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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Quantifier Spreading Errors during Pronoun Processing in Aphasia

Afazide Adılların İşlemlenmesi Sırasında Gözlenen Niceleyici Yayma Hataları

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ABSTRACT

Aphasia is an acquired language disorder that impacts all language abilities, rendering normal communication extremely difficult. Grammatical processing is often impaired in aphasia. Pronouns are often found to be effortful, with difficulty interpreting to whom a pronoun might refer. This study aimed to investigate whether interpreting pronouns and reflexives with and without potential quantified antecedents (i.e., "Every rabbit / Rabbit is pointing at itself/it/monkey") are impaired in aphasia in Turkish, and whether quantifier spreading errors occur during pronoun/reflexive processing. A total of 12 people with aphasia (PWA) (two females, M_{age}= 59.7, *SD* = 14.55) and 15 age-matched healthy controls were recruited and asked to listen to 24 sentences in conditions of non-quantified and quantified subjects in which different referential and pronominal variables were controlled for (pronoun, reflexive, and R-expression). These participants were admitted to a picture-sentence matching paradigm with an end-of-trial truth-value judgment task. They were presented with a picture which either matched or mismatched the sentence contexts, and they were asked to respond. Their accuracy and response times were recorded and analyzed using mixed-effects regression models. The findings showed that the PWA performed more poorly and slowly than the control group and that both the groups performed more slowly responding to the quantified subjects than non-quantified ones. The PWA made interpretation errors in mismatch conditions, particularly for quantified subjects, evoking longer response times compared to non-quantified subjects. In conclusion, this study showed that quantifier spreading errors are observed in Turkish aphasia, which does not necessarily depend on pronominal/anaphoric resolution. It is suggested that the PWA's sentence interpretation difficulty was underlined in two forms of separate impairments: interpreting quantifier scope and impairments in resolving pronominal/anaphoric elements.

Keywords: Aphasia, quantifier, pronoun, quantifier spreading, binding

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ÖZ

Afazi, tüm dil yetilerini etkileyerek bireyin güçlükle iletişim kurmasına neden olan edinilmiş bir dil bozukluğudur. Dilbilgisel yapıları işlemleme, afazide çoğunlukla güçtür. Adıllar, afazide sıklıkla etkilenen bir dilbilgisi yapısıdır ve afazili bireyler adılların kimi işaret edebileceğini yorumlamada güçlük yaşamaktadır. Bu çalışma, (i) Türkçe afazide niceleyicisi olan ve olmayan öznelerin bulunduğu tümcelerde adıl/adılsıları işlemlemenin (örneğin, "Her tavşan/Tavşan kendini/onu/maymunu gösteriyor.") etkilenip etkilenmediğini ve (ii) adıl/adılsıl işlemleme sırasında oluşan niceleyici yayma hatalarını incelemeyi hedeflemektedir. Çalışmaya 12 afazili birey (iki kadın, $Ort._{Yaş}$= 59.7, *SS* = 14.55) ve benzer yaşlardaki 15 sağlıklı yetişkin katılmıştır. Katılımcılardan, farklı göndergesel ve adılsıl değişkenlerin kontrol edildiği (adıl, dönüşlü adıl ve G-anlatım) niceleyicili ve niceleyicisiz özne koşullarında 24 tümce dinlemeleri istenmiştir. Mevcut araştırma kapsamında, tümce sonu doğruluk-değer yargısı göreviyle birlikte bir resim-tümce eşleştirme paradigması kullanılmıştır. Bu doğrultuda, katılımcılara tümce bağlamlarıyla eşleşen ya da eşleşmeyen bir resim sunulmuş ve kendilerinden yanıt vermeleri istenmiştir. Katılımcıların doğruluk oranlarının ve yanıt sürelerinin kaydedilmesiyle elde edilen veriler, karmaşık etkili regresyon modelleri kullanılarak analiz edilmiştir. Analizler sonucunda elde edilen bulgular, afazili bireylerin kontrol grubuna göre daha zayıf ve yavaş performans gösterdiğini ve her iki grubun da niceleyicili koşulda niceleyicisiz olanlara göre daha yavaş yanıt verdiğini ortaya koymuştur. Afazili bireyler, özellikle niceleyicili tümcelerin bulunduğu uyumsuz koşulunda yorumlama hataları yapmış ve bu durum niceleyicisiz cümlelere kıyasla daha uzun yanıt sürelerine neden olmuştur. Sonuç olarak, bu çalışma Türkçe konuşan afazili bireylerde adılsıl/göndergesel çözünürlüğe bağlı olmayan niceleyici yayma hatalarının gözlemlendiğini göstermiştir. Mevcut araştırmada kullanılan tümcelerin işlemlenmesinde, afazili bireylerin niceleyici kapsamını yorumlama ve adılsıl/göndergesel öğeleri çözme şeklinde iki farklı bozukluk biçimi gösterdiği sonucuna varmak mümkündür.

