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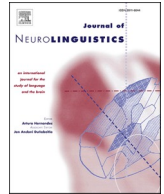
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# Limitations during processing of variable reflexive anaphors and overt/null object pronouns in Turkish aphasia revealed by eye-tracking during listening studies

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## ABSTRACT

This study investigated how reflexives and object pronouns in Turkish are processed in aphasia as compared to a group of unimpaired controls. We aimed to understand (i) the moment-by-moment time course of processing reflexive forms, and (ii) overt/null object pronouns in Turkish people with aphasia (PWA). We administered two eye-movement-monitoring during-listening experiments exploring resolution of reflexive variables (Experiment 1) and object pronouns (Experiment 2) in 6 PWA and their controls (n = 26). Our findings showed that interpretation of reflexive anaphors in Turkish is variable, and PWA are employing a non-local interpretation of reflexive anaphors to tackle down referential ambiguity in the absence of an ability to integrate contextual cues. Furthermore, PWA inappropriately considered inaccessible local antecedents for object pronouns, and they encountered limitations processing discourse antecedents. We argue that anaphoric processing profiles in aphasia face strong limitations by variable interpretability of pronominal reference and PWA's inability to integrate contextual cues to disambiguate the intended antecedents.

## 1. Introduction

Aphasia, a language disorder acquired after brain injury, profoundly impairs linguistic capabilities, often severely hindering the ability to process language. In this paper, we are focusing on an area of grammar, pronouns, which has been consistently shown to be affected in PWA across many languages (Blumstein et al., 1983; Burkhardt et al., 2008; Choy & Thompson, 2010; Edwards & Varlokosta, 2007; Friederici et al., 1991; Grodzinsky et al., 1993; Ruijndijk et al., 2006; Vasić, 2006; Westergaard et al., 2019; among many others), see also Arslan et al., (2021) for a review. Research on pronouns in aphasia has exclusively focused on certain types of pronouns including (personal) object pronouns and reflexives. It has been suggested that the challenge of pronoun interpretation in aphasia may stem from structural deficits in pronominal processing, as indicated by Grodzinsky et al. (1993). Nonetheless, studies report that PWA are able to resolve pronominal dependencies, albeit with a slower interpretation (Burkhardt et al., 2008; Love et al., 1998). Additionally, PWA have often been shown to pattern with controls in their online processing, but they demonstrate difficulties in interpreting of information (Choy & Thompson, 2010; Thompson & Choy, 2009).

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The binding theory holds that reflexive and (personal) object pronouns are constrained by the following principles: Principle A expresses that a reflexive anaphor must be bound in its local domain. Principle B indicates that a pronoun must be unbound in its local domain, suggesting that it should refer to an antecedent outside its own structural local domain (Chomsky, 1981). Therefore, in ‘[Jack thought that [Fred adored himself]]’ the reflexive anaphor ‘himself’ can be bound to Fred or to an extra-sentential antecedent, while in ‘[Jack thought that [Fred adored him]]’ the personal pronoun ‘him’ cannot be Fred. Rizzi (1990) analyses these locality constraints based on structural distance, which have often been applied in aphasia research, for instance, dependencies requiring discourse interpretation are assumed to be more demanding than structures that solely rely on syntactic analysis (Grodzinsky et al., 1993). Another explanation based on the structural locality comes from the **Structural Intervention** hypothesis (e.g. Engel, Shapiro, & Love, 2018; Garraffa, 2009; Sheppard et al., 2015) which holds that intervening sentence material between pronouns and their antecedents causes sentence interpretation to fail in aphasia. This model predicts object pronouns to be more severely impaired than reflexives due to the structural distance between a pronoun and its antecedent being shorter than for reflexives (i.e., unlike pronouns, a reflexive anaphor has co-indexing relationship with the proximally closest antecedent: *Jack<sub>j</sub> thought that Fred<sub>i</sub> adored him<sub>j</sub>/himself<sub>j</sub>*). Engel et al. (2018), using an eye-movement monitoring study, examined groups of English-speaking PWA. The authors compared reflexives and pronouns in complement clauses (e.g., ‘The *grandma* said that the *baker* cleaned *herself/her* ...’) and in subject relatives (e.g., ‘The *baker* that helped the *grandma* cleaned *herself/her* ...’). Their PWA showed longer fixations towards the intended referent for reflexives than for object pronouns, and this pattern was more stable for complement clauses. The authors report that this advantage for reflexives was also present in their offline sentence comprehension task, on which the PWA performed virtually unaffected in interpreting reflexives but not object pronouns, indicating that structural intervention may impact pronoun interpretation in aphasia.

The **Resource Reduction** hypothesis posits that deficits in interpreting pronouns are linked with declining cognitive resources in aphasia including reduced working memory capacity (Caplan et al., 2013, 2015). In support of the Resource Reduction hypothesis, using self-paced listening experiments, Caplan et al. (2013, 2015) examined comprehension of reflexive and direct object pronouns. Their results showed that PWA’s ability to interpret reflexives is better retained than object pronouns, and that this interpretation difficulty is correlated with PWA’s low performance on digit span tasks. This suggests that pronoun processing difficulty in aphasia is associated with reductions in cognitive resources, particularly in working memory capacity. The better retention of reflexive elements over object pronouns is in fact consistent with a number of previous studies (Gavarró, 2008; Grodzinsky et al., 1993; Hickok & Avrutin, 1995; Ruigendijk et al., 2006), while some other studies report equally impaired reflexive and object pronoun processing in aphasia (Choy & Thompson, 2010; Edwards & Varlokosta, 2007). The latter pattern of findings seems to be compatible with the **Delayed Lexical Integration** hypothesis (Choy & Thompson, 2010; Thompson & Choy, 2009) which proposes that sentence interpretation difficulty arises due to delays in the integration of lexical and syntactic information in aphasia. Choy and Thompson (2010) examined a group of PWA using an eye-movement monitoring study with sentential contexts where pronoun/reflexive elements are manipulated (i.e., ‘The *soldier* told the *farmer* with glasses to shave *himself/him* ...’). Their PWA performed equally poorly on both pronoun and reflexive conditions, and the PWA’s target fixations showed no group differences compared to healthy controls in both reflexive and pronoun regions. The authors argue that the locality constrains do not affect reflexive and pronoun conditions in aphasia per se as the authors found no differences in their PWA’s performances. An intriguing finding from this research was that PWA were able to fixate on the correct target visuals even when they incorrectly responded to a trial, suggesting that the sentence interpretation difficulty does not stem from a structural impairment in binding, but rather from delays in processing lexical items in those sentences.

Studies focusing on sentence contexts that allow object dropping (i.e., null objects) are limited in aphasia research. Peristeri and Tsimpli (2013), using offline picture-sentence matching and self-paced listening tasks, investigated how Greek-speaking PWA processed overt and null subject pronouns. The authors found that in a sentence-picture matching task their PWA performed indifferent from the control norms in comprehending number (i.e., ‘them’) and gender (i.e., ‘s/he’) distinctions for object clitic pronouns. In their self-paced listening study, the authors studied both subject and object pronouns in subordinate clauses (e.g., ‘The *doorman* waived *hastily* at the *postman* while *ø/pro* was opening the door.’). Outcomes from a self-paced listening study showed that processing is delayed in aphasia as compared to controls, and that virtually all PWA performed better on null subject than overt subject condition while there were no overt vs. null differences for object pronouns. The authors argue that aphasia leads to a difficulty in processing overt subject constructions in their behavioural responses and a delay in their segment-by-segment comprehension in self-paced listening task, suggesting that processing in aphasia is delayed. Using a cross-modal picture matching task, Wang and Thompson (2022) examined the processing of null objects in PWA speaking Mandarin Chinese, a language that allows object NPs to be dropped within elliptical constructions (e.g., ‘Zhangsan rode his horse and Lisi rode \_\_, too.’). They showed that healthy controls exhibited priming effects at the first verb phrase but not the second one whereas PWA demonstrated the reverse pattern of priming effects. The authors argue that the presence of activation effects in later regions in PWA’s processing is associated with a delayed processing of lexical integration. These results expand upon Vasić (2006), who demonstrated that, in such elliptical constructions lacking an object noun phrase, PWA often encounter challenges in interpreting discourse-level meanings.

An explanation for why PWA encounter pronoun resolution difficulty varies with accounts on linguistic grounds, such as structural interveners, or on the potential reduction of cognitive resources or delayed-lexical integration. However, languages investigated present a large bias to well-studied European languages including English or Dutch. In contrast to other languages, Turkish presents an intriguing distinction with its dual reflexive forms: *kendi*, typically functioning as a local reflexive, and *kendisi*, which exhibits unrestricted behavior, as delineated in analyses in Turkish linguistics (see e.g., Gökgöz-Kurt, 2021; Kornfilt, 2001). Our understanding of the ways in which aphasia may disrupt such a binding system remains incomplete, a gap this study seeks to address.

### 1.1. Pronominal system in Turkish and the current study

Turkish contains two forms of reflexive pronouns: *kendi* ‘oneself’ which is analyzed as a local anaphor, and *kendisi* as an anaphor behaving as a long-distance reflexive exhibiting an unconstrained behavior (Enç, 1989; Gürel, 2002; Kornfilt, 1997, 2001; Sezer, 1979). The anaphor ‘*kendi*’ is assumed to necessitate a local c-commanding antecedent requiring to be bound in its local domain, in line with the binding theory (Chomsky, 1981). Nonetheless, experimental work has shown that Turkish speakers may have strong non-local interpretations, suggesting that they both can refer to non-local and/or discourse antecedents (Gračanin-Yukseket al., 2017; Knospe, 2019; Özbek & Kahraman, 2016), see (1a-b). The unconstrained behavior in *kendisi* has been rather established in Turkish linguistics, see Gökgez-Kurt (2021) who suggested that *kendisi* shows both local and non-local binding properties. By contrast, third-person object pronoun *o* ‘it’ refers to antecedents outside of its local domain or to an extra-sentential antecedent, but not to local antecedents in line with the Principle B in the binding theory (Gürel, 2002; Kornfilt, 1997; Underhill, 1976), see (1c). As Turkish is a pro-drop language, arguments such as subjects or objects can be expressed by a null pronoun.

- (1) a. Ali<sub>j</sub> Ayşe'nin<sub>k</sub> kendine<sub>j/k</sub> kızmasına şaşır<sub>ı</sub>. (Enç, 1989, p. 58)  
 Ali.NOM Ayşe.GEN self.DAT angry.MSD.ACC surprise.PST  
 ‘Ali was surprised at Ayşe getting angry at onself’
- b. Ali<sub>j</sub> Ayşe'nin<sub>k</sub> kendisine<sub>j/k</sub> kızmasına şaşır<sub>ı</sub>.  
 Ali.NOM Ayşe.GEN self.3SG.DAT angry.MSD.ACC surprise.PST  
 ‘Ali was surprised at Ayşe getting angry at oneself’
- c. Ali<sub>j</sub> Ayşe'nin onaj<sub>ı</sub> kızmasına şaşır<sub>ı</sub>.  
 Ali.NOM Ayşe.GEN it.3SG.DAT angry.MSD.ACC surprise.PST  
 ‘Ali was surprised at Ayşe getting angry at it’

Research on pronoun impairments in PWA within the context of the Turkish language is scarce. In a conference contribution, Akyüz and Arslan (2021), using a spontaneous speech task, showed that Turkish-speaking PWA have an elevated number of object dropping instances and reduced reflexive forms overall compared to the control norms whereas there was no reduction in object pronoun use. Arslan, Yeşilli Puzella, Selvi-Balo, Aydın, & Maviş, 2024 using a sentence-to-picture matching experiment recruited 12 Turkish-speaking PWA and a group of healthy controls to examine pronominal resolution in sentential contexts (*Tavşan kendini/onu/maymunu gösteriyor*. ‘The rabbit is pointing at itself/it/the monkey’). The authors report that Turkish-speaking PWA demonstrated poorer comprehension of sentences containing pronouns and reflexives overall compared to controls. However, no significant differences were observed between the comprehension of object pronouns and reflexive conditions, indicating that the reflexive forms were comparable in difficulty to object pronouns.

Summarizing, growing pieces of psycholinguistic evidence seem to indicate that Turkish reflexive anaphors rather present an unconstrained behavior (Gračanin-Yukseket al., 2017; Knospe, 2019; Özbek & Kahraman, 2016). The scarcity of studies on real-time pronoun resolution in Turkish-speaking PWA creates a gap in our understanding, particularly regarding the effects of aphasia on Turkish that permits unconstrained reflexive conditions and object dropping. Many of the hypotheses explaining pronoun difficulty in aphasia, particularly those derived from behavioural data, align with the idea of a proximal binding strategy, wherein the nearest antecedent becomes a default option, leading to correct identification of the antecedents of reflexive forms in languages like English. However, less has been understood what happens in aphasic processing when pronominal binding involves structural differences, as observed with Turkish. We explore these nuances in Experiments 1 and 2.

