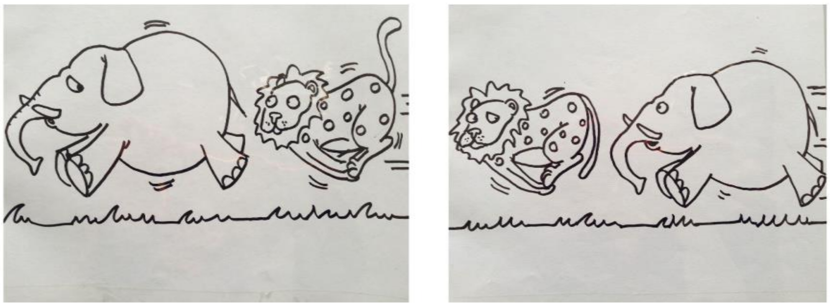
Participant	Sex	Age/ Year	Education	Aphasia Type	Etiology
ab	f	49	11	Broca	Hemorrhagic infarct& cerebral abscess
ay	m	30	11	Broca	CVA*
fk	f	57	5	Broca	Left parietal infarct
hk	m	39	5	Broca	Epileptic attack
iu	m	65	13	Broca	Acute infarct in the left MCA**
kk	m	33	5	Broca	CVA + left frontoparietal infarct
ms	m	37	5	Broca	CVA
ng	f	62	5	Broca	Left frontoparietal infarct
nk	f	58	15	Broca	Cerebral hemorrhage
st	m	31	8	Broca	CVA
sa	m	71	5	Broca	Ischemic stroke

* CVA: Cerebrovascular Accident ** MCA: Middle Cerebral Artery

2.1.2 Stimuli and procedure

We used a sentence-picture matching task. A triple of pictures accompanied each sentence. In each of the three pictures, two animate entities appeared as part of an action either as an agent or a patient (Figure 1). Only one picture depicted the sentence correctly and the others served as distracters (one reversing the roles and the other depicting an irrelevant activity with the same participants). For example, for the sentence “the lion that the elephant chased has spots”, the correct picture showed an elephant chasing a lion with spots, the reverse picture showed a lion with spots chasing an elephant, and the irrelevant picture depicted a lion with spots and an elephant walking together. We used the irrelevant picture to make sure that the lexical items were correctly understood and all participants attended to the task.

Figure 1: Sample Pictures Used for the Experiment



The stimuli consisted of 20 target items (i.e., 10 subject RCs and 10 object RCs) and 10 control items (i.e., canonical sentences). All sentences in the task were semantically reversible (i.e., all referents were animate and could equally function as an agent). To keep the sentence length short and to make the modified NP the first argument of the matrix verb of a canonical sentence, we used relative clauses that appear as the subject of an adjectival predicate as shown in (2a) and (2b) below.[1] All of the verbs used in the sentences were agentive action verbs such as *kiss*, *kick*, *hug*, *push*, *kill*, and *chase*.

(2) a. *Subject Relative Clause*

Fil-i	kovala-yan	aslan	benek-li.
elephant-Acc	chase-SubRel	lion	spot-with

"The lion that is chasing the elephant has spots."

b. *Object Relative Clause*

Fil-in	kovala-dığ-ı	aslan	benek-li.
Elephant-Gen	chase-ObjRel-Poss.3sg	lion	spot-with

"The lion that the elephant is chasing has spots."

[1] Note that the relative clause in each sentence precedes the head noun as Turkish relative clauses are pre-nominal and the adjectival predicate is at the end of the sentence in line with the canonical SOV order of the language.

c. *Canonical SOV Sentence*

Aslan	fil-i	koval-ıyor.
Lion	elephant-Acc	chase-Prog

"The lion is chasing the elephant."

The stimuli were pseudo-randomized to prevent presentation of more than two items of the same type in a row. All lexical items were repeated three times in each list. To ensure that the correct response for the canonical items were not always the same as the correct response for subject relative clauses, the subject of the canonical sentence type was the same as the subject of the object relative clause (e.g., *The elephant is chasing the lion*) half of the times and it was the same as the subject of the subject relative clause (e.g., *The lion is chasing the elephant*) in the other half.

Each participant was tested individually in a quiet room. They were asked to listen to the sentences while looking at the pictures laid on the desk and pick up the correct picture depicting the spoken sentence. They were free to listen to each sentence as many times as they wanted.