Anahtar Kelimeler: Afazi, niceleyici, adıl, niceleyici yayma, bağlama

Aphasia is an acquired language disorder which is often brought on by a stroke. Aphasia renders successful communication extremely effortful by impacting virtually all language abilities leading to profound difficulty in speaking fluently, understanding sentences, and repeating verbal stimuli. Studies on non-fluent 'agrammatic' aphasia have shown that the locus of the deficit in non-fluent people with aphasia (PWA) is underlined by impairments not only in language production but also in comprehending complex sentences (Caramazza & Zurif, 1976; Grodzinsky, 1991). Within the large amount of sentence processing studies conducted on aphasia, pronouns constitute an important place as this grammatical category is often found to be impaired in PWA speaking many different languages (e.g., Blumstein et al., 1983; Choy & Thompson, 2010; Edwards & Varlokosta, 2007; Friederici et al., 1991; Grodzinsky et al., 1993; Ruigendijk et al., 2006; see also Arslan et al., 2021 for reviews). The current study addressed how object pronouns and reflexive forms referring to quantified and non-quantified antecedents are worked out in PWA who speak Turkish.

Pronouns have been a focus of interest in aphasiology due to their relevance to the binding theory (Chomsky, 1981). To be able to interpret pronouns (*her, herself, she*, etc.), a referential link with a potential 'salient' antecedent or referent must be established (e.g., $\underline{Elif_i}$ *understood that Mehmet likes* $\underline{her_i}$). This relationship between antecedents and pronouns is called 'co-reference'. According to the binding theory, a reflexive anaphor can have a co-reference relationship with a local antecedent; that is, antecedent and reflexive must be within the same domain (i.e., Principle A), whereas a pronoun cannot be bound to a local antecedent (i.e., Principle B). In other words, a pronoun referring to an antecedent within its local domain would be ungrammatical (e.g., **Elif understood that* $Mehmet_j$ *likes* $\underline{him_j}$). Stemming from this theoretical frame, earlier studies on aphasia have compared comprehension of object pronouns (i.e., pronominals) and reflexive anaphors

(i.e., anaphors) in aphasia to find that the interpretation of co-reference relationship overall is relatively impacted in aphasia. However, outcomes from those studies have shown relatively incompatible results. Some of these studies report non-fluent PWA's distinctive impairments in object pronouns as compared to reflexives (Grodzinsky et al., 1993; Love et al., 1998), whereas other studies indicated an opposite pattern of dissociations pointing to affected reflexive forms (Blumstein et al., 1983) or equal patterns of impairments in both object pronoun and reflexive comprehension tasks (Choy & Thompson, 2010; Edwards & Varlokosta, 2007).

Dependencies requiring discourse interpretation are often found to be more effortful in aphasia than structures that solely rely on syntactic analysis. That is, discourse-linked elements (not only pronouns but also which+NP questions, past-time reference), which have representation beyond the sentence boundaries, are often impaired in aphasia (Avrutin, 2006; Bastiaanse et al., 2011). Grodzinsky and colleagues (1993) studied PWA's interpretation of object pronouns/reflexives representing a co-reference relationship between pronoun and its antecedents (i.e. *Is mama bear touching her/herself?*) and pronouns with quantified antecedents (i.e. *Is every bear touching her/herself?*). The authors found that the PWA in their study performed more poorly on referential pronouns than on quantified pronouns. In their further study, Grodzinsky and Reinhart (1993) argued that while interpreting referential object pronouns, PWA need to analyze discourse information in addition to applying binding relations which overloads processing in aphasia. In contrast, during interpreting reflexive anaphors PWA may rely on syntactic information only. However, it should be noted that selective impairments in referential pronominal elements over quantified pronouns is far from being clear-cut. Edwards and Varlokosta (2007) conducted a study with similar materials to those in Grodzinsky and colleagues (1993) and showed that their PWA demonstrate an important individual variability regarding their impairment patterns as some PWA performed more poorly on pronouns with quantified antecedents than on the co-reference condition.

Error patterns observed in Grodzinsky and colleagues (1993), and Edwards and Varlokosta (2007) suggest that some PWA might have difficulty interpreting the scope of quantified noun phrases while resolving pronouns. These kinds of interpretation errors are referred to as 'quantifier spreading' (Brooks & Parshina, 2019). Although this phenomenon has often been observed in language acquisition studies (O'Grady et al., 2010; Sekerina & Sauermann, 2015), there is evidence that PWA may also be prone to quantifier spreading errors (Grodzinsky et al., 1993; Philip & Avrutin, 1998; Saddy, 1995), but Roca Hoogsteder (2012) showed that number of quantifier spreading errors are not different in aphasia and controls. Using a sentence-picture matching task, Philip and Avrutin (1998) presented sentence contexts with quantified referential expressions (e.g., *Every boy is driving a car*). For such contexts, a group of non-fluent, but not fluent, PWA exhibited an elevated number of quantifier spreading errors by pointing to a picture where one of the cars had no driver as opposed to a picture where all three cars were being driven by different drivers. This type of quantifier interpretation error is known as non-exhaustive pairing, where participants fail to correctly interpret the intended quantification of 'every driver' (see also Drozd & Loosbroek, 2006). Further explanations come from children's acquisition studies on why quantifier spreading errors might occur. A possibility is that quantifier interpretation

fails due to inaccurate syntactic representation (see Kang, 2001; Philip, 1994). A second possibility is that quantifier scope is misinterpreted due to erroneous associations between syntactic and semantic representation (Brooks & Braine, 1996). A third strong possibility is reduced visual attention or lack of visual salience (Minai et al., 2012; O'Grady et al., 2010; Sekerina & Sauermann, 2015). This explanation also seems to be compatible with Philip and Avrutin (1998) who argued that quantifier misinterpretation in aphasia might occur due to reduced processing resources. However, quantifier spreading, and in fact, pronoun resolution in general, is a less understood concept in PWA speaking languages other than English. Turkish provides a remarkable case of a pronominal system regarding the reflexive form. Unlike in English, a reflexive can refer to antecedents in the long distance outside the local clause. Therefore, the current study aims to examine whether this cross-linguistic difference affects quantifier spreading.