The aims of this study are two-fold: first, to investigate processing of reflexive forms, and second, to examine the processing of overt and null object pronouns in Turkish individuals with and without aphasia using eye-movement monitoring during listening experiments. Experiments 1 and 2 utilized eye-movement monitoring during auditory listening tasks, conducted with Turkish-speaking PWA (n = 6) and with unimpaired control groups (n = 26), aiming to examine the time-course associated with the processing of reflexive anaphors together with both null and overt object pronouns. Eye-tracking offers the most optimal methodology for investigating sentence interpretation deficits in aphasia, especially when sentential contexts place high demands on working memory (see Ivanova & Hallowell, 2012). Visual world eye-tracking paradigm has been extensively used in understanding aphasic deficits (see Sharma et al., 2021 for a comprehensive review).

Based on the above-mentioned literature, it is reasonable to predict challenges in sentence interpretation in aphasia within the context of the Turkish language for both reflexive anaphor and object pronoun conditions as compared to unimpaired controls. However, different accounts may lead to different predictions. Concerning potential outcomes related to unconstrained reflexive anaphors in aphasia, the concept of locality constraints is especially intriguing. *The Structural Intervention hypothesis* (e.g., Engel et al., 2018) predicts that pronominal elements referring to antecedents outside their local binding domains are more effortful in aphasia.

Consequently, if this theory holds, we anticipate that PWA would perform better with reflexive anaphors, especially *kendisi*, when they are contextually biased towards an interpretation with a local antecedent, as opposed to when they are associated with a non-local antecedent. To test this prediction, we manipulated the contexts within our sentence materials to induce a bias toward either local or non-local interpretations for reflexive anaphors. Under the *Delayed Lexical Integration* account, it is anticipated that both types of reflexive anaphors would be equally impacted in aphasia. This account holds that the primary challenge in sentence interpretation is not an impairment in resolving pronouns, but rather a delay in the processing of lexical information (Choy & Thompson, 2010; Thompson & Choy, 2009). The *Resource Reduction* hypothesis (Caplan et al., 2013, 2015), by contrast, forecasts a difficulty in anaphor resolution in PWA, which is affiliated with diminished working memory capacity. Therefore, following this hypothesis, it is plausible that working memory measurements (i.e., digit span scores) would modulate anaphor processing outcomes. Lastly, in relation to the overt and null pronoun conditions being investigated in Experiment 2, due to the fact that studies focusing on such pronominal conditions in aphasia are sporadic, our predictions are somewhat blunt. Building on the findings of Peristeri and Tsimpli (2013), it could be anticipated that PWA would exhibit no extensive differences in processing between null and overt object pronoun conditions. Alternatively, drawing parallels with prior research on null objects in elliptical structures, we may anticipate that PWA would face considerable challenges in the discourse-level interpretation of null pronouns (Vasić, 2006; see also Wang & Thompson, 2022).

## 2. Experiment 1. Processing of reflexive anaphors in Turkish aphasia – an eye-movement monitoring during listening study

### 2.1. Methods

#### 2.1.1. Participants

A total of 6 individuals suffering from fluent and non-fluent aphasia (1 female, 5 males; age range = 32–78,  $M_{age} = 48.66$ ) were recruited at Anadolu University, Speech and Language Therapy Research and Rehabilitation Centre (DILKOM) in Eskişehir, Turkey. The PWA experienced a single stroke unilaterally impacting the left hemisphere. No other neurological or psychiatric disability were present. All participants had dominant use of their right hand before the stroke. At the time of testing, the PWA had chronic aphasia, and more than 12 months had passed since the onset of their symptoms. The participants were all native monolingual speakers of Turkish and they had normal or corrected-to-normal visual acuity. The diagnosis of aphasia and the patterns of language impairments in the PWA were detailed by using the Aphasia Language Assessment Test for Turkish (Maviş & Toğram, 2009). We report their performance on auditory sentence comprehension and spontaneous speech subtasks, and their overall test score (see Table 1). Three of our PWA were diagnosed with fluent aphasia and the other three with non-fluent aphasia; we included both types of participants because they presented forms of difficulty comprehending and producing grammatical structures. It is not unusual to include small sample sizes with different PWAs in eye-movement experiments (e.g., Hanne et al., 2016). In order to control for the potential severity of PWA, particularly with regard to auditory input, we utilized the Token Test (De Renzi & Faglioni, 1978) employing the revised tablet-based Token Test App version in Turkish (Bastiaanse et al., 2016).

Additionally, 26 unimpaired participants (13 females and 13 males, age range = 30–75,  $M_{age} = 42.51$ ) took part in the study. The control participants reported no history of neurological, developmental, or psychiatric disorders that might impact their language processing ability. The control participants were all monolingual Turkish speakers residing in Eskişehir, Turkey. To assess cognitive abilities in both the PWA and control participants, we administered the ‘Test Your Memory’ Turkish version (Maviş et al., 2015) and the digit span tasks in forward order (Wechsler, 2008).<sup>1</sup> Cognitive task scores are presented in Table 1. The procedures reported in this study were approved by the ethics committee of the University of Groningen (CETO ref. No. [76006271]). Data collection for this experiment was conducted at Anadolu University/DILKOM aphasia clinics. The participants received 10€ per hour in return for their time.

#### 2.1.2. Materials

We used a two-by-two design, which included 12 items shown in four conditions: *kendi-local*, *kendi-nonlocal*, *kendisi-local*, and *kendisi-nonlocal*. We manipulated the type of reflexive used (*kendi* vs. *kendisi*) and the presence of contextual bias to a potential antecedent (local vs. non-local).

A total of 48 picture displays, each containing four visual drawings, as demonstrated in Fig. 1, were generated. All visual objects used in this study represented concrete nouns. There were 36 unique human referents and 12 non-human objects, which were distributed over 12 displays so that each display featured three human referents and a non-human object. One of the human referents acted as a local antecedent, and another one as non-local antecedent. The remaining two referents included a non-mentioned (a potential discourse) human referent and a non-human distractor. A non-human distractor was incorporated to maintain consistent grid areas for eye-movement recordings. To avoid interference with processing of critical human referents which represent antecedents, semantically pertinent non-human referents, such as ‘hospital’, were employed. Name agreement for those images were checked by four native Turkish speakers, who were professional speech and language therapists at Anadolu University, Turkey at the time of testing. Disagreements were discussed and minimal amendments were made to the images when necessary.

<sup>1</sup> We administered the digit span task in pointing modality. Each span contained two items, and the span length increased diagonally starting from digit strings with a span of two (i.e., ‘four-seven’) up to digit strings with a span of seven. The participants were asked to point at digits on a response sheet on which the digits were printed in numeric symbols from 1 to 9. The task was terminated when two mistakes were done on the same span.

**Table 1**

Demographic, medical and aphasiological details of participants. Mean scores from screening tests (TYM - Test Your Memory, max score = 50; Token Test max score = 36, Digit span max = 8; ADD, Spontaneous Speech subtest max score = 32; ADD, Comprehension subtest max score = 66; ADD, overall max score = 98). MPO = month post onset time; NA = not available. \*

Participant	Aphasia Type	Sex	Age	Edu. (years)	Lesion information	MPO	TYM	Token Test	Digit Span	Spontaneous Speech	Comprehension	Overall score
A01	Fluent	M	54	5	NA	60	34	11.5	2	31	66	97
A02	Non-fluent	M	78	12	Left temporal areas	35	5	5.5	0	8	20	28
A03	Non-fluent	M	48	8	NA	36	14	9.5	3	26	60	86
A04	Fluent	M	48	5	Left temporal intracerebral hematoma	37	20	26	3		62	
A05	Fluent	F	32	16	Left MCA syndrome	12	37	15.5	NA	29	64	93
A06	Non-fluent	M	32	16	Bilateral frontal areas	48	NA	2	3	28	55	83
<i>Aphasia <math>\bar{x}</math></i>			<i>48.66</i>	<i>10.33</i>			<i>22.00</i>	<i>11.66</i>	<i>1.83</i>			
<i>Controls (n = 26) <math>\bar{x}</math></i>			<i>42.51</i>	<i>11.85</i>			<i>46.88</i>	<i>34.47</i>	<i>6.07</i>			

\* PWA and control groups were not individually one-to-one matched, but we have chosen to control for the following demographic factors across the two groups: age (aphasia mean = 48.66 vs. control mean = 42.51;  $t = -1.08$ ,  $df = 31$ ,  $p = 00.28$ ), and years of education (aphasia mean = 10.33 vs. control mean = 11.85;  $t = 0.89$ ,  $df = 31$ ,  $p = 00.38$ ). These factors were not different across groups. On a side note, PWA performed more poorly as compared to cognitive screening tasks: TYM (22.00 vs. 46.88;  $t = 9.17$ ,  $df = 30$ ,  $p < 00.001$ ), Token Test (11.66 vs. 34.47;  $t = 13.66$ ,  $df = 31$ ,  $p < 00.001$ ), and digit span task (1.83 vs. 6.07;  $t = 7.66$ ,  $df = 31$ ,  $p < 00.001$ ). These data clearly show that in cognitive tasks PWA performed below the control norms.

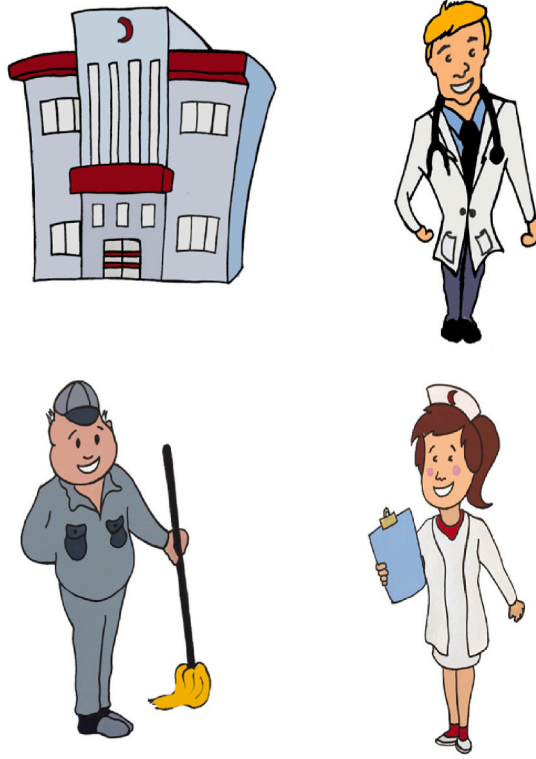


Fig. 1. An example visual display showing three human referents (a doctor, nurse, and a janitor) as potential antecedents for reflexive anaphors, and a hospital as a non-human distractor object.

Across different conditions and items, each referent appeared in a distinct quadrant of the displays. We used 21 male and 15 female referents, each representing a clearly distinguishable professional stereotypes (e.g., nurse, teacher). We created displays containing either two female and one male referent, or two male and one female referent,<sup>2</sup> across the visual stimulus.

The linguistic stimuli included 12 sentential contexts across four conditions: (i) kendi-local, (ii) kendi-nonlocal, (iii) kendisi-local, and (iv) kendisi-nonlocal. We manipulated the reflexive anaphors (*kendi/kendisi*) and their potential interpretation with respect to local and nonlocal antecedents, see (2). The local vs. nonlocal bias was generated by adding an initial phrase before the critical sentence material introducing either of the human referents that would later appear as local or nonlocal antecedents. This makes it less ambiguous to the reader who is being referred to. The participants were presented with 12 sentence contexts in four conditions summing to a total of 48 items; see [Appendix A](#) for a full list of sentence stimuli.

(2)	<i>Bir hemşirenin/doktorun tutuklandığı</i>	<i>davada,</i>	<i>Hemşire</i>	<i>doktorun</i>	
A	nurse/doctor.POSS	arrest.PASTPART	court.LOC	Nurse	doctor.POSS
	<i>kendini/kendisini</i>	<i>savunduğunu</i>	<i>vurguladı.</i>		
	oneself	defend.PASTPART	emphasized.PAST		

“At the court a nurse/doctor was arrested. The nurse emphasized that the doctor was defending *kendini/kendisini*-oneself.”