2.1 Results

The control group (i.e., neurologically intact adults) performed at ceiling in all structures therefore only the data from our target groups was included in the analysis. Table 2 shows the mean percentage of correct responses for each sentence type in the target groups. To see the effect of sentence type on successful comprehension, we conducted a Repeated Measures Analysis of Variance (ANOVA) with the Group (aphasic and child) as between subjects factor, and Sentence Type (subject RC, object RC, and simple canonical sentences) as within subjects factor. According to this, there was a significant effect of sentence type $F(2, 50) = 24.69$, $p < .001$. Pairwise comparisons with Bonferroni correction revealed that both simple canonical sentences and subject RCs were significantly better performed than object RCs whereas the difference between canonical sentences and subject RCs was not significant. There was no significant effect of group $F(1, 25) = .201$, $p > .05$ and no interaction between sentence type and group $F(2, 50) = 1.56$, $p > .05$ (Table 2).

Table 2. Percentage of Correct Responses for Each Sentence Type

Participants	Sentence Type		
	Canonical	Subject RC	Object RC
Children	M = 82.94	M = 73.53	M = 51.76
	SD = 14.03	SD = 15.38	SD = 13.80
Adults with Broca's Aphasia	M = 73.00	M = 75.00	M = 54.00
	SD = 18.88	SD = 17.79	SD = 19.55

To see whether there was an effect of sentence type on the percentage of other response types, namely the reverse (i.e., where the agent of the sentence is depicted as the patient and the patient of the sentence is depicted as the agent) and irrelevant responses, we conducted two similar ANOVAs with Group (aphasic and child) as between subjects factor, and Sentence Type (subject RC, object RC, and simple canonical sentences) as within subjects factor. For irrelevant response type, we did not find any effect of sentence type $F(2,50) = .118$, $p > .05$, group $F(1, 25) = 1.43$, $p > .05$, or interaction between the two $F(2, 50) = 2.03$, $p > .05$ (Table 3).

Table 3. Percentage of Reversed Responses for Each Sentence Type

Participants	Sentence Type		
	Canonical	Subject RC	Object RC
Children	M = 14.71	M = 22.94	M = 47.65
	SD = 12.80	SD = 13.58	SD = 13.47
Adults with Broca's Aphasia	M = 23.00	M = 21.00	M = 40.00
	SD = 18.28	SD = 11.97	SD = 19.43

For reverse type errors, there was a significant effect of sentence type $F(2, 50) = 28.10$, $p < .001$. According to the pairwise comparisons with Bonferroni correction, this was due to the fact that object RCs led to significantly greater number of reversal errors ($M = 44.81$, $SD = 16.02$) compared to canonical sentences ($M = 17.78$, $SD = 15.27$) or subject RCs ($M = 22.22$, $SD = 12.81$) (Table 3). Also, there was no effect of group $F(1, 25) = .011$, $p > .05$ and no interaction between sentence type and group $F(2, 50) = 2.47$, $p > .05$ (Table 4).

Table 4. Percentage of Irrelevant Responses for Each Sentence Type

Participants	Sentence Type		
	Canonical	Subject RC	Object RC
Children	M = 2.35	M = 3.53	M = .59
	SD = 5.62	SD = 6.06	SD = 2.42
Adults with Broca's Aphasia	M = 4.00	M = 4.00	M = 6.00
	SD = 6.99	SD = 9.66	SD = 8.43