Reflexive Anaphors and Object Pronouns in Turkish and The Current Study

The Turkish reflexive form *kendi* 'oneself'[1] is proposed to comply with Principle A of the binding theory, which means that it binds to local antecedents (Enç, 1989; Gürel, 2002; Kornfilt, 2001; Sezer, 1979). A long-distance reading is particularly viable in third person referents. The available psycholinguistic studies on reflexives in healthy Turkish speakers have shown that *kendi* has strong long-distance readings and hence show a rather unconstrained behavior (Arslan et al., submitted; Gračanin-Yuksek et al., 2017; Knospe, 2019; Özbek & Kahraman, 2016). In example (1), *kendi* is ambiguous between a local interpretation (i.e. 'Mehmet likes himself') and a long-distance interpretation (i.e. 'Mehmet likes Elif'). The third-person object pronoun *onu*, by contrast, is syntactically non-variable and can only refer to long-distance antecedents (see, Underhill, 1976), as illustrated in example (2).

(1) Elif$_j$ Mehmet'in$_k$ kendini$_{j/k}$ beğendiğini anladı.

Elif Mehmet.$_{GEN}$ oneself.$_{ACC}$ like.$_{PASTPART.AGR..ACC}$ understand.$_{PST.3SG}$

'Elif understood that Mehmet likes oneself.'

(2) Elif$_j$ Mehmet'in onu$_j$ beğendiğini anladı.

Elif Mehmet.$_{GEN}$ she.$_{ACC}$ like.$_{PASTPART.AGR..ACC}$ understand.$_{PST.3SG}$

'Elif understood that Mehmet likes her.'

Studies on pronouns in Turkish PWA are rather limited. In a conference contribution, Akyüz and Arslan (2021) analyzed different pronoun variables in spontaneous speech samples of a group of Turkish PWA and reported that Turkish non-fluent aphasia is rather characterized by an overuse of pronouns in narrative production. In particular, the authors found that an overall number of pronouns, pronoun-to-noun and pronoun-to-word ratios (i.e., ratio of pronouns to lexically nominal elements and that of all words) were inflated

[1] Please note that a second distinct form of reflexive *kendisi* exists in Turkish, and there is a consensus that this form is strongly unconstrained as it can show co-reference relationship with both local and non-local/discourse antecedents. However, this form is out of the scope of the current study.

as compared to the norms of healthy controls. Turkish PWA showed typical patterns of object/subject personal pronouns within control ranges; however, the total number of object and subject dropping instances was excessive compared to the controls. These findings are in line with studies that have reported findings in languages with complex inflectional paradigms, where pronouns are often overused as an 'empty category' to be able to compensate for the lack of lexical access (Menn & Obler, 1990). Arslan and colleagues (Submitted) have conducted eye-movement monitoring studies on groups of Turkish PWA, exploring the resolution of object pronoun and reflexive conditions in sentence contexts ("*Hemşire doktorun onu/kendini/ Ø savunduğunu vurguladı*. / The nurse emphasized that the doctor was defending oneself/it"). The authors revealed that the PWA responded to the *kendi* conditions by choosing long-distance referents more often in comparison to control participants who preferred local antecedents for this condition. A recent multiple case study by Kurada and colleagues (Submitted), which used a very similar task to ours, examined whether Turkish-German bilinguals with aphasia extend to binding structures and whether pronoun variables show selectivity in the impairment of bilingual PWA. They found no significant differences in the binding of pronoun, anaphor, and DP binders to quantified and non-quantified antecedents in Turkish for their two participants. However, the findings for one of the participants are in line with the findings in the literature which show that there is a selectivity for the binding of referent elements to their antecedents in PWA. This participant performed better in reflexivity than in direct object pronouns in Turkish. Kurada and colleagues' (Submitted) data revealed that in general, the participants made more errors when the antecedents were quantified.

In the current study, we examine the resolution of the object pronoun *onu* and the reflexive form *kendi* as compared to overt noun phrases as referential expressions (e.g., 'rabbit' or 'monkey'). We critically manipulated the potential antecedents in referential and quantified forms (i.e., 'rabbit' vs. 'every rabbit') in order to examine comprehension of quantified and non-quantified antecedents in Turkish PWA. We particularly aimed to investigate (i) whether Turkish PWA are susceptible to quantifier spreading errors, and (ii) whether quantifier spreading errors impact referential processing more severely than binding errors (pronoun, reflexive).

Method

Participants

A total number of 12 PWA were recruited (two females, M_{age} = 59.7, SD = 14.55) who were suffering from non-fluent aphasia due to a single unilateral stroke at the time of testing. These PWA were recruited at Anadolu University, Speech and Language Therapy Research and Rehabilitation Centre (DILKOM) in Eskişehir, Türkiye. The PWA had no other neurological or psychiatric disability and were right-handed before the stroke. We included PWA with a post-onset time of a minimum of four months since the aphasia diagnosis. Those individuals spoke Turkish as their native language and had normal or corrected-to-normal vision and hearing acuity. The presence of aphasic symptoms was confirmed with the Aphasia Assessment Test ADD in Turkish (Maviş & Toğram, 2009). PWA's demographic details are given in Table 1. In addition, 15 non-aphasic healthy

subjects who were matched with PWA on age and education were recruited as a control group.