The sentence contexts were recorded by a male native speaker of Turkish at a normal speech rate (on average, 8.41 syllables per second). Each sentence stimulus started with a storyline without any human referents introduced (e.g., *Silikon davasında ilk duruşma yapıldı.* — ‘The first hearing took place at the silicon case’). Following the storyline, a two-clause critical stimulus appeared, as seen in (2). We avoided reflexive verbs such as *yıkanmak* ‘to wash oneself’. We paid particular attention to not selecting predicates that are

<sup>2</sup> Note that third-person object pronouns and reflexives in Turkish do not express gender distinctions.

strongly biased for local or nonlocal readings. These predicates included the following 12 verbs: *savunmak* ‘to defend’, *suçlamak* ‘to blame’, *zorlamak* ‘to force’, *yaralamak* ‘to injure’, *övmek* ‘to praise’, *görevlendirmek* ‘to appoint’, *kurtarmak* ‘to save’, *önermek* ‘to suggest’, *korumak* ‘to protect’, *zehirlenmek* ‘to poison’, *eleştirmek* ‘to criticize’, *vurmak* ‘to shoot’. Due to the lack of initial benchmarks for how unimpaired adults might interpret the sentence structures used in our study without time constraints, we introduced an offline antecedent preference task among unimpaired Turkish adults. This was done to ensure the validity of our sentence materials. The task was completed by 63 native Turkish speakers, comprising 54 females and 9 males. This offline task revealed that unimpaired Turkish readers, in *kendi* conditions, favoured both local and non-local antecedents equally. However, in *kendisi* condition, they predominantly chose non-local antecedents; see [Appendix B](#) for further details.

### 2.1.3. Procedure

Prior to the experiment, we administered an offline familiarization task in which participants were presented with each piece of visual material used in the experiment and were asked to repeat the names of the professions associated with the presented objects/referents. This session had the sole purpose of increasing participants’ familiarity over referents and was not scored.

The 48 experimental sentence contexts described above were intermixed with 24 filler items that resembled the experimental items in terms of length and complexity. The stimuli were programmed using the GazePoint Control software V6.3.0, connected to a remote desk-mounted GP3 eye-tracker system ([GazePoint, 2021](#)). A participant viewed one display with four pictures, as demonstrated in [Fig. 1](#) above, on a 1280 × 1080 pixel wide screen. Each quadrant of a given display contained individual referents, each with equal width and height measuring 540 × 540 pixels. Therefore, the four quadrants were displayed over a 1080 × 1080 area, leaving 100-pixel wide regions on the left and right sides of the screen, which were not used as a critical area of interest. We used a fully crossed design in which each participant was exposed to all items. The items were randomly presented and distributed over four blocks, with breaks given between each block.

The eye-tracking system was calibrated with a 5-point calibration for each participant at the beginning of the experimental blocks. Each trial started with a fixation cross that lasted for 500ms to attract the participants’ attention to the centre of the screen. The fixation cross always appeared in the centre of the screen with black fonts on a white background. Following the fixation cross, the visual displays appeared, and the linguistic stimuli were delayed by 1000ms in all trials. The participants were instructed to listen to the sentences carefully and to click on (or point to) the most suitable referent for the reflexive form. We recorded eye movements at a 60 Hz sampling rate (one data point per frame, approximately 16.67ms) using an infrared eye-tracking system positioned under the stimulus screen. The participants were seated at a comfortable viewing distance from the screen, approximately 70 cm away. They were asked not to divert their gaze during the trials. We used three practice trials, which were repeated until the task was clearly understood by the participants. The experiment lasted up to 45 min.

### 2.1.4. Analysis

We analyzed two kinds of variables: antecedent preference and the proportions of looks for critical antecedent types. The antecedent preference data consisted of proportions for how frequently the participants clicked on target pictures for local and nonlocal antecedents and distractors. The antecedent preference was analyzed with Multinomial Logit Models using the *mblogit* package in R ([Elf, 2018](#)). The participants and items were added to models as random effects. Proportions of looks data were pre-processed using the *eyetrackerR* package ([Dink & Ferguson, 2015](#)). Areas of interest (AOI) were computed for each local and nonlocal antecedents as the number of fixations on the target picture in proportion to the fixations on the non-target pictures. The AOI data were averaged across 50ms time bins time-locked to the onset of the critical reflexive region for a time window of 2000ms. We excluded first 200ms from the analysis as this early time-window is too short to program eye movements ([Huettig & Altmann, 2005](#); [Rayner et al., 1983](#)). The AOI data were analyzed using the Growth Curve Analysis ([Mirman et al., 2008](#)). Proportions of looks were transformed using the empirical logit transformation [ $\text{Elog} = \log(\text{Prop} + e/(1 - \text{Prop} + e))$ ]. Off-screen and non-AOI looks were removed before the analysis (the removed data constituted 18.81% of all raw recordings in aphasia and 16.28% in the control group).

## 2.2. Results

### 2.2.1. Antecedent preference results

The mean antecedent preference data are given in [Table 2](#) and visually depicted in [Fig. 2](#). Outputs from an overall Multinomial Logit Model are given in [Table 3](#). The model returned two sets of outputs, one for Local vs Nonlocal contrast and one for the Local and

**Table 2**

Mean and SDs of antecedent preference of the PWA and control groups. Means are given in proportions of clicks on an antecedent in proportion to other referents.

Group	Antecedent	Kendi_Local	Kendi_Nonlocal	Kendisi_Local	Kendisi_Nonlocal
Aphasia	Local	0.20 (0.40)	0.29 (0.45)	0.27 (0.44)	0.22 (0.42)
	Nonlocal	0.61 (0.49)	0.58 (0.49)	0.57 (0.49)	0.60 (0.49)
	Discourse	0.13 (0.33)	0.14 (0.35)	0.11 (0.32)	0.12 (0.33)
Control	Local	0.56 (0.49)	0.34 (0.47)	0.28 (0.45)	0.14 (0.35)
	Nonlocal	0.39 (0.48)	0.56 (0.49)	0.65 (0.47)	0.82 (0.37)
	Discourse	0.03 (0.18)	0.04 (0.20)	0.04 (0.20)	0.02 (0.16)



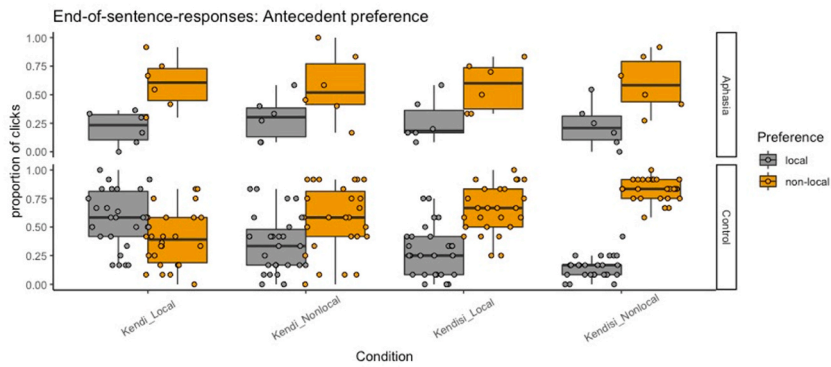


Fig. 2. End-of-sentence antecedent preference tasks data obtained from the reflexive task. Boxplots show median quartiles and distribution of individual data per condition per group.

Table 3

Statistics summary from Multinomial Logit Models  $\beta$  = Model estimate in logit transformed proportions.

	Local vs Nonlocal				Discourse vs Local			
	$\beta$	SE	z	p	$\beta$	SE	z	p
Intercept	-0.41	0.13	-3.12	0.001	-2.73	0.32	-8.33	<0.001
Digit Span	0.13	0.11	1.25	0.20	-0.12	0.21	-0.60	0.54
Group	1.74	0.41	4.19	<0.001	2.07	0.71	2.90	0.003
Reflexive	1.17	0.18	6.37	<0.001	0.91	0.43	2.08	0.03
Referential Bias	0.79	0.18	4.33	<0.001	0.72	0.43	1.66	0.09
Group $\times$ Reflexive	-1.53	0.47	-3.20	0.001	-1.34	0.77	-1.72	0.08
Group $\times$ Contextual Bias	-1.30	0.47	-2.7	0.006	-0.99	0.75	-1.30	0.19
Reflexive $\times$ Contextual Bias	0.14	0.28	0.50	0.61	-0.46	0.64	-0.72	0.46
Group $\times$ Reflexive $\times$ Contextual Bias	0.61	0.67	0.90	0.36	1.01	1.10	0.92	0.35

Code: `mclgfit:mblgfit(formula = Antecedent_Preference ~ scale(FwdDigitSpan) + Group  $\times$  ReflexiveType * ReferentialBias, data = model.data, random = list(~1 | Item), method = "ML")`.

Discourse contrast. For the Nonlocal vs Local contrast, we observed significant fixed effects of Group, indicating that the PWA performed differently from the controls, and significant fixed effects for and interactions between Group  $\times$  Reflexive and Group  $\times$  Contextual Bias. For the Local vs Discourse contrast, we found significant fixed effects of Group and Reflexive, no other effects returned significant outputs. Importantly, the digit span scores did not significantly predict antecedent preference. Although, the PWA group made more click responses on the discourse referents than the controls ( $\beta = 1.34$ ,  $SE = 0.32$ ,  $z = 4.18$ ,  $p < 0.001$ ), the preference for discourse antecedents was minimal in both the groups with around 14% vs 3% of the time, respectively. We therefore have removed the discourse referents from the current antecedent preference analysis and focused on the local vs nonlocal contrast.

To understand the nature of Group  $\times$  Reflexive and Group  $\times$  Contextual Bias interactions, we have run a set of post-hoc Tukey tests. The outputs from these tests have shown that the PWA group differs from the controls in *kendi* conditions as the controls responded by clicking on local referents for *kendi* confidently more often than the PWA ( $\beta = -0.81$ ,  $SE = 0.22$ ,  $z = -3.61$ ,  $p = 0.001$ ). This suggests that the PWA, unlike the controls, had preferred nonlocal antecedents for *kendi*. This group difference was not found for *kendisi* conditions, for which both the groups had a similar tendency to select a nonlocal antecedent ( $\beta = 0.41$ ,  $SE = 0.22$ ,  $z = 1.82$ ,  $p = 0.26$ ). A similar pattern has been found for the Group  $\times$  Contextual Bias interaction effect: the PWA significantly selected a nonlocal antecedent although the contextual bias was pointing towards a local antecedent, this was different in the controls who selected a local antecedent more frequently compared to the PWA ( $\beta = -0.69$ ,  $SE = 0.22$ ,  $z = -3.09$ ,  $p = 0.010$ ). Nonetheless, for sentences with a nonlocal contextual bias, we observed no critical group differences ( $\beta = 0.29$ ,  $SE = 0.22$ ,  $z = 1.31$ ,  $p = 0.55$ ). Within groups contrasts have yielded that the controls considered local antecedents more strongly for *kendi* than for *kendisi* ( $\beta = 1.24$ ,  $SE = 0.13$ ,  $z = 9.36$ ,  $p < 0.0001$ ), the PWA consistently considered nonlocal antecedents with no critical differences across reflexives conditions ( $\beta = 0.02$ ,  $SE = 0.29$ ,  $z = 0.08$ ,  $p = 0.99$ ).<sup>3</sup> This pattern remained the same in both fluent and non-fluent participants without any significant differences in their local ( $\beta = 0.26$ ,  $SE = 0.34$ ,  $z = 0.78$ ,  $p = 0.43$ ) and non-local antecedent preferences ( $\beta = -0.35$ ,  $SE = 0.35$ ,  $z = -0.99$ ,  $p = 0.31$ ).

<sup>3</sup> In response to an anonymous reviewer's observation regarding the broad age range of PWA potentially influencing anaphora interpretation, we computed supplementary generalized linear models. This analysis, which included the age of PWA as a predictor variable, revealed that age does not significantly influence responses for either local ( $\beta = -0.001$ ,  $SE = 0.002$ ,  $t = -0.52$ ,  $p = 0.60$ ) or non-local antecedent preferences ( $\beta = 0.001$ ,  $SE = 0.002$ ,  $t = 0.56$ ,  $p = 0.57$ ). Consequently, we rule out age as a variable affecting performance in our PWA.

**Table 4**

Statistical outputs from a set of Growth Curve models.  $\beta$  represents Elog transformed proportions of looks and Ot1, Ot2, Ot3 represent linear, quadratic, cubic components of time in milliseconds following the onset of critical anaphors.