3 Discussion

We set out to investigate whether individuals with Broca's aphasia show comprehension patterns similar to typically developing children, and whether their interpretation patterns reflect impaired/immature interpretation of complex syntax and morphosyntactic cues. Individuals with aphasia performed similarly to children in their comprehension of relative clauses. Both groups had significantly less correct responses in object relative clauses compared to subject relative clauses and canonical sentences (for similar results in Broca's aphasia and second language learners, see Aydın, 2007). Better performance in subject relative clauses compared to object relative clauses is in line with many previous cross-linguistic studies showing a subject preference in the comprehension of relative clauses (for a review, see Özge, et al., 2015; Arnon, 2010). With respect to the type of errors made, there were very few responses pointing to the irrelevant picture indicating that all participants understood the task, ignored the control picture and looked for the contrast between the agent and the patient depending on the sentence type. In addition, both groups were more likely to select the pictures where the reverse of the activity was depicted for object relative clauses than they did for subject relative clauses. In reversal errors, the correct agent of the activity is depicted as the patient of the same activity so the thematic roles are reversed (e.g., selection of the picture where the lion is chasing the elephant for the sentence "the lion the elephant is chasing"). In the case of English relative clauses, reversal errors were taken to reflect a canonical order strategy where the first noun is selected as the agent by default. In the case of Turkish, however, this is not possible as the first noun in object relative clauses is already the agent noun (e.g., Fil-in kovala-dığ-ı aslan, elephant-Gen chase-ObjRel-Poss.1sg lion, 'the lion that the elephant kissed'). One possibility for this type of error might be the misinterpretation of the initial genitive case (-ın) as the accusative case (-ı) (Özge et al., 2015; Özge, Marinis, & Zeyrek, 2009). This is possible if the final –n sound in the genitive marked noun was not salient enough to recognize. Alternatively, the reversal errors might also be selected if the relations between arguments are not correctly interpreted while the lexical items received correct interpretation. Our participants seem to have interpreted the lexical items correctly given the few irrelevant responses for all other sentence types. This indicates that the morphosyntax revealing the relations between arguments might have been problematic in object relative clauses. This involves the genitive case, the object relativizer, and the possessive-agreement morphology, which will be discussed in detail below.

The present findings are in line with models such as Regression Hypothesis and Retrogenessis Model, which predict similarity between aphasic and child language. In these models, impaired brain and child brain essentially share common fragile neural features; late maturing cortical regions or connections during childhood are also more prone to decay as a result of brain damage (Reisberg, et al., 1999; Braak & Braak, 1996; Huttenlocher & Dabholkar, 1997; Pujol, et al., 2006; Perani, et al., 2011). Similar comprehension patterns in Broca's patients and children in our study might thus be reflecting the fragile neural characteristics in these populations. This is possible especially given previous neuroimaging studies showing little or no activation in these late developing regions in children younger than six compared to adults during syntactic interpretation (Oberecker, Friedrich, & Friederichi, 2005; Schipke, et al., 2011; 2012). Another support for this interpretation comes from studies where these regions are activated in ambiguity resolution and cognitive control tasks (Fiebach et al., 2004; Mason et al. 2003; Noppeney & Price, 2004; Jonides, et al., 1998; Nelson, et al., 2003; A.W. MacDonald, Cohen, Stenger, & Carter, 2000; Brass & von Cramon, 2004). What stands in all of these studies is that these late developing LIFG regions are involved in various complex tasks ranging from complex syntactic processing to executive functions. Therefore, this might be why our participants performed poorly in object relative clauses.

The second question we were interested in was whether the performance patterns would reveal any information about the function of these late maturing cortical regions. The question was whether Broca's area hosted a very specific syntactic operation, namely *movement*, which assigns meaning to noun phrases that appear in a non-canonical position and their case markers (Grodzinsky, 2000; Friederici, et al., 2006; Friederici, 2011; 2012). According to both of such hypotheses, namely the TDH (Grodzinsky, 2000) and the SMH (Friederici, et al., 2006; Friederici, 2011; 2012), the thematic role of the moved noun phrases both in subject and object relative clauses should go un-interpreted and participants should assign a universal strategy that assigns the first noun the agent role leading to better comprehension in object relatives in Turkish. Neither of these hypotheses receives support given the present data because (i) we have not seen any evidence for a lack of interpretation of the moved nouns, and (ii) we have not seen any evidence for the canonical order strategy. If syntactic movement had been problematic in these populations, we would have observed low performance in both relative clause types as both structures involve dislocated nouns. Moreover, if our participants had used the canonical order strategy, we would have observed poorer performance in subject relative clauses that have the patient referent as the first noun phrase and a good performance in object relative clauses locating the agent as the first noun phrase.