Table 1. *Demographic Details of PWA (MPO = Months post-onset)*

Participant	Age	Gender	Education (years)	MPO
01IY	19	M	11	20
02AI	49	M	8	20
03ŞK	52	F	13	25
04AB	58	M	5	23
05HB	59	F	8	6
06MY	59	M	5	28
07NT	60	M	5	9
08MÇ	70	M	5	27
09VG	71	M	5	4
10ZI	73	M	11	19
11RG	78	M	5	9
12MT	62	M	11	13

Materials

Verbal materials used in this study were adapted to Turkish from Chien and Wexler's (1990) picture-sentence matching truth-value judgment task, and the visual materials were drawn in color for the purpose of this study. The task included 24 stimulus materials presented in each of the two conditions making a total of 48 trials: sentence contexts with non-quantified subjects, see (3), and with quantified subjects, see (4). In sentence materials, different anaphoric variables in the object were controlled for (pronoun, reflexive, and r-expression).

(3) Tavşan kendini/onu/maymunu gösteriyor.

rabbit itself/it/monkey.$_{ACC}$ shows.$_{PRESPROG.3SG}$

'The rabbit is pointing at itself /it /the monkey'.

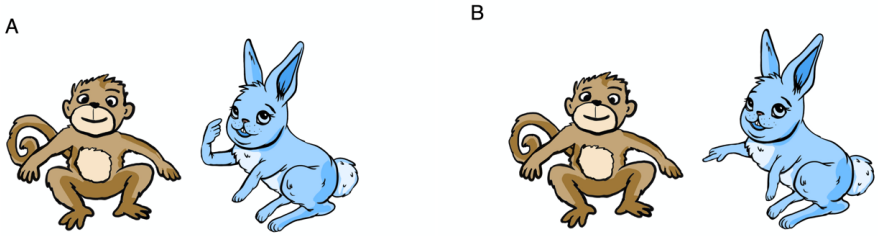
(4) Her tavşan kendini/onu/maymunu gösteriyor.

every rabbit itself/it/monkey.$_{ACC}$ shows.$_{PRESPROG.3SG}$

'Every rabbit is pointing at itself /it /the monkey'.

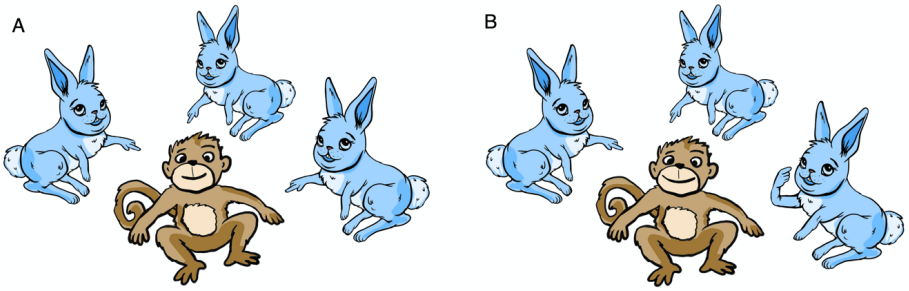
Each sentence stimulus material was depicted in visual displays, as demonstrated in Figure 1. Half of the total 48 trials were matched to a correct visual depiction of the sentence meaning, while the other half was matched with an incorrect depiction of the intended sentence meaning.

Figure 1. *An Example of Visual Depiction for (A) Reflexive: 'Rabbit is Pointing at Itself' and (B) Object Pronoun Condition: 'Rabbit is Pointing at Him/It'.*



As shown in Figure 2, the sentence stimulus 'Every rabbit is pointing at the monkey' was presented twice, once in match and once in mismatch conditions. In the match condition, the visual depiction exhibits three rabbits each of which is pointing at the monkey (Figure 2a), whereas in the mismatch condition, only two of the rabbits are pointing at the monkey and one rabbit is pointing at itself (Figure 2b).

Figure 2. *An Example Visual Depiction for Correct (A) and Incorrect (B) Interpretations for the Quantified Pronoun Sentence 'Every Rabbit is Pointing at the Monkey'.*



Procedure

These verbal and visual materials were programmed using the Super Lab software (Haxby et al., 1993). The participants' task was to make a judgment on whether the visual depiction presented to them correctly described the sentence content. Each trial started with a fixation cross presented for 1000 ms followed by the visual stimulus materials. The participants listened to the sentence materials while they gazed at the picture presented in the middle of a laptop screen. Auditory verbal stimuli were presented twice per trial immediately after each other. The participants were asked to respond to an end-of-trial judgment task by pressing on keyboard buttons labeled as 'yes' when the sentence and picture matched or 'no' when the sentence did not match with the picture. The experiment started with four practice trials which were repeated when necessary to make sure the participants fully understood the task. The task was completed in two blocks with a break in the middle. These blocks included an equal number of trials from both critical conditions presented in a random order.

The procedures described above were approved by the ethics commission of the

University of Groningen [file no. CETO 76006271]. We confirm that all parts of these methods were conducted in line with the Helsinki Declaration for research on human subjects. All participants signed an informed consent form and received no monetary remuneration.