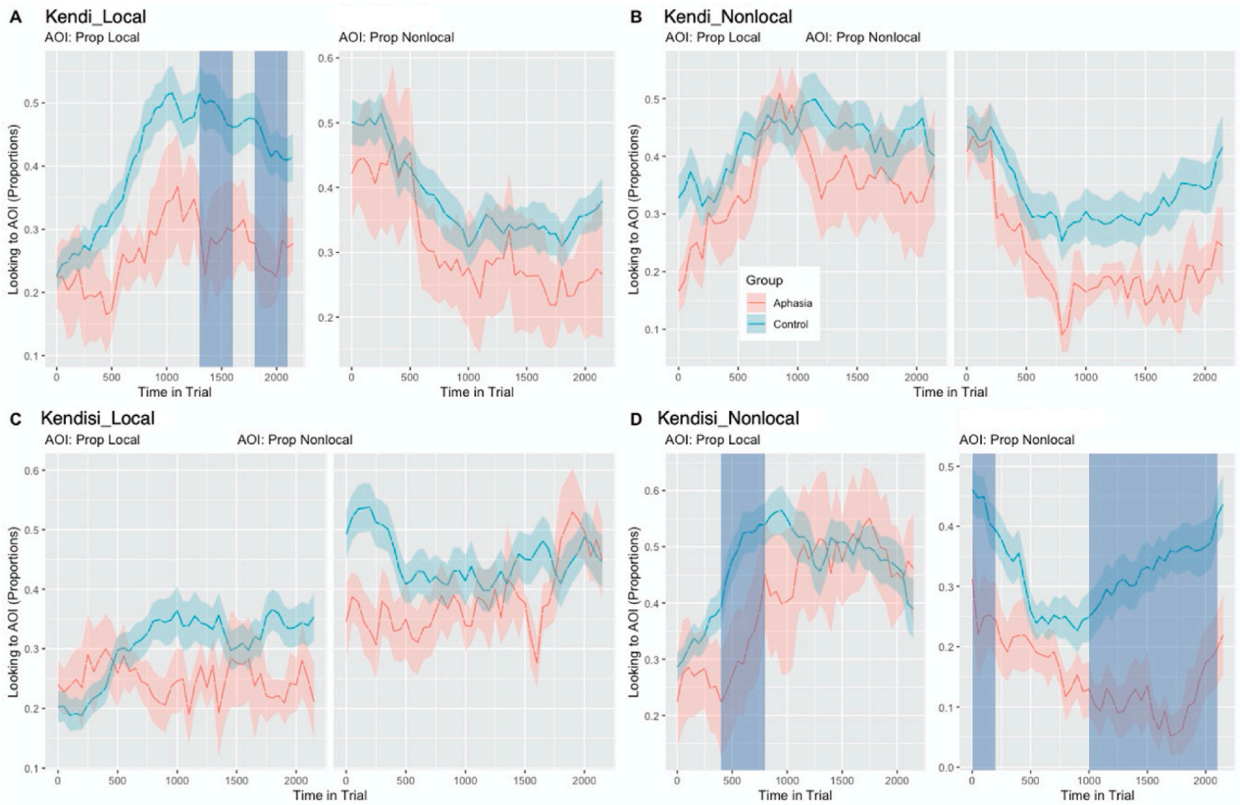
	AOI Local Antecedents				AOI Nonlocal Antecedents			
	$\beta$	SE	<i>t</i>	<i>p</i>	$\beta$	SE	<i>t</i>	<i>p</i>
<b><i>Kendi</i> anaphors</b> rowhead								
Intercept	-0.87	0.17	-5.03	<0.001	-0.71	0.15	-4.69	<0.001
Group	0.55	0.16	3.37	0.001	0.28	0.14	1.92	0.06
Referential Bias	0.33	0.13	2.37	0.02	-0.34	0.11	-3.15	0.003
Linear	0.68	0.66	1.03	0.30	-1.52	0.66	-2.28	0.026
Quadratic	-0.51	0.47	-1.08	0.28	0.63	0.46	1.37	0.17
Cubic	-0.31	0.38	-0.86	0.38	0.22	0.49	0.46	0.64
Group x Referential Bias	-0.32	0.54	-6.02	<0.001	0.15	0.05	2.78	0.005
Group x Linear	0.92	0.61	1.50	0.14	0.34	0.67	0.51	0.61
Group x Quadratic	-0.97	0.43	-2.22	0.031	0.26	0.47	0.57	0.57
Group x Cubic	0.17	0.38	0.45	0.65	-0.22	0.50	-0.44	0.65
Referential Bias x Linear	0.05	0.60	0.08	0.93	0.13	0.51	0.26	0.78
Referential Bias x Quadratic	-0.78	0.49	-1.56	0.12	0.87	0.41	2.10	0.03
Referential Bias x Cubic	1.09	0.39	2.76	0.006	-0.64	0.42	-1.51	0.13
Group x Referential Bias x Linear	-1.21	0.36	-3.36	<0.001	0.62	0.35	1.73	0.08
Group x Referential Bias x Quadratic	1.41	0.36	3.88	<0.001	-0.57	0.36	-1.59	0.11
Group x Referential Bias x Cubic	-0.46	0.36	-1.27	0.20	0.36	0.36	1.00	0.31
<b><i>Kendisi</i> anaphors</b> rowhead								
Intercept	-0.97	0.17	-5.85	<0.001	-0.45	0.16	-2.76	0.007
Group	0.29	0.15	1.93	0.06	0.24	0.15	1.58	0.12
Referential Bias	0.69	0.1	4.77	<0.001	-0.86	0.13	-6.54	<0.001
Linear	0.14	0.53	-0.26	0.79	-0.78	0.57	1.36	0.17
Quadratic	0.01	0.56	0.01	0.98	0.53	0.54	0.98	0.32
Cubic	0.21	0.39	0.54	0.58	0.14	0.39	0.36	0.72
Group x Referential Bias	-0.16	0.05	2.69	0.002	0.44	0.05	8.14	<0.001
Group x Linear	1.28	0.55	2.32	0.02	-1.15	0.58	-1.99	0.05
Group x Quadratic	-0.73	0.56	-1.30	0.19	0.22	0.56	0.41	0.68
Group x Cubic	0.11	0.38	0.31	0.75	-0.46	0.39	-1.15	0.22
Referential Bias x Linear	2.04	0.43	4.68	<0.001	-1.64	0.47	-3.48	<0.001
Referential Bias x Quadratic	-1.31	0.47	-2.77	0.007	0.38	0.42	0.89	0.37
Referential Bias x Cubic	-0.92	0.41	-2.21	0.02	0.31	0.40	0.79	0.43
Group x Referential Bias x Linear	-2.52	0.36	-6.96	<0.001	2.19	0.36	6.04	<0.001
Group x Referential Bias x Quadratic	0.43	0.36	1.20	0.22	0.23	0.36	0.65	0.51
Group x Referential Bias x Cubic	0.96	0.36	2.67	0.007	-0.56	0.36	-1.56	0.11

Code: `lmer(Elog ~ Group*(ot1 + ot2 + ot3)* Ref_Bias + (1 + ot1 + ot2 + ot3 | MEDIA_NAME) + (1 + ot1 + ot2 + ot3 | Participant), data = data, REML = FALSE, control = lmerControl(optimizer = 'bobyqa'))`.

### 2.2.2. Eye-movement monitoring results

An overall model on the target proportion of looks showed significant effects of Group for both local ( $\beta = 0.53$ ,  $p < 0.001$ ) and non-local AOIs ( $\beta = 0.31$ ,  $p = 0.012$ ) indicating that the PWA's target looks for both AOIs were reduced. A three-way interaction between Reflexive  $\times$  Contextual Bias  $\times$  Group emerged as significant for local ( $\beta = 0.16$ ,  $p = 0.043$ ) and non-local AOIs ( $\beta = 0.28$ ,  $p < 0.001$ ). Full outputs from those models are given in [Appendix C](#).

Given the distinct nature of preferences for *kendi* and *kendisi* conditions, we analyzed them separately. Outputs from these analyses are given in [Table 4](#), and group differences in proportions of looks towards local and non-local targets are demonstrated in [Fig. 3](#). Regarding *kendi* anaphors, we ran two models, one per each AOI for local and non-local antecedents. Both the models showed significant interactions for Reflexive  $\times$  Contextual Bias. In the *kendi-local* condition, the participants gazed towards local antecedents while in the *kendi-nonlocal* condition they gazed towards non-local antecedents immediately after the critical anaphor and this trend peaked around 1000 ms post stimulus. From about 1000ms onwards, the control group began to consider alternative antecedents while this pattern was less stable in the PWA group (see [Fig. 3A](#) and [B](#)). The Group  $\times$  Time interaction in the local proportions of looks indicates that different group differences emerged across time. We performed a cluster-based permutation analysis to determine precise nature of group differences. In the *kendi-local* condition, the cluster-based permutation tests revealed significant group differences in target looks for local antecedents between 1300 and 1600ms ( $sum\ statistics = 6.49$ ,  $p < 0.05$ ) and between 1800 and 2100ms ( $sum\ statistics = 6.61$ ,  $p < 0.05$ ). No clusters with significant group differences emerged for non-local looks within this time window, or in either of the proportion of looks in *kendi-nonlocal* condition.



**Fig. 3.** Mean proportions of looks towards local and non-local antecedents for the control and PWA groups for the 2000ms time window from the onset of the reflexive anaphors. Blue shaded areas show clusters with significant group differences.

Regarding *kendisi* anaphors, two models, one for each AOI for local and non-local antecedents, were run. Both models returned a significant fixed effect of Contextual Bias and three-way significant interactions for Group  $\times$  Contextual Bias  $\times$  Time (Linear). In the *kendisi-nonlocal* condition, the controls increasingly gazed towards local antecedents immediately after the critical anaphor region, while this was not immediately available in the PWA data, they reached up to the controls from around 800ms post stimulus region. Outputs from the cluster-based permutation analysis showed that no critical group differences emerged in *kendisi-local* condition. Nonetheless, in the *kendisi-nonlocal* conditions, we found that the PWA had reduced looks to local antecedents between 400 and 800ms (sum statistics = 11.09,  $p < 0.001$ ) and that they had reduced looks to non-local antecedents within two large clusters between 0 and 200ms (sum statistics = 5.04,  $p < 0.05$ ) and 1000–2200ms (sum statistics = 39.74,  $p < 0.001$ ), see blue shaded areas in Fig. 3C and D.

### 2.3. Discussion

The aim of this experiment was to examine whether Turkish-speaking PWA show differences in processing reflexive anaphors compared to unimpaired controls. We can confirm that our findings reveal a notable group effect in antecedent preference responses. Specifically, the PWA demonstrated a marked preference for non-local antecedents when processing the reflexive anaphor *kendi*, in contrast to the controls who showed a tendency to favour local antecedents. Such a group difference was not found in the *kendisi* conditions. The PWA consistently considered nonlocal antecedents with no critical differences across reflexive conditions. Critically, digit span task scores did not predict anaphoric resolution patterns (see Table 3, for both AOIs, fixed effect of digit spans returned  $>0.20$ ). Eye-movement patterns showed important group differences across different conditions. While the controls considered local antecedents more strongly, the PWA consistently looked at nonlocal antecedents. This was clearly the case in local antecedent looks in the *kendi-local* and *kendisi-nonlocal* conditions. It seems that the PWA had a strong consideration for non-local referents as potential antecedents for both kinds of reflexive anaphors.

## 3. Experiment 2. Processing of null and overt objects in Turkish aphasia

### 3.1. Methods

The same participants were recruited as in Experiment 1. The sentence materials accommodated 12 sentential contexts in four conditions: (i) overt-nonlocal, (ii) overt-discourse, (iii) null-nonlocal, (iv) null-discourse. We manipulated the dropping conditions of

**Table 5**

Mean and SDs of antecedent preference of the PWA and control groups. Means are given in proportions of clicks on an antecedent in proportion to other referents.

Group	Antecedent	Nullpro-discourse	Nullpro-non-local	Overtpro-discourse	Overtpro-non-local
Aphasia	Local	0.21 (0.41)	0.20 (0.40)	0.24 (0.43)	0.31 (0.46)
	Nonlocal	0.41 (0.49)	0.55 (0.50)	0.42 (0.49)	0.52 (0.50)
	Discourse	0.35 (0.48)	0.16 (0.37)	0.31 (0.46)	0.12 (0.33)
Control	Local	0.06 (0.23)	0.09 (0.29)	0.09 (0.28)	0.04 (0.20)
	Nonlocal	0.29 (0.45)	0.73 (0.44)	0.34 (0.47)	0.90 (0.29)
	Discourse	0.63 (0.48)	0.06 (0.24)	0.64 (0.47)	0.04 (0.21)

object pronoun (*overt/null*) and the potential interpretation of these anaphors to nonlocal or discourse antecedents, see (3). The nonlocal vs. discourse bias, like in the previous task, was induced by an initial phrase introducing two human referents, one of which would later appear as nonlocal antecedent (i.e., nurse). The second human referent is not later mentioned in the critical clause, and hence, becomes a discourse entity (i.e., janitor). There were 48 sentence trials in total.

(3) *Bir hemşirenin/hademenin tutuklandığı davada, Hemşire doktorun*

A nurse/janitor.POSS arrest.PASTPART court.LOC Nurse doctor.POSS

*onu/∅ savunduğunu vurguladı.*

*it.ACC/∅.NULL defend.PASTPART emphasized.PAST*

“At the court a nurse/doctor was arrested. The nurse emphasized that the doctor was defending *it* /  $\emptyset$ -nullpro.”