Different from the expectations of the TDH and the SMH, our participants showed better performance in subject relative clauses and they failed to assign the correct thematic roles to the referents in object relative clauses. We conjecture that case markers were selectively interpreted depending on their reliability and ambiguity. The first noun in a subject relative clause is marked with the accusative case, which is a reliable object marker. The first noun in an object relative clause is marked with the genitive case, which has two functions, namely the possessor of a possessive noun phrase (i.e., *kedi-nin mama-sı; cat-Gen food-Poss.3sg; 'cat's food'*) and the subject of an embedded verb (i.e., *kedi-nin kovala-dığ-ı; cat-Gen chase-DIK-Poss.3sg; the one that the cat chased*). Conflicting with the hypotheses of the TDH and the SMH, this pattern diminishes the possibility that the late developing PLIFG regions are responsible for the computation of a very specific transformational syntactic operation. Yet, the present pattern would be explained if children and Broca's patients relied on early appearing reliable cues and ignored the late-coming ones (Choi & Trueswell, 2010). In the case of subject relative clauses, initial interpretation of the accusative case already leads one to the correct interpretation. However, in the case of object relative clauses participants would fail because the genitive case has multiple functions and its more probable interpretation is its possessor function (Özge, et al., 2015). Therefore, this initial wrong interpretation of the genitive case as the possessor requires a revision in line with the upcoming relativizer. However, the object relativizer is also ambiguous between an object relativizer and complementizer. In other words, for the correct interpretation of subject relative clauses, it would be enough to interpret the accusative case on the sentence-initial noun. This is straightforward because it has a clear object function. Moreover, the subject relativizing morpheme following the accusative case also reliably supports this initial object interpretation. For the correct interpretation of object relative clauses, on the other hand, either the genitive case should be correctly interpreted (i.e., the correct function of the genitive case should be selected) or if the genitive case is misinterpreted, the correct function of the second available morphosyntactic cue, which is the verbal morpheme –dIk, should be correctly interpreted. Therefore, the interpretation of object relative clauses would be problematic if (i) the genitive case on the first noun is misinterpreted initially and this initial parse is not revised in line with the upcoming verbal cue, or (ii) neither the genitive case nor the verbal morpheme is interpreted.

This line of explanation is in line with accounts positing that PLIFG regions do not have a purely syntactic function but the area is specialized in executive function tasks that require cognitive control and inhibition. In such executive function tasks, evaluation of multiple sources of conflicting information is required as well as the conflict resolution via the use of inhibition (MacLeod, 1991; Thomson-Schill, Jonides, Marschuetz, Smith, D'esposito, Kan, Knight & Scick, 2002; Novic, Trueswell & Thomson-Schill, 2005; 2010). Under this account, most linguistic stimuli lead to multiple competing interpretations and parsing inherently involves activation and selection of the most plausible alternative among multiple alternatives. Importantly, this selection process mostly requires the evaluation of multiple analyses and inhibition of the normally reliable but currently unavailable parsing choices (Novic, et al., 2005). For the processing of Turkish relative clauses, this account would predict better performance in subject relative clauses where the accusative case marking on the sentence initial noun is more reliable than the genitive case in object relative clauses. In subject relative clauses, early case marking as a consistent object marker leads to a single possible interpretation and the subsequent subject relativizing morpheme *–(y)An* does not require the reanalysis of this initial interpretation. In object relative clauses, on the other hand, sentence-initial genitive case is ambiguous between the possessor of a possessive phrase and the subject of an embedded clause. The genitive case (-in) also shares some phonological features with the accusative case (-i). If participants selected the possessor interpretation of the genitive case or if they misheard the genitive case as the accusative case, this initial misinterpretation needs to be revised with the upcoming verbal cue (i.e., object relativizer *-dIk*). If they could not inhibit and revise their initial misinterpretation, this would lead to reversed responses in object relative clauses, which is exactly compatible with our results. Thus, the correct interpretation of the initial accusative case (as the object) leads to correct interpretation in the case of subject relative clauses whereas the initial misinterpretation of the genitive case (as a possessor or as an accusative) and inability to revise this wrong parse leads to lower performance in object relative clauses.

This is by no means to say that these regions have no role in syntactic processing. PLIFG regions, especially the dorsal pathways connecting temporal lobes to Broca's area might be involved in the computation of syntax and disruption in these fiber tracks might be causing comprehension difficulties in syntactically complex sentences (Griffiths, Marslen-Wilson, Stamatakis & Tyler, 2002). However, the very same regions might be involved in other cognitive domains (e.g., inhibition) and domain-general combinatorial operations which might be rendering the computation of hierarchical syntax difficult in groups with immature or impaired Broca's area. It is far from clear with what mechanism the human brain computes syntax and to what extent other cognitive functions are involved in these processes. Yet, the present study rules out that these late developing regions are responsible for only a very specific mechanism called *transformation* that is supposed to assign meaning to dislocated noun phases and their case markers (Grodzinsky, 2000).