Data Analysis

Accuracy data was recorded and analyzed using generalized mixed-effects linear regression models with the *lme4* package in R (Bates et al., 2015), using the accuracy and response times measures as the dependent variables and the following predictors: Group (PWA, control), Condition (pronoun, reflexive, r-expression), Matching (match, mismatch), Quantifier (quantified, non-quantified subjects). The independent variables were sum-to-zero coded, and dependent variables were pre-processed. Response times shorter than 200ms were removed from the data in order to eliminate button press responses that occurred haphazardly, and the data were log-transformed before analysis. Binary accuracy data were logit transformed prior to running the models. The information criteria (IC), Akaike information criterion (AIC) and the Bayesian information criterion (BIC) were used to select the best fitting model. Participants and items were added as random intercepts. We initially built a global model for the whole data with fixed effects of Group × Quantifier × Mismatch; however, due to the ceiling performances of the control group, we further analyzed the PWA group data with the removal of fixed effect of Group and addition of the Condition. Therefore, the final model reported included the fixed effects of Mismatch (*Match vs. Mismatch*) × Condition (*Object Pronoun vs. Reflexive vs. R-expression*) + Quantifier (*Quantified vs. Non-quantified*) as this was the best performing model. The fixed effects in those models were sum-to-zero contrast coded so as to reduce bias. Furthermore, we ran a quantifier spreading analysis focusing only on data subsets with mismatch sentences as this type of error only occurs in those. Individual PWA data were analyzed using the McNemar test in R (McNemar, 1947).

Results

Overall Group Comparison

Table 2 demonstrates the mean proportions of correct responses per condition, individual scores are given in Appendix 1, and outputs from statistical analysis for overall models are given in Appendix 2. A generalized mixed effects regression model showed a significant fixed-effect of Group (ß = -2.31, $p < .001$). This provides statistical evidence that the PWA group performed more poorly as compared to the control group. We also found a significant effect of Mismatch (ß = 1.09, $p < .001$), indicating that both groups performed better on the match as compared to the mismatch conditions. No other effects revealed a significant result. As the control group showed a ceiling performance and there were no significant interaction effects for Group×Quantifier or for Group×Mismatch (see full outputs of this model in Appendix 2), we did not further analyze the control group data in relation to accuracy of responses.

Table 2. *Statistical Outputs from Generalized Mixed-Effects Regression Model on PWA's End-Of-Trial Response Data.*

	Non-quantified subjects		Quantified subjects	
	Match	Mismatch	Match	Mismatch
Accuracy				
Aphasia $\bar{x}$	0.73 (0.44)	0.55 (0.49)	0.73 (0.44)	0.45 (0.50)
Control $\bar{x}$	0.99 (0.07)	0.93 (0.24)	0.99 (0.07)	0.86 (0.34)
Response times				
Aphasia $\bar{x}$	3441 (3913)	3866 (4222)	4063 (4097)	4950 (5104)
Control $\bar{x}$	1180 (1393)	1772 (2431)	1375 (1640)	1826 (2147)

Regarding response times, our initial linear mixed-effects regression model showed significant fixed effects of Group (ß = 0.28, $p < .001$), Quantifier (ß = -0.09, $p = .03$) and Mismatch (ß = -0.08, $p = .02$). It is clear from the output that the responses from the participants with aphasia were slower than those from the control group, and overall responses were slower in Mismatch and Quantified conditions than was the case with their Match and Non-quantified counterparts. As the results showed no other significant effects, and as there were no interaction effects with Group (full outputs of this model are given in Appendix 2), we removed the control group data from further analyses.

Within Group Comparison for PWA

Table 3 exhibits outputs from a mixed effects generalized regression model, which showed a non-significant fixed-effect of Quantifier; this manifests that the PWA responded equally accurately to sentences with and without quantified subjects overall. The fixed-effects of Mismatch and anaphoric Conditions together with an interaction between Mismatch and Condition indicate that PWA had difficulty judging the truth value in sentences with a mismatching visual depiction over matching ones and that this pattern has significant associations across different conditions. Regarding response times data, however, a strong fixed-effect of Quantifier returned significant, revealing that the PWA performed more slowly when responding to sentences with quantified subjects than with non-quantified subjects.

A set of post-hoc comparisons using Tukey tests indicated that the PWA performed more poorly on the mismatch than the match condition with R-expression objects (i.e. *maymun* 'monkey'; ß = -1.55, $SE = 0.32$, $z = -4.73$, $p < .001$), object pronouns (i.e., *onu* 'him'; ß = -1.03, $SE = 0.47$, $z = -2.18$, $p = .02$), but not for reflexives (i.e., *kendi* 'oneself'; ß = -0.66, $SE = 0.38$, $z = -1.72$, $p = .08$). The performance of participants with aphasia was found to be more affected in mismatch conditions than their match counterparts in both quantified (ß = -1.19, $SE = 0.25$, $z = -4.72$, $p < .001$) and non-quantified sentences (ß = -0.76, $SE = 0.25$, $z = -3.05$, $p = .002$). However, this difference was more pronounced in the former.