Procedures reported above in Experiment 1 were consistently adhered to in Experiment 2, with the two experiments being carried out in separate sessions.

### 3.2. Results

#### 3.2.1. Antecedent preference results

The mean antecedent preference data are presented in Table 5 and illustrated in Fig. 4. The outputs from a Multinomial Logit Model, computed with antecedent preference data, are provided in Table 6. Two sets of outputs were obtained: one for the Discourse vs Non-local AOI contrast and one for the Local vs Non-local AOI contrast. For the Discourse vs Non-local contrast, a three-way interaction of Group  $\times$  Pronoun  $\times$  Contextual Bias was significant. For the Local vs Non-local contrast, we observed a significant fixed effect of Pronoun and a significant interaction for Group  $\times$  Pronoun, indicating that antecedent preference largely depended on the Pronoun and Group. In the control group, the preference for local antecedents was minimal in any condition (around 4–6%, see Fig. 4); however, this was considerably higher in the PWA group (as high as 31% in the *overtpro-nonlocal* condition). Overall, the selection of local antecedents was more frequent in PWAs than in the controls ( $\beta = 1.11$ , SE = 0.43,  $z = 2.58$ ,  $p < 0.009$ ). Although the PWA group showed a much larger variation in their antecedent preference, the most frequently preferred antecedent type was the non-local ones, occurring around 41–55% of the time.

Given the Group  $\times$  Pronoun interaction, we have run a set of post-hoc tests to compare groups' antecedent preference across overt and null pronouns. The PWA did not differ in their selection for non-local antecedents between overt and null pronouns ( $\beta = 0.04$ , SE = 0.250,  $z = 0.19$ ,  $p = 0.99$ ) while the unimpaired controls selected non-local antecedents more often in overt than null pronoun condition ( $\beta = -0.47$ , SE = 0.11,  $z = -4.01$ ,  $p < 0.001$ ). Regarding selecting a discourse antecedent, both the unimpaired controls and the PWA showed no differences between overt and null pronoun conditions (all  $ps > 0.88$ ). However, a strong modulator was Contextual Bias. When the sentential context is biased for a non-local reading, the controls clearly consider non-local referent as a suitable antecedent over discourse ones for both null pronoun ( $\beta = -2.02$ , SE = 0.18,  $z = -10.80$ ,  $p < 0.001$ ) and overt pronouns ( $\beta = 3.08$ , SE = 0.26,  $z = 13.06$ ,  $p < 0.001$ ). When the context is biased for a discourse reading, by contrast, the controls considered discourse referents as appropriate in both null ( $\beta = 3.45$ , SE = 0.27,  $z = 12.79$ ,  $p < 0.001$ ) and overt pronouns ( $\beta = -3.82$ , SE = 0.30,  $z = -12.73$ ,  $p < 0.001$ ). The PWA comparably showed a stronger preference for non-local referents over discourse ones when the context is biased for a non-local reading in both null ( $\beta = -1.21$ , SE = 0.44,  $z = -2.75$ ,  $p = 0.03$ ) and overt pronouns ( $\beta = -1.25$ , SE = 0.46,  $z = -2.71$ ,  $p = 0.03$ ). However, there were no clear preference for an antecedent over another when the context was biased for a discourse reading (all  $ps > 0.24$ ) in the PWA. Further, we found no differences between fluent and non-fluent PWA's non-local antecedent preferences ( $\beta = -0.16$ , SE = 0.27,  $z = -0.61$ ,  $p = 0.54$ ). Interestingly, however, non-fluent PWA showed lower discourse preference for antecedents overall compared to fluent PWA (%15 vs. % 32;  $\beta = -0.95$ , SE = 0.29,  $z = -3.21$ ,  $p = 0.001$ ).

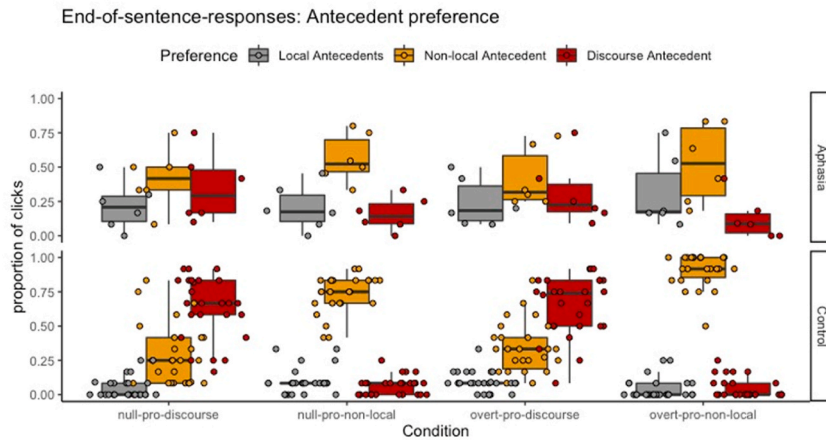


Fig. 4. End-of-sentence antecedent preference tasks data obtained from the null-pronoun task. Boxplots show median quartiles and distribution of individual data per condition per group.

Table 6  
Statistics summary from Multinomial Logit Models.  $\beta$  = Model estimate in logit transformed proportions.

	Discourse vs Non-local				Local vs Non-local			
	$\beta$	SE	z	p	$\beta$	SE	z	p
Intercept	0.79	0.20	3.85	<0.001	-1.46	0.35	-4.07	<0.001
Digit Span	-0.05	0.22	-0.24	0.81	-0.37	0.34	-1.06	0.28
Group	-1.02	0.63	-1.60	0.11	0.18	0.97	0.19	0.84
Pronoun Type	-3.71	0.31	-11.84	<0.001	-1.49	0.41	-3.61	<0.001
Referential Bias	-3.21	0.28	-11.14	<0.001	-0.41	0.35	-1.14	0.25
Group $\times$ Pronoun	2.47	0.60	4.10	<0.001	1.63	0.67	2.42	0.01
Group $\times$ Contextual Bias	2.09	0.57	3.64	<0.001	0.02	0.66	0.03	0.97
Pronoun $\times$ Contextual Bias	6.69	0.42	15.76	<0.001	1.36	0.56	2.41	0.01
Group $\times$ Pronoun $\times$ Contextual Bias	-4.64	0.84	-5.51	<0.001	-1.12	0.96	-1.16	0.24

Code: `mclgfit:mblogit(Antecedent_Preference ~ scale(FwdDigitSpan) + Group  $\times$  PronounType*ReferentialBias, data = model.data, random = list (~1|Item, ~1|Participant), method = "MQL")`.

### 3.2.2. Eye-movement monitoring results

A global model on target proportion of looks, we found significant four-way interactions for PronounType  $\times$  ContextualBias  $\times$  Group  $\times$  Time for local AOIs ( $\beta = 1.05, p = 0.03$ ) for non-local AOIs ( $\beta = -2.04, p < 0.001$ ), and multiple interactions for discourse AOIs (PronounType  $\times$  Group  $\beta = 0.23, p < 0.0001$ ; ContextualBias  $\times$  Group  $\times$  Time  $\beta = -0.82, p = 0.005$ ). Full outputs of this global model are given in Appendix D.

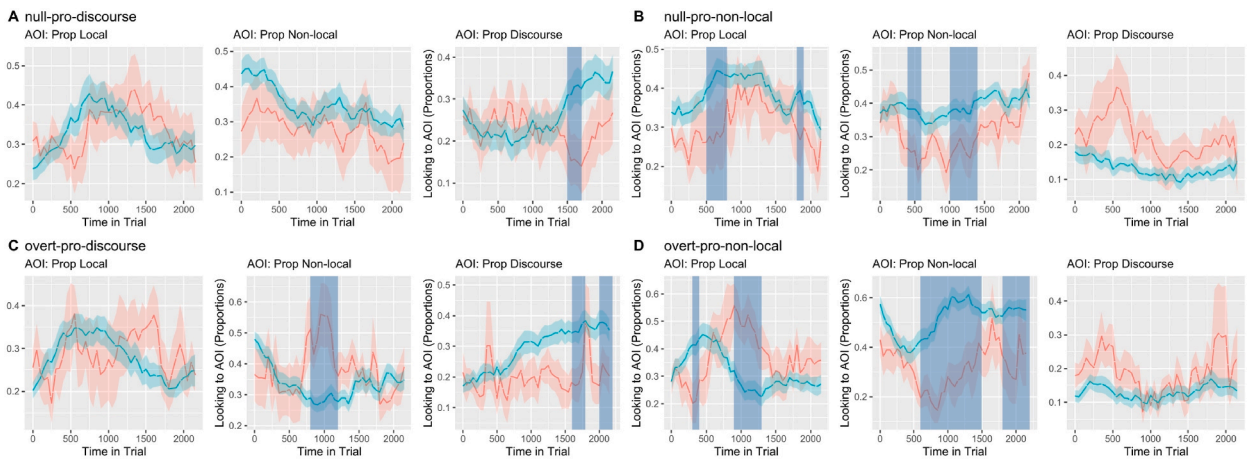
We conducted separate analyses for null and overt pronouns, as shown in Table 7. Regarding Overt pronouns, we ran three models, one for each AOI for local, non-local and discourse antecedents. All three models showed significant interactions for Group  $\times$  Contextual Bias  $\times$  Time. To understand the nature of group differences across time and conditions, we performed a permutation-based cluster analysis. In the *overtpro-nonlocal* condition, the PWA had more target looks to the local antecedents between 300 and 400 ms (sum statistics = 2.88,  $p < 0.05$ ), and then this pattern shifted later, and the PWA turned their gaze towards the local antecedents more often than the controls within the 900–1300ms cluster (sum statistics = -9.79,  $p = 0.02$ ). The PWA therefore did not clearly consider the non-local antecedents in this condition, as they had reduced amounts of looks than the controls to non-control antecedents within two large clusters: 600–1500ms (sum statistics = 29.94,  $p < 0.001$ ) and 1800–2200ms (sum statistics = 10.95,  $p < 0.001$ ). Further, the PWA tended to have more target looks to discourse antecedents in 400–500ms (sum statistics = -2.03,  $p < 0.05$ ), while no other differences were found during the remaining of the time course. In the *overtpro-discourse* condition, no critical condition differences appeared for local looks as both groups had fewer target looks. In non-local looks, there was a difference between 800 and 1200ms (sum statistics = -5.51,  $p < 0.01$ ). Furthermore, there were critical differences in target looks for discourse antecedents 1600–1800ms (sum statistics = 2.30,  $p < 0.05$ ), and 2000–2200ms (sum statistics = 2.00,  $p < 0.05$ ).

Regarding null pronoun conditions, our model outputs showed significant Group  $\times$  Referential Bias and Group  $\times$  Time interactions for local target looks, while in both non-local and discourse AOIs, we have observed three-way interaction between Group  $\times$  Referential Bias  $\times$  Time. A critical group difference was observed in the *nullpro-non-local* condition, in which the PWA had a greater number of targets looks than the controls towards local antecedents between 500 and 800 ms (sum statistics = 7.63,  $p < 0.001$ ) and 1800–1900 (sum statistics = 2.49,  $p < 0.05$ ) ms post critical stimulus regions. On the other hand, in this condition, the PWA had fewer looks than the controls toward the non-local antecedents, particularly two large clusters returned the most critical group differences for 400–600

**Table 7**

Statistical outputs from a set of Growth Curve models for Null and Overt pronoun experiment.  $\beta$  represents Elog transformed proportions of looks and Ot1, Ot2, Ot3 represent linear, quadratic, cubic components of time in milliseconds following the onset of critical pronoun.