In conclusion, the present study addressed the question of whether adults with Broca's aphasia present similar patterns to typically developing child language in terms of their comprehension of Turkish relative clauses. Both adult Broca's patients and healthy pre-school children showed good performance in their comprehension of subject relative clauses in a sentence-picture matching task. We concluded that the present pattern of similarity might be resulting from the fact that PLIFG regions are fragile in children and Broca's patients due to maturation and damage, respectively. This is in line with the Regression Hypothesis and the Retrogenesis Model suggesting that late developing cortical regions and their associated functions are more likely to be lost first as a result of brain damage. As for the function of these late developing PLIFG regions, our study presented evidence that children at 3 years of age, whose PLIFG regions are in the process of maturation, and adults with Broca's aphasia, who has damage in PLIFG regions, are able to interpret non-canonical sentences selectively depending on the reliability of early appearing morphological cues, and they do not apply a default canonical word order strategy. They performed poorly in object relative structures where the early appearing morphosyntactic markers are ambiguous. This pattern is not in line with the accounts such as the TDH and the SMH attributing the PLIFG regions a single role of applying a transformational syntactic mechanism that assigns meaning to dislocated nouns and their case markers. We remain agnostic about the exact role of PLIFG in this study, as we did not directly measure the brain activity in these regions during syntactic functions or during executive functions. However, given the previous findings showing an activation in PLIFG during executive function and cognitive control tasks (Novic, Trueswell & Thomson-Schill, 2010; January, Trueswell, & Thompson-Schill, 2009) and given the previous findings showing that Broca's area may not be active during the processing of complex syntax in morphologically rich languages like Japanese (Yokoyama, Watanabe, Iwata, Ikuta, Haji, Usui,... & Horie, K., 2007), we can argue that the sole function of PLIFG cannot be to compute complex syntax. The immature or impaired PLIFG and the associated limited syntactic and executive function skills may be one reason behind difficulty comprehending relative clauses in our study. Our study revealed that neither Broca's patients nor children use the canonical word order strategy; instead they use reliable case marking cues to compensate their comprehension difficulty. This is in line with recent eye-tracking findings showing that 4-year-old children use adultlike parsing mechanisms assigning incremental and predictive meaning to case marking cues during the course of online interpretation in Turkish (Özge, et al., 2015; Özge, et al., 2019) and in German (Özge, Kornfilt, Münster, Knoeferle, Küntay, & Snedeker, 2016).

Although providing insights about the role of PLIFG in sentence comprehension and the strategies used by Turkish-speaking children and Broca's patients in their comprehension of relative clauses, there are some limitations in this study that could be addresses in future studies. First, the exact role of the brain regions addressed here cannot be effectively specified due to the fact that the present design does not involve brain imaging techniques (fMRI) or neurocognitive measures (ERPs). Although the processing mechanism of complex syntax interpretation cannot be clearly articulated, we can state that the present pattern concurs with the pattern previous studies with 4-year-old children (Özge et al., 2016; Özge et al., 2019). Second, the precise role of other linguistic and cognitive abilities on our participants' comprehension performance cannot be described, as we lacked complementary linguistic and cognitive measures, which also prevents us from focusing on individual differences in cognitive abilities. Third, the developmental trajectory in the comprehension of relative clauses cannot be presented as we tested a single age group. Therefore, future studies should combine linguistic and non-linguistic tasks and support offline studies with online neurolinguistic ones in various age groups in order to pinpoint the exact nature of neurocognitive mechanism of language processing in children and Broca's patients. Finally, we cannot discuss the effect of age or education on the performance of Broca's patients, as we did not have enough number of participants in different groups. Despite the fact that there was a variation in our Broca's patients with respect to their age and educational level, they showed similar subject-object asymmetry while showing a good performance in canonical sentences. Nevertheless, the fact that there were 3 patients who opted out from the study shows that Broca's aphasia does not display uniform symptoms or processing patterns. There surely must be individual differences that cannot be pursued further in the present study, which could be a direction for future studies. Despite these limitations, one the few studies using the same task both with children and Broca's patients, the present study clearly rules out the possibility that 3-year-old children and Broca's patients rely on word order cues when they cannot interpret complex sentences. What stands out as a crucial finding in this study is that individuals with maturing or impaired PLIFG can still utilize case marking cues during the interpretation of complex syntax as long as these cues are unambiguous and reliable.

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