A further analysis into response times obtained from incorrect responses showed that the sentences with mismatches evoked longer response times than the matching ones in the quantified subjects (5621ms vs. 3504ms; ß = -2117, $SE = 1004$, $t = -2.108$, $p = .03$). However, this difference was not significant in non-quantified subjects (4320 ms vs. 4536 ms; ß = 217, $SE = 987$, $t = 0.219$, $p = .82$). This pattern is visually depicted in Figure 3B.

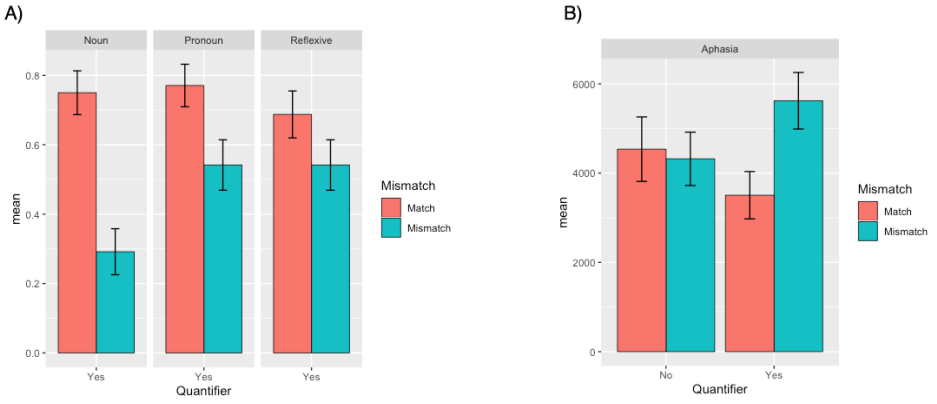
Table 3. *Statistical Outputs from Generalized Mixed-Effects Regression Model on PWA's End-Of-Trial Response Data.*

	Accuracy				*Response times*			
	ß	SE	*Z*	*p*	ß	SE	*t*	*p*
Intercept	0.23	0.23	1.01	.31	7.85	0.22	35.46	< .001
Mismatch	0.78	0.16	4.83	< .001	-0.12	0.06	-1.93	.05
Condition (Pronoun)	0.52	0.22	2.30	.021	-0.01	0.09	-0.12	.90
Condition (Reflexive)	0.45	0.22	2.03	.042	-0.14	0.09	-1.58	.11
Quantifier	0.11	0.09	1.19	.23	-0.13	0.03	-3.48	< .001
Mismatch × Condition (Pronoun)	-0.29	0.22	-1.31	.19	0.09	0.09	0.97	.32
Mismatch × Condition (Reflexive)	-0.46	0.22	-2.03	.042	0.11	0.09	1.19	.23

Quantifier Spreading Error Analysis

These differences indicate that the PWA might be prone to certain kinds of quantifier spreading errors as both response times and sentence interpretation errors increased in quantified mismatch conditions. Therefore, we further analyzed the mismatch data in detail. The PWA had an increased difficulty in interpreting sentences with R-expressions in comparison to both reflexives (ß = 0.93, *SE* = 0.31, *z* = 2.99, *p* = .007) and pronouns (ß = 0.83, *SE* = 0.31, *z* = 2.70, *p* = .01); there were no differences between pronoun and reflexive variables, however (ß = 0.093, *SE* = 0.30, *z* = 0.30, *p* = .94). In our experimental setup, quantifier spreading errors strongly occurred in the R-expression condition, as this condition allowed such a visual setup, see Figure 3A.

Figure 3. *The PWA's Mean Accuracy of Responses to Different Pronominal Variables with Quantified Subjects (A), and Responses Times in Milliseconds to Quantified and Non-Quantified Subjects, Correct Responses Only (B).*



A greater number of misinterpretation errors in quantified mismatch sentences over match ones was subject to important individual variability. In seven individuals, within the quantified subject condition, there were significantly more errors in the mismatch than in the match condition (H.B.: 66% vs. 33% McNemar's X^2 = 10.343, *df* = 1, *p* = .001; M.C.:

91% vs 25% McNemar's $X^2 = 36.422$, $df = 1$, $p < .001$; M.T.: 91% vs. 66% McNemar's $X^2 = 3.6688$, $df = 1$, $p = .05$; MY 91% vs 58% McNemar's $X^2 = 6.8725$,$df = 1$, $p = .008$; N.T.: 91% vs 8% McNemar's $X^2 = 67.919$, $df = 1$, $p < .001$; R.G.: 91% vs 33% McNemar's $X^2 = 26.202$, $df = 1$, $p < .001$; Ş.K.: 100% vs. 50% McNemar's $X^2 = 16.007$, $df = 1$, $p < .001$). In all other PWA, this difference was not significant. Specifically, in mismatching r-expression conditions (i.e., when one rabbit is pointing at itself while the other two are pointing at the rabbit in 'Every rabbit/ rabbit is pointing at the monkey') six PWA performed significantly better on non-quantified subjects than quantified ones (M.C.: 50% vs. 0% McNemar's $X^2 = 48.02$, $df = 1$, $p < .001$; M.T.: 100% vs. 0% McNemar's $X^2 = 98.01$, $df = 1$, $p < .001$; M.Y.: 100% vs. 25% McNemar's $X^2 = 43.808$, $df = 1$, $p < .001$; N.T 50% vs. 0% McNemar's $X^2 = 48.02$, $df = 1$, $p < .001$; V.G. 50% vs. 25% McNemar's $X^2 = 7.68$, $df = 1$, $p = .005$; Z.İ.: 50% vs. 100 McNemar's $X^2 = 16.007$, $df = 1$, $p < .001$). In two PWA, this pattern was reversed. That is, they performed more poorly on non-quantified subjects than quantified ones (A.I.: 0% vs. 25% McNemar's $X^2 = 23.04$, $df = 1$, $p < .001$; Ş.K.: 25% vs. 50% McNemar's $X^2 = 7.68$, $df = 1$, $p = .005$), and in four PWA this difference was not significant (A.B. 50% vs. 50%; H.B. 25% vs. 25%; İ.Y.: 50% vs. 50%; R.G. 0% in both; in all comparisons McNemar's X^2 = null).