	Local AOIs				Non-local AOIs				Discourse AOIs			
	$\beta$	SE	t	p	$\beta$	SE	t	p	$\beta$	SE	t	p
<b><u>OVERT Pronouns</u></b>												
Intercept	-0.82	0.13	-5.96	<0.001	-0.44	0.14	-3.01	0.003	-1.08	0.13	-8.29	<0.001
Group	0.02	0.14	0.14	0.88	-0.16	0.13	-1.24	0.22	0.31	0.11	2.63	0.012
Referential Bias	<b>0.37</b>	<b>0.08</b>	<b>4.28</b>	<b>&lt;0.001</b>	-0.17	0.13	-1.33	0.19	-0.15	0.11	-1.38	0.17
Linear	0.12	0.59	0.20	0.84	-0.75	0.59	-1.27	0.21	0.43	0.49	0.87	0.38
Quadratic	-0.48	0.53	-0.92	0.36	-0.62	0.45	-1.35	0.18	-0.08	0.37	-0.21	0.83
Cubic	0.02	0.48	0.04	0.96	0.21	0.42	0.50	0.61	0.07	0.26	0.27	0.78
Group x Referential Bias	<b>-0.26</b>	<b>0.05</b>	<b>-4.96</b>	<b>&lt;0.001</b>	<b>0.85</b>	<b>0.05</b>	<b>15.5</b>	<b>&lt;0.001</b>	<b>-0.44</b>	<b>0.04</b>	<b>-9.71</b>	<b>&lt;0.001</b>
Group x Linear	-0.58	0.61	-0.95	0.34	0.32	0.57	0.57	0.57	<b>1.21</b>	<b>0.49</b>	<b>2.47</b>	<b>0.017</b>
Group x Quadratic	-0.25	0.54	-0.47	0.64	<b>1.66</b>	<b>0.45</b>	<b>3.66</b>	<b>&lt;0.001</b>	-0.31	0.36	-0.85	0.39
Group x Cubic	0.76	0.46	1.67	0.10	-0.64	0.42	-1.53	0.13	-0.21	0.27	-0.76	0.44
Referential Bias x Linear	0.28	0.43	0.65	0.51	<b>1.40</b>	<b>0.51</b>	<b>2.70</b>	<b>0.009</b>	-0.65	0.39	-1.65	0.10
Referential Bias x Quadratic	<b>-0.82</b>	<b>0.41</b>	<b>-2.00</b>	<b>0.048</b>	<b>1.76</b>	<b>0.43</b>	<b>4.01</b>	<b>&lt;0.001</b>	0.61	0.37	1.63	0.10
Referential Bias x Cubic	0.57	0.46	1.22	0.22	<b>-1.31</b>	<b>0.42</b>	<b>-3.08</b>	<b>0.002</b>	0.33	0.28	1.16	0.24
Group x Referential Bias x Linear	<b>-0.90</b>	<b>0.35</b>	<b>-2.55</b>	<b>0.011</b>	0.01	0.36	0.05	0.95	<b>-0.86</b>	<b>0.30</b>	<b>-2.85</b>	<b>0.004</b>
Group x Referential Bias x Quadratic	<b>1.74</b>	<b>0.35</b>	<b>4.97</b>	<b>&lt;0.001</b>	<b>-3.05</b>	<b>0.36</b>	<b>-8.34</b>	<b>&lt;0.001</b>	-0.003	0.30	-0.01	0.99
Group x Referential Bias x Cubic	-0.51	0.35	-1.47	0.14	<b>0.93</b>	<b>0.36</b>	<b>2.56</b>	<b>0.01</b>	-0.10	0.30	-0.34	0.72
<b><u>NULL Pronouns</u></b>												
Intercept	<b>-0.58</b>	<b>0.16</b>	<b>-3.58</b>	<b>&lt;0.001</b>	<b>-0.83</b>	<b>0.18</b>	<b>-4.54</b>	<b>&lt;0.001</b>	<b>-0.98</b>	<b>0.16</b>	<b>-6.13</b>	<b>&lt;0.001</b>
Group	-0.04	0.14	-0.28	0.77	0.25	0.14	1.75	0.08	0.11	0.14	0.79	0.43
Referential Bias	-0.12	0.13	-0.87	0.38	0.11	0.18	0.58	0.56	-0.02	0.14	-0.15	0.87
Linear	0.51	0.70	0.72	0.47	-0.49	0.52	-0.94	0.35	-0.11	0.53	-0.22	0.82
Quadratic	-0.74	0.56	-1.33	0.19	0.11	0.62	0.17	0.77	0.35	0.29	1.21	0.23
Cubic	-0.43	0.40	-1.08	0.28	0.11	0.40	0.28	0.77	0.47	0.32	1.47	0.14
Group x Referential Bias	<b>0.31</b>	<b>0.05</b>	<b>6.03</b>	<b>&lt;0.001</b>	0.06	0.05	1.30	0.19	<b>-0.49</b>	<b>0.04</b>	<b>-11.4</b>	<b>&lt;0.001</b>
Group x Linear	-0.54	0.73	-0.74	0.46	-0.64	0.47	-1.37	0.17	<b>1.36</b>	<b>0.55</b>	<b>2.45</b>	<b>0.018</b>
Group x Quadratic	-0.38	0.54	-0.70	0.48	0.25	0.60	0.42	0.67	0.35	0.26	1.34	0.18
Group x Cubic	<b>1.05</b>	<b>0.39</b>	<b>2.69</b>	<b>0.009</b>	-0.39	0.39	-1.01	0.31	<b>-0.75</b>	<b>0.33</b>	<b>-2.28</b>	<b>0.026</b>
Referential Bias x Linear	-0.25	0.45	-0.56	0.57	<b>1.13</b>	<b>0.53</b>	<b>2.13</b>	<b>0.038</b>	-0.66	0.38	-1.73	0.08
Referential Bias x Quadratic	-0.33	0.49	-0.68	0.49	0.91	0.53	1.70	0.096	-0.05	0.34	-0.15	0.88
Referential Bias x Cubic	-0.27	0.41	-0.65	0.51	-0.36	0.40	-0.89	0.37	0.46	0.30	1.50	0.13
Group x Referential Bias x Linear	0.21	0.34	0.61	0.54	0.41	0.34	1.19	0.23	<b>-0.97</b>	<b>0.28</b>	<b>-3.39</b>	<b>0.0006</b>
Group x Referential Bias x Quadratic	0.56	0.34	1.61	0.11	<b>-0.98</b>	<b>0.34</b>	<b>-2.87</b>	<b>0.004</b>	-0.27	0.28	-0.95	0.34
Group x Referential Bias x Cubic	-0.18	0.34	-0.53	0.59	0.53	0.34	1.57	0.11	-0.04	0.28	-0.14	0.88



**Fig. 5.** Mean proportions of looks towards local and non-local antecedents for the control and PWA groups for the 2000ms time window from the onset of the pronouns. Blue shaded areas show clusters with significant group difference.

(sum statistics = 2.55,  $p < 0.05$ ) and 1000–1400 ms (sum statistics = 4.54,  $p < 0.05$ ). Further, the PWA had greater number of looks towards the discourse antecedent during 500–700 ms (sum statistics = -5.50,  $p < 0.05$ ). In the *null-pro-discourse* condition, we found no critical group differences in looks towards local or non-local antecedents, while the PWA had reduced target looks towards the discourse antecedents between 1500 and 1700ms (sum statistics = 4.581,  $p < 0.05$ ), as illustrated in Fig. 5A and B.

### 3.3. Discussion

Experiment 2 addressed whether processing differences emerged during the resolution of null and overt object pronouns in aphasia in Turkish. Our findings indicated that the PWA performed distinctly from the unimpaired controls by often selecting a non-local antecedent. Furthermore, the PWA showed a greater number of fixations towards and an elevated selection of a local antecedent (21%–31% across conditions), which was the least favoured option for the unimpaired controls. Above we mentioned that a local antecedent in Turkish should structurally be inaccessible for object pronouns (see Gürel, 2002; Underhill, 1972). Therefore, there appears to be a difficulty in applying this constraint in aphasic processing. Further, we were curious to disentangle whether the participants would perform differently across overt and null object pronoun conditions. We found that unimpaired controls selected non-local antecedents more often in overt than in null pronoun conditions, while the PWA did not demonstrate a difference. There was no difference in discourse antecedent selection in both overt and null pronoun conditions; however, we observed reduced target looks towards the discourse antecedents in the PWA compared to the controls in relatively later time windows, following 1500 ms onwards (see Fig. 5). This may be due to difficulty in accessing and processing discourse-level information, which is evidently affected in aphasia (Avrutin, 2006; Hickok & Avrutin, 1995; Piñango et al., 2001). Additionally, the difficulty in accessing discourse antecedents was more pronounced among the non-fluent PWA compared to compared to their fluent counterparts.

## 4. General discussion

This study was founded on two aims: (i) The first was to investigate the real-time processing of reflexive forms in groups of Turkish-speaking PWA compared to their controls, using eye-movement monitoring tasks (Experiment 1). (ii) The second was to determine whether Turkish-speaking PWA experience challenges in discerning between overt and null object pronouns in Turkish, also assessed through an eye-movement monitoring during listening tasks (Experiment 2). Summarizing the key outcomes of these experiments, Experiment 1 revealed that the PWA exhibited a marked difference from the control participants in processing reflexive anaphors. Specifically, the PWA demonstrated a pronounced preference for non-local antecedents when resolving both types of reflexive anaphors. Eye movement data confirmed that the PWA's consideration for local antecedents in the *kendi* reflexive form was reduced compared to the controls. Furthermore, the PWA's looks towards non-local antecedents were fewer than those of the controls in *kendisi* reflexives during the critical time window. Experiment 2 demonstrated that resolving object pronouns in Turkish is highly context-dependent; however, in aphasia, a strong preference for non-local antecedents is noticeable. Eye movement data indicated that the PWA had fewer looks towards discourse antecedents in later time windows for discourse-biased pronouns and more frequent looks towards local antecedents. We will discuss the implications of these findings below.

As mentioned above, the binding behavior of Turkish reflexive anaphors is rather unconstrained and variable (see Gračanin-Yuksekk et al., 2017; Özbek & Kahraman, 2016). We clearly know from our sentence material used in this study that, when the unimpaired individuals are not under time limitations, *kendi* behaves almost ambiguously between local and non-local interpretations (45.9% vs. 51.6%, respectively), and *kendisi* is often interpreted as referring to non-local rather than local antecedents (68.4% vs. 26.0%), see Appendix B. Drawing from these results, it becomes evident that the anaphoric resolution observed here diverges from the 'traditional' pronoun processing patterns documented in prior neurolinguistic research involving English or German PWA (e.g., Burkhardt et al., 2008; Choy & Thompson, 2010; Grodzinsky et al., 1993; Love et al., 1998). Recall that reflexives that strongly adhere locality constraints cannot refer to antecedents outside their local domains. In the following English example, '[Jack thought that [Fred adored himself]]', a reading where the reflexive form himself refers to Jack is virtually impermissible. Evidently, this is not the case in Turkish, where reflexive anaphors are variable in interpretation. A rather unconstrained reflexive system poses a challenge for the neuro-linguistic theory explaining PWA's difficulty in interpreting object pronouns and reflexives based on locality constraints. We explore these implications below.

### 4.1. Reflexive processing in Turkish individuals with and without aphasia

One potential reason why the PWA selected non-local antecedents across virtually all conditions might be due to task effects. We rule out this possibility, as such a task effect would also have been observed in the unimpaired individuals. Furthermore, the positions of target images were randomized and shuffled across trials. Hence, it is conceivable that our PWA appeared to have followed a processing strategy by consistently responding to non-local antecedents over other possibilities. This may have been due to an overall processing strategy in PWA to cope with referential ambiguity. It is conceivable that the capacity to integrate contextual information to disambiguate referential ambiguities is poor in aphasia (Chapman & Ulatowska, 1989). This explanation is in fact supported by our finding that group differences in this antecedent selection task were modulated by contextual bias indicating that the unimpaired

individuals were able to follow the contextual bias cues and clicked on the intended antecedent more frequently than the PWA did. In this regard, a strong possibility is that the PWA were unable to pick up those contextual cues to disambiguate the intended antecedent. Additionally, during an online pronoun processing task, time limitations render the task cognitively more demanding in memory, the lack of which may have posed additional challenges navigating potential antecedents during online sentence comprehension (Baauw et al., 2011).

It seems to us that the PWA had difficulty accessing local antecedents while processing sentence material with reflexive anaphors. This was reflected in our eye-movement data, as the PWA had rather delayed looks at local antecedents. This pattern was particularly visible in the *kendisi-Nonlocal* condition. In a rather earlier time cluster (400–800ms post critical reflexive), the unimpaired individuals immediately began considering local antecedents; however, such an early activation of the local antecedent for *kendisi* was absent in the PWA during this time cluster. The PWA nevertheless patterned with the unimpaired individuals following 800ms onwards, suggesting that the consideration for a local antecedent was delayed in anaphoric reflexive resolution in aphasia. A similar pattern of PWA's reduced looks towards local antecedents than the unimpaired controls was also observed in the *kendi-local* condition in later time windows from 1300ms onwards. This signifies that at a later stage, the PWA no longer considered local antecedents for the *kendi-local* condition unlike the unimpaired controls.

