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# **Quantifier spreading errors during pronoun processing in aphasia**

*(Afazide adılların işlemlenmesi sırasında gözlenen niceleyici yayma hataları)*

\*\*\* *This is an author pre-print, post-accept print will soon be available* \*\*\*

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## **Quantifier spreading errors during pronoun processing in aphasia**

*(Afazide adılların işlemlenmesi sırasında gözlenen niceleyici yayma hataları)*

### **ÖZ**

Adıllar, edinilmiş bir dil bozukluğu olan afazide, sıklıkla etkilenen bir dilbilgisi yapısıdır, afazili bireyler adılların kimi işaret edebileceğini yorumlamada güçlük yaşamaktadır. Bu çalışmada, Türkçe konuşan afazili bireylerin, niceleyicisi olan ve olmayan öznelere bulunduğu tümcelerde adıl/adılsılları nasıl işlemlendiği ve dezavantaj gösterip göstermedikleri araştırılmıştır (örneğin, 'Her tavşan/Tavşan kendini/onu/maymunu gösteriyor). Çalışmaya 12 afazili birey (2 kadın, yaş= 59.7, sd=14.55) ve yaşları eşlenmiş 15 sağlıklı yetişkin katılmıştır. Katılımcılardan, farklı göndergesel ve adılsız 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 karışık 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 göstermiştir. 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 tümcelerın işlenmesinde, afazili bireylerin iki farklı bozukluk biçimi gösterdiği sonucuna varmak mümkündür: niceleyici kapsamını yorumlama ve adılsıl/