Discussion

In this study, we aimed to investigate whether Turkish PWA are prone to quantifier spreading errors, and if so, whether and how quantifier spreading errors impact pronominal processing. Our findings reveal that the PWA group performed more poorly and slowly overall as compared to the control group and that both the groups performed more slowly responding to the quantified subjects than the non-quantified ones. The PWA's performance was not equal across all referential/pronominal variables; that is, their performance on object pronouns and reflexives was indifferent. Nonetheless, they did show significant dissociations by responding more poorly to objects with R-expressions than to object pronouns and reflexives, and this dissociation was even more pronounced within the Mismatch condition. This finding is consistent with the Turkish results of one of the PWA reported in Kurada and colleagues (Submitted). When PWA made errors by clicking on an incorrect depiction of the sentence meaning, these errors evoked longer response times in the quantified subject condition (i.e., *her tavşan* 'every rabbit') as compared to the non-quantified condition. This supplied evidence that the PWA were prone to forms of quantifier spreading errors as they took a long time to respond to and were less accurate in sentences with r-expressions in comparison to both reflexives and object pronouns. Therefore, the points in our first aim proved true, as Turkish PWA seem to be susceptible to quantifier spreading errors, in line with studies reporting evidence that PWA may be prone to quantifier spreading errors (Grodzinsky et al., 1993; Philip & Avrutin, 1998; Saddy, 1995).

Following Grodzinsky and colleagues (1993), we may have expected our PWA to perform more poorly on referential/non-quantified pronouns than on quantified ones. On the contrary, we found significant effects of mismatch in this truth-value judgment task, suggesting that the PWA had no pressing difficulty judging the correct depiction of sentence meaning when the picture and sentence material matched. Nonetheless, the increased

number of errors made by the participants with aphasia in the mismatch condition implies that their difficulty does not necessarily lie in resolving pronominal variables. Similar levels of impairments in both reflexive and object pronoun variables are not unfamiliar indeed, see Choy and Thompson (2010) who reported equal levels of impairments for their PWA's comprehension of reflexive and object pronoun variables. Our findings are fully compatible with those of Edwards and Varlokosta (2007), who also showed that their PWA performed equally poorly in mismatch conditions in both reflexives and object pronouns. Further, Edwards and Varlokosta (2007) showed that their PWA had greater difficulty in variables with quantified antecedents than in those with non-quantified antecedents, similar to our PWA. Our data differed from those of Edwards and Varlokosta (2007) in that they found a greater number of errors in reflexive anaphors in sentences with quantified subjects. On the contrary, we found a greater number of errors in sentences with r-expression objects (i.e., 'every rabbit is pointing at monkey') as compared to pronominal variables (i.e., 'every rabbit is pointing at it/itself'). We believe this is because Turkish anaphors are rather unconstrained and hence their interpretation might be more variable as compared to English anaphors (see Arslan et al., submitted; Gračanin-Yuksek et al., 2017; Knospe, 2019; Özbek & Kahraman, 2016). In essence, the greater number of misinterpretation errors made by PWA in mismatch and quantified antecedents puts doubt on the explanation that pronouns are more impaired in aphasia over reflexives due to purely structural considerations.

A question remaining at this stage is why our PWA showed reduced performance on r-expressions as compared to pronominal variables. This finding seems unexpected at first sight as our PWA were all suffering from non-fluent aphasia, which is widely known for impaired processing ability in grammatical structures. Both response times and sentence interpretation errors were found to increase in mismatch sentences with quantified subjects, and this difference was especially strong for r-expression objects in contrast to object pronouns and reflexives. This pattern is best explained by the presence of a greater amount of quantifier spreading errors over binding errors. In other words, our PWA had less of a problem resolving pronominal variables on this task than they did for interpreting quantifier scope in sentences in r-expression objects (see, Figure 3A above). This pattern was significant in six out of 12 PWA. The presence of quantifier spreading errors was also reported by Philip and Avrutin (1998) for their non-fluent PWA, suggesting that a form of non-exhaustive pairing occurred while PWA were interpreting sentences with quantified antecedents/subjects. That is, the PWA were presented with sentence stimulus with a quantified subject, such as, 'Every rabbit is pointing at the monkey' and with two rabbits pointing at the monkey while one rabbit is pointing at itself (see, the image demonstrated in Figure 2A). The PWA simply judged such a setting as acceptable due to a misinterpretation of quantifier scope in relation to the image presented to them. This is known as non-exhaustive or *under*-exhaustive pairing. We submit to earlier studies that report that such quantifier spreading errors often occur due to reduced visual attention and/or reduced processing resources in young children (Minai et al., 2012; O'Grady et al., 2010; Sekerina & Sauermann, 2015) and in aphasia (Philip & Avrutin, 1998).