How can difficulty accessing local antecedents in aphasia be explained? Following structural locality constraints "accounts", we might have predicted resolving reference to non-local antecedents outside the local binding domain to be more effortful than to antecedents positioned inside the binding domain (e.g., Engel et al., 2018; Garraffa, 2009; Sheppard et al., 2015). This assumes that the intervening structural distance for an anaphoric element would be longer for non-local antecedents, and consequently, result in interpretation failures. Under this account, we expected that the PWA would have less difficulty selecting local antecedents particularly for *kendi* anaphors. This was not how the PWA reported in the current study performed, however. The PWA oftentimes had reduced consideration of local antecedents and showed a reliance on responding by selecting non-local antecedents. Therefore, this pattern cannot be explained by the *Structural Intervener* account. The issue might lie in different structural nature of our sentence material. In languages, such as, English, where locality constrains prove a suitable explanation for PWA's non-target performance, gender marking on the pronominal element often provides a salient cue for its interpretation. In Turkish on the other hand, third-person reflexive anaphors are not marked for gender, making them indistinguishable based on semantic features. When such semantic cues overlap, it might be possible that structurally inaccessible antecedents may be considered, which was attested for unimpaired individuals (Lewis & Vasishth, 2005). Borrowing insights from psycholinguistics, it might be reasonable to argue that when they encountered ambiguities stemming from such semantic overlaps, the PWA considered non-local antecedents more often than unimpaired individuals who were able to work out contextual manipulations to disambiguate sentence interpretation. A second point of difference in our sentence materials here as compared to languages with strong locality constraints has to do with Turkish being a verb-final language in which the matrix clause predicate is positioned at the end of the critical sentence (i.e., [Hemşire<sub>ς</sub> [doktorun *kendini* savunduğunu]<sub>O</sub> belirtti<sub>v</sub>] vs. [The nurse<sub>ς</sub> stated<sub>v</sub> that [the doctor defended *him/herself*]]). In Turkish, anaphoric reflexive comes before both the complement and the matrix clause predicate, unlike in English, speakers of which may rely on verb semantics during their sentence interpretation (Hartshorne & Snedeker, 2013). However, in Turkish, semantic information from verb argument structure would only be available after the anaphor. Therefore, in varied ways from earlier studies, the PWA may have followed different processing strategies to resolve anaphora. Drawing a circle of contemplation from this point onwards, PWA's increased difficulty based on lexical-semantic processing seems in line with the *Delayed Lexical Integration* account, which holds that PWA's difficulty is not a structural pronominal resolution per se, but rather delays in processing lexical items during sentence comprehension (Choy & Thompson, 2010; Thompson & Choy, 2009). We cannot rule out this possibility. Can reduced consideration for local antecedents be due to reduced capacity in cognitive resources, particularly with declining short-term memory outcomes (see e.g., Caplan et al., 2015)? Although, we did not observe a direct relationship between digit span outcomes and the PWA's antecedent selection preference, reduced capacity in aphasia to process syntactically complex and working memory demanding contexts might be at issue here. As anaphora resolution in a task as ours is not simply composed of finding the rights referent for a given anaphor, but also navigating and retrieving potential antecedents during the course of processing, which is evidently impacted in aphasia.

#### 4.2. Processing overt and null object pronouns

Experiment 2 examined how Turkish-speaking PWA process overt and null object pronouns compared to unimpaired individuals. Previous literature has consistently shown that a form of object pronoun processing difficulty is expected in aphasia (see e.g., Choy & Thompson, 2010; Edwards & Varlokosta, 2007; Friederici et al., 1991; Grodzinsky et al., 1993; Vasić, 2006). Our finding adds to those burgeoning studies providing evidence from Turkish that pronominal processing is indeed impacted. We observed critical group differences in our PWA's performances showing that they often considered an inappropriate antecedent measured by a greater number of fixations and an elevated selection of a local antecedent. Given that PWA may exhibit long viewing durations on non-target objects in other eye-tracking experiments (Seckin et al., 2016), the PWA's greater number of fixations on inappropriate antecedents does not seem to be a methodological issue. Moreover, consideration of local antecedents for object pronouns was visually absent in the unimpaired controls Experiment 2. We conclude that the PWA may not strictly adhere to the structural locality constraints that typically



apply to object pronouns in Turkish, building on the evidence that the PWA often bypassed this constraint, opting instead for non-local antecedents. This suggests that the application of locality constraints may be compromised in aphasia in Turkish.

An additional finding worth discussing in detail is the PWA's overreliance on non-local antecedents in both overt and null pronoun conditions. This behavior contrasts with that of the unimpaired controls, who preferred non-local antecedents more often in overt than in null object pronouns. This finding is reconcilable with previous psycholinguistic evidence from unimpaired Turkish speakers (see Gürel, 2002; Özbek & Kahraman, 2016). Specifically, the PWA did not show a difference in their preference for both non-local and discourse antecedents between overt and null pronoun conditions. This finding is in line with Peristeri and Tsimpli (2013) who also did not observe differences in their Greek-speaking PWA's performances between overt and null object conditions. Following Vasić (2006), we expected our PWA to encounter difficulty in discourse-level interpretations of null pronouns. This expectation is borne out. Although the PWA's end-of-trial responses for discourse antecedents did not differ across overt and null pronoun conditions, they exhibited fewer fixations toward discourse antecedents similarly in both null and overt pronoun conditions. Notably, a reduced number of looks towards discourse antecedents in the PWA occurred in later time clusters after 1500ms, suggesting that the PWA was not able to compute referential relationships, particularly discourse level information, in a timely manner (see Wang & Thompson, 2022). Difficulties in processing discourse level information during processing pronominal/referential elements in aphasia are in fact not entirely new, and this has been shown to be affected (Avrutin, 2006; Hickok & Avrutin, 1995; Piñango et al., 2001). Interestingly, we have shown that difficulty accessing discourse antecedent was more difficult in our people with non-fluent aphasia. This finding aligns with the broader challenges in grammar processing that affect discourse-level interpretation for pronominal elements, which is particularly at stake in non-fluent aphasia (see Devers et al., 2016; Martínez-Ferreiro et al., 2017).

Undoubtedly, this study faced certain limitations. The sample size for PWA was modest, with only six participants under our eye-movement monitoring studies. This challenge is not unique to our research; it mirrors a widespread issue in aphasia studies employing similar methodologies, where sample sizes are often below ten individuals (see e.g., Burkhardt et al., 2008; Engel et al., 2018; Hanne et al., 2016; Thompson & Choy, 2009). The limited size of the sample is a constraint that casts doubt on the generalizability of the results. We might consider pursuing a future direction that involves analysing experimental data derived from eye movement measurements from PWA using a case-controls design in addition to analysing group means.

#### 4.3. Conclusions

In conclusion, this paper reports three important findings: (i) Results from an eye-movement monitoring experiment demonstrated that the PWA had reduced selection and fewer fixations toward local antecedents while processing reflexive anaphors, and they were unable to integrate contextual information to resolve anaphoric references. The PWA's greater reliance on non-local interpretations of reflexive anaphors is not what neurolinguistic theory based on structural locality would predict. We argued that this might be due to structural differences in binding domains and certain semantic factors in Turkish, such that its non-gender-marked pronominal elements and verb-final nature may have made anaphoric resolution less salient compared to well-examined PWA speaking English. As a result, Turkish-speaking PWA encounter difficulties as antecedent salience and referential ambiguity increase. (ii) Turkish-speaking PWA tested in the current study do encounter difficulties processing object pronouns as they often inappropriately considered a local antecedent, which is structurally inaccessible. The PWA did not show a difference in selecting non-local or discourse antecedents across overt and null pronoun conditions, despite their indisputable difficulty accessing discourse antecedents, particularly in the non-fluent PWA. In summary, the Turkish-speaking PWA demonstrated a strong consideration toward non-local antecedents as a processing strategy to tackle referential ambiguities within a variable/unconstrained anaphoric reflexive system. They also demonstrated such a strategy during the processing of object pronouns, while their performance faced limitations in accessing discourse antecedents. The most viable explanation for these processing profiles in aphasia is a combination of reduced salience in pronominal reference and the PWA's inability to integrate contextual cues to disambiguate the intended antecedent.

#### CRediT authorship contribution statement

**Seçkin Arslan:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing, Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Semra Selvi-Balo:** Conceptualization, Resources. **İlknur Maviş:** Conceptualization, Writing – review & editing.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

### Data availability

Data will be made available on request.

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### Appendix A. Sentence materials used in the experiments

1. *Silikon davasında ilk duruşma yapıldı. Bir hemşirenin/doktorun tutuklandığı davada hemşire doktorun onu/kendini/kendisini/Ø savunduğunu vurguladı.* "The first hearing was held in the silicone case. In the case where a nurse was arrested, the nurse emphasized that the doctor defended *anaphora*"
2. *Yılbaşı partisinde ofisteki bilgisayar çalındı. Bir sekreterin/çaycının arandığı durumda sekreter çaycının onu/kendini/kendisini/Ø suçladığını hatırlattı.* « At the New Year's Eve party, the computer in the office was stolen. When a secretary was sought, the secretary reminded that the tea maker had blamed *anaphora*"
3. *Okuldaki veli toplantısında tartışma çıktı. Bir öğretmenin/mudurun söz aldığı toplantıda Öğretmen öğrencinin onu/kendini/kendisini/Ø zorladığını açıkladı.* "An argument broke out at the parent-teacher meeting at the school. During the meeting where a teacher spoke, the teacher explained that the student had challenged *anaphora*."
4. *Tamirhanede alacak sebebiyle arbeye yaşandı. Bir sürücünün/çırağın karıştığı kavgada Sürücü tamircinin onu/kendini/kendisini/Ø yaraladığını söyledi.* "A brawl broke out at the repair shop over a debt. In the fight that a driver was involved in, the driver claimed that the mechanic injured *anaphora*."
5. *Yeni yayımlanan albüm büyük başarıya ulaştı. Bir şarkıcının/gazetecinin verdiği röportajda gazeteci şarkıcının onu/kendini/kendisini/Ø övdüğünü yazdı.* "The newly released album was a huge success. In an interview with a singer, the journalist wrote that the singer praised *anaphora*"
6. *Havayolu şirketinin aldığı önlemler onaylandı. Bir pilotun/hostesin yer aldığı eğitimde hostes pilotun onu/kendini/kendisini/Ø görevlendirdiğini öğrendi.* "The measures taken by the airline company were approved. During the training, in which a pilot took part, the stewardess learned that the pilot had assigned *anaphora*."
7. *Mahallede akşam açığa çıkan yangın söndürüldü. Bir itfaiyecinin/polisin tehlike atlattığı olayda polis itfaiyecinin onu/kendini/kendisini/Ø kurtardığını bildirdi.* "A fire that broke out in the neighborhood in the evening was extinguished. In the incident where a firefighter overcame danger, the police reported that the firefighter had saved *anaphora*."
8. *Yeni yapılacak olan projenin yöneticisi atandı. Bir profesörün/mühendisin yönetici seçildiği toplantıda mühendis profesörün onu/kendini/kendisini/Ø önerdiğini anlattı.* "A manager has been appointed for the project that is to be undertaken. At the meeting where a professor was selected as the manager, an engineer explained that the professor had nominated *anaphora*."
9. *Çiftlikte geçen yıl hırsızlık olayı meydana geldi. Bir çiftçinin/bekçinin saldırıya uğradığı olayda bekçi çiftçinin onu/kendini/kendisini/Ø koruduğunu kaydetti.* "Last year, a theft occurred on the farm. In the incident where a farmer was attacked, the guard noted that the farmer defended *anaphora*."
10. *Yıldızlı restoran savcılık soruşturmasına alındı. Bir aşçının/garsonun hastaneye kaldırıldığı vakada garson aşçının onu/kendini/kendisini/Ø zehirlediğini söyledi.* "The star-rated restaurant was taken under prosecution. In the case where a chef was hospitalized, the waiter said that the chef had poisoned *anaphora*."
11. *Tiyatro oyununun provası esnasında tartışma yaşandı. Bir yönetmenin/oyuncunun işi bıraktığı provada oyuncu yönetmenin onu/kendini/kendisini/Ø eleştirdiğini belirtti.* "During the rehearsal of the theater play, a dispute occurred. At the rehearsal where a director quit, an actor pointed out that the director criticized *anaphora*."
12. *Olay yerine çok sayıda ambulans sevk edildi. Bir hırsızın/temizlikçinin silahla yaralandığı kazada temizlikçi hırsızın onu/kendini/kendisini/Ø vurduğunu tekrarladı.* "Numerous ambulances were dispatched to the scene of the incident. In the accident where a thief was wounded by a firearm, the cleaner repeated that the thief shot *anaphora*."