This study was not without any limitations. First of all, we followed a design on a par with Grodzinsky and colleagues (1993); however, it seems to us that truth-value judgment tasks impose certain meta-linguistic domain-general cognitive processes, such as memory

and attention, which might be reduced in aphasia. Hence it is difficult to measure the extent to which precise linguistic processes are affected. In a forthcoming study, we address this shortcoming using an eye-movement monitoring experiment with a visually depicted antecedent selection task (Arslan et al., submitted). This study showed that in fact, the responses of Turkish PWA are biased towards first-mentioned entities (i.e., a form of a subject advantage) during anaphoric pronoun/reflexive resolution. A second limitation was that the visual materials we used only allowed for potential non-exhaustive quantifier spreading errors to occur (i.e., not every rabbit point to *him*). However, at present, we are not able to contemplate whether those quantifier spreading errors extend to the over-exhaustive search errors reported in Sekerina and Sauermann (2015), such as where the sentence material mentions '*every alligator is in a bathtub*' but there are three alligators in different bathtubs and one alligator has no bathtub. In both instances, visual search errors, the most plausible explanation for quantifier spreading errors in aphasia, include the lack of visual attention and the reduction of other relevant cognitive resources such as visual and verbal working memory. Without further individual measures of working memory and attention from our PWA, we are only able to speculate on this. It would be worth conducting a future study which would examine quantifier spreading errors in aphasia with greater details of the cognitive profiles of participants.

In conclusion, the outcomes from this study suggest that Turkish PWA are prone to quantifier spreading errors. However, such quantificational scope errors seem independent of pronominal/anaphoric resolution. This is based on the finding that within mismatch conditions, our PWA performed significantly better on sentences with object pronouns and reflexives than those with r-expressions. Therefore, a clear conclusion we can arrive at here is that there are two different types of difficulty in aphasia: (i) forms of difficulty in interpreting quantifier scope due possibly to reduced visual attention and cognitive resources, and (ii) forms of impairment in resolving pronominal/anaphoric elements, which seems to have a similar impact on both pronouns and reflexive variables.

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Ethics Committee Approval: The procedures of this study was approved by the ethics commission of the University of Groningen [file no. CETO 76006271]. We confirm that all parts of these methods were conducted in line with the Helsinki Declaration for research on human subjects.

Informed Consent: All participants signed an informed consent form and received no monetary remuneration.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception/Design of Study- İ.M., G.Y.P., Ö.A.; Data Acquisition- G.Y.P.; Data Analysis/Interpretation- S.A.; Drafting Manuscript- S.A., S.S.B.; Critical Revision of Manuscript- S.S.B., İ.M.; Final Approval and Accountability- S.A., İ.M., S.S.B., Ö.A., G.Y.P.

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Appendix 1.

Appendix 1. *Individual Scores of PWA across Different Conditions*

	Non-quantified subjects		Quantified subjects	
	Match	Mismatch	Match	Mismatch
01IY	0.58 (0.51)	0.50 (0.52)	0.58 (0.51)	0.41 (0.14)
02AI	0.58 (0.51)	0.33 (0.49)	0.58 (0.51)	0.58 (0.51)
03ŞK	0.83 (0.38)	0.33 (0.49)	1.00 (00)	0.50 (0.52)
04AB	0.66 (0.49)	0.50 (0.52)	0.41 (0.51)	0.41 (0.51)
05HB	0.58 (0.51)	0.33 (0.49)	0.66 (0.49)	0.33 (0.49)
06MY	0.91 (0.28)	0.91 (0.28)	0.91 (0.28)	0.58 (0.51)
07NT	0.75 (0.45)	0.41 (0.51)	0.91 (0.28)	0.08 (0.28)
08MÇ	0.75 (0.45)	0.58 (0.51)	0.91 (0.28)	0.25 (0.45)
09VG	0.58 (0.51)	0.66 (0.49)	0.33 (0.49)	0.50 (0.52)
10ZI	0.83 (0.38)	0.75 (0.45)	0.66 (0.49)	0.83 (0.38)
11RG	0.66 (0.49)	0.41 (0.51)	0.91 (0.28)	0.33 (0.14)
12MT	1.00 (00)	0.91 (0.28)	0.91 (0.28)	0.66 (0.49)

Appendix 2.

Appendix 2. *Statistical Outputs from Overall Models Reported under Subsection '3.1. Overall Group Comparison'*

	Accuracy				*Response times*			
	ß	SE	*Z*	*p*	ß	SE	*t*	*p*
Intercept	2.74	0.38	7.17	<.001	7.35	0.12	58.10	<.001
Group	-2.31	0.35	-6.53	<.001	0.28	0.07	3.85	<.001
Quantifier	0.19	0.21	0.91	.36	-0.09	0.03	-2.53	.03
Mismatch	1.09	0.21	5.06	<.001	-0.08	0.03	-2.25	.02
Group × Quantifier	-0.08	0.19	-0.43	.66	-0.04	0.02	-1.76	.07
Group × Mismatch	-0.51	0.19	-2.64	.008	0.02	0.02	0.93	.34
Quantifier × Mismatch	-0.19	0.21	-0.93	.34	-0.01	0.03	-0.48	.63
Group × Quantifier × Mismatch	0.07	0.19	0.38	.70	-0.01	0.02	-0.58	.55