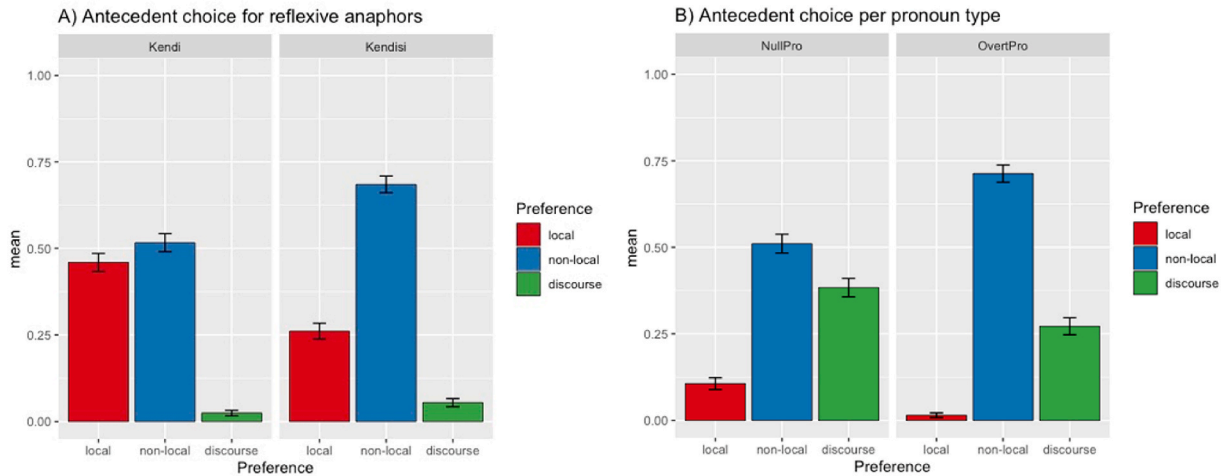
### Appendix B. An offline antecedent preference study with unimpaired Turkish speakers

Given the initial absence of baseline expectations regarding the behavior of unimpaired adults in interpreting the sentence structures used in our study, we therefore implemented an offline antecedent preference task with unimpaired Turkish adults to control for our sentence materials.

A total of 63 native speakers of Turkish participated (54 females, 9 males, age = 23.73, sd = 4.85), all of whom acquired Turkish from birth in monolingual settings. The antecedent preference experiment contained the same sentence materials from both tasks (Experiment 2 and 3), see (2) and (3) above. The experiment was programmed in the IbeXFarm platform and conducted via the web (Drummond, 2013). Sentences per trial were presented in centre of the screen in black fonts on white background. Underneath the presented sentence, a question phrase was presented (*Doktor kimi savundu?* 'Who did the doctor defend?') followed by three answer options: (i.e., *Doktor*, *Hemşire*, *Hademe* 'Doctor, Nurse, Janitor'). The participants read the sentences and clicked on the most

appropriate answer option. All trials were intermixed and presented fully randomly using the Latin Square design.

Figure B1 presents the mean antecedent choice proportions in both *reflexive anaphor* and *Overt/Null object pronoun* task. Measures from both the tasks reveal that all three potential antecedents were considered as referents for pronoun variables to differing degrees.



**Appendix Fig. B1.** Mean antecedent preference measures for A) reflexive anaphors and B) null vs. overt object pronoun conditions.

*Reflexive anaphors.* For the *kendi* reflexive condition, the participants selected a local antecedent in 45.9%, a non-local antecedent in 51.6% and a discourse antecedent only in 2.4% of the total trials. For the *kendisi* reflexive condition, local antecedents were selected in 26.0%, non-local antecedents in 68.4%, and discourse ones in 5.4% of all trials. Statistical outputs have shown that, for *kendi* reflexive anaphors, consideration for discourse antecedents was less frequent than both local ( $\beta = 3.52$ ,  $SE = 0.35$ ,  $z = 9.97$ ,  $p < 0.001$ ) and non-local antecedents ( $\beta = 3.75$ ,  $SE = 0.35$ ,  $z = 10.62$ ,  $p < 0.001$ ). We found no difference between local and non-local antecedents ( $\beta = -0.23$ ,  $SE = 0.14$ ,  $z = -1.54$ ,  $p = 0.26$ ), manifesting that our Turkish readers considered both local and non-local antecedents for *kendi* anaphors equally frequently. For *kendisi* reflexive anaphors, by contrast, non-local antecedents were more frequently considered as potential referents in comparison to local ( $\beta = -1.82$ ,  $SE = 0.16$ ,  $z = -11.12$ ,  $p < 0.0001$ ) and discourse antecedents ( $\beta = 3.63$ ,  $SE = 0.25$ ;  $z = 14.19$ ,  $p < 0.001$ ). Local antecedents were chosen more often than discourse ones ( $\beta = 1.82$ ,  $SE = 0.25$ ,  $z = 7.01$ ,  $p < 0.001$ ).

*Overt/Null object pronouns.* In the overt pronoun condition, a local antecedent was preferred in 1.5%, a non-local antecedent in 71.2%, and a discourse antecedent in 27.2% of all trials. In the null pronoun condition, our Turkish speakers preferred a local antecedent in 10.6%, a non-local antecedent in 51%, and a discourse one in 38.3% of the trials. In overt pronoun condition, non-local antecedents were more frequently preferred in comparison to local ( $\beta = -5.09$ ,  $SE = 0.46$ ,  $z = -10.90$ ,  $p < 0.0001$ ) and discourse ( $\beta = 1.89$ ,  $SE = 0.17$ ,  $z = 10.93$ ,  $p < 0.0001$ ). Local antecedents were less preferred as compared to discourse antecedents ( $\beta = -3.19$ ,  $SE = 0.46$ ,  $z = -6.83$ ,  $p < 0.0001$ ). In short, in the overt pronoun condition, Turkish readers strongly preferred non-local over other potential antecedents. In the null pronoun condition, similarly, non-local antecedents were more frequently selected than local ( $\beta = -2.17$ ,  $SE = 0.20$ ,  $z = -10.48$ ,  $p < 0.0001$ ) and discourse antecedents ( $\beta = 0.51$ ,  $SE = 0.15$ ,  $z = 3.31$ ,  $p = 0.002$ ). Discourse antecedents were selected more often than local antecedents in this condition ( $\beta = -1.65$ ,  $SE = 0.21$ ,  $z = -7.93$ ,  $p < 0.0001$ ). Non-local interpretation of object pronouns is stronger for over pronoun than null ones ( $\beta = 0.89$ ,  $SE = 0.17$ ,  $z = 5.20$ ,  $p < 0.001$ ) whilst discourse antecedent interpretation is found to be stronger in null pronouns than overt ones ( $\beta = -0.51$ ,  $SE = 0.17$ ,  $z = -2.92$ ,  $p = 0.003$ ).

Turkish readers equally preferred either a local or non-local antecedent for *kendi* condition while for *kendisi* condition the most frequently selected option was a non-local antecedent. Further, overt object pronouns elicited preference for non-local antecedents while this non-local preference was maintained for null object condition, preference for discourse antecedents was stronger in null than over overt conditions. When an overt pronoun is used, Turkish readers have a strong consideration of non-local antecedents, for null pronouns, in contrast, discourse antecedents become a strong competitor for non-local ones (see Gürel, 2002). One clear conclusion we can draw from this control experiment is that Turkish anaphors are rather unconstrained, and their interpretation is variable, but object pronouns are not, in line with previous psycholinguistic studies (see Gračanin-Yukseket al., 2017).

### Appendix C. Outcomes from the overall models computed with proportions of looks data reflexive anaphors

Sample code in R: `lmer (Elog ~ Reflexive × ContextualBias*Group*(ot1 + ot2 + ot3)+(1 | MEDIA_NAME) + (1 | Participant), data = data)`.

Predictors	Local AOIs		Non-Local AOIs	
	Estimates	p	Estimates	p
(Intercept)	-0.87	<0.001	-0.71	<0.001
Reflexive	-0.08	0.555	0.23	0.062
ContextualBias	0.32	0.024	-0.33	0.006
Group	0.53	<0.001	0.31	0.012
ot1	0.56	0.016	-1.37	<0.001
ot2	-0.58	0.012	0.65	0.005
ot3	-0.37	0.114	0.21	0.369
Reflexive × ContextualBias	0.36	0.074	-0.51	0.003
Reflexive × Group	-0.25	<0.001	-0.05	0.411
Locality × Group	-0.32	<0.001	0.14	0.012
Reflexive × ot1	-0.68	0.039	2.08	<0.001
Reflexive × ot2	0.60	0.071	-0.18	0.583
Reflexive × ot3	0.61	0.065	-0.05	0.881
Locality × ot1	0.11	0.733	0.16	0.630
Locality × ot2	-0.76	0.022	0.88	0.008
Locality × ot3	1.10	0.001	-0.68	0.042
Group × ot1	1.17	<0.001	0.28	0.276
Group × ot2	-0.95	<0.001	0.32	0.207
Group × ot3	0.22	0.398	-0.27	0.295
Reflexive × ContextualBias *Group	0.16	0.043	0.28	<0.001
Reflexive × ContextualBias *ot1	2.08	<0.001	-1.67	<0.001
Reflexive × ContextualBias *ot2	-0.67	0.158	-0.35	0.455
Reflexive × ContextualBias *ot3	-2.11	<0.001	1.00	0.035
Reflexive × Group * ot1	0.04	0.916	-1.31	<0.001
Reflexive × Group * ot2	0.21	0.557	-0.08	0.822
Reflexive × Group * ot3	-0.10	0.794	-0.23	0.528
Locality × Group * ot1	-1.32	<0.001	0.61	0.093
Locality × Group * ot2	1.39	<0.001	-0.60	0.103
Locality × Group * ot3	-0.45	0.219	0.41	0.266
Reflexive × ContextualBias *Group × ot1	-1.35	0.010	1.40	0.007
Reflexive × ContextualBias *Group × ot2	-0.82	0.119	0.72	0.168
Reflexive × ContextualBias *Group × ot3	1.50	0.004	-0.95	0.067

**Appendix D. Outcomes from the overall models computed with proportions of looks data for null and overt pronouns**

Sample code in R: `lmer (Elog ~ PronounType × ContextualBias*Group*(ot1 + ot2 + ot3)+(1 | MEDIA_NAME) + (1 | Participant), data = data).`

Predictors	Local AOIs		Non-Local AOIs		Discours AOIs	
	Estimates	p	Estimates	p	Estimates	p
(Intercept)	-0.57	<0.001	-0.83	<0.001	-0.98	<0.001
PronounType	-0.26	0.026	0.35	0.031	-0.13	0.300
ContextualBias	-0.12	0.297	0.11	0.492	-0.02	0.857
Group	-0.05	0.722	0.25	0.034	0.11	0.306
ot1	0.61	0.007	-0.50	0.026	-0.09	0.636
ot2	-0.76	0.001	0.01	0.969	0.41	0.030
ot3	-0.44	0.048	0.03	0.890	0.52	0.006
PronounType × ContextualBias	0.50	0.002	-0.27	0.230	-0.13	0.477
PronounType × Group	0.07	0.204	-0.38	<0.001	0.23	<0.001
ContextualBias × Group	0.31	<0.001	0.07	0.214	-0.49	<0.001
PronounType × ot1	-0.53	0.105	-0.07	0.824	0.40	0.151
PronounType × ot2	0.04	0.895	-0.53	0.106	-0.56	0.040
PronounType × ot3	0.53	0.103	0.00	0.996	-0.42	0.124
ContextualBias × ot1	-0.18	0.563	1.14	<0.001	-0.81	0.002
ContextualBias × ot2	-0.30	0.343	0.91	0.005	-0.10	0.704
ContextualBias × ot3	-0.25	0.427	-0.36	0.265	0.50	0.063
Group × ot1	-0.63	0.011	-0.66	0.008	1.35	<0.001
Group × ot2	-0.43	0.087	0.39	0.125	0.32	0.128
Group × ot3	1.05	<0.001	-0.32	0.207	-0.79	<0.001
PronounType × ContextualBias* Group	-0.57	<0.001	0.78	<0.001	0.04	0.574
PronounType × ContextualBias * ot1	0.40	0.378	0.26	0.574	0.15	0.696
PronounType × ContextualBias * ot2	-0.42	0.359	0.84	0.071	0.66	0.085

(continued on next page)

(continued)

Predictors	Local AOs		Non-Local AOs		Discours AOs	
	Estimates	p	Estimates	p	Estimates	p
PronounType × ContextualBias* ot3	0.81	0.077	−0.90	0.051	−0.18	0.639
PronounType × Group* ot1	0.03	0.936	0.86	<b>0.018</b>	−0.00	0.987
PronounType × Group* ot2	0.39	0.273	1.18	<b>0.001</b>	−0.57	0.059
PronounType × Group* ot3	−0.32	0.381	−0.19	0.606	0.54	0.074
ContextualBias × Group* ot1	0.12	0.738	0.40	0.260	−0.83	<b>0.005</b>
ContextualBias × Group* ot2	0.57	0.105	−1.00	<b>0.005</b>	−0.24	0.412
ContextualBias × Group* ot3	−0.20	0.577	0.54	0.131	−0.09	0.773
PronounType × ContextualBias* Group × ot1	−0.87	0.084	−0.40	0.441	−0.08	0.855
PronounType × ContextualBias* Group × ot2	1.05	<b>0.037</b>	−2.05	<b>&lt;0.001</b>	0.32	0.457
PronounType × ContextualBias* Group × ot3	−0.37	0.461	0.42	0.415	0.02	0.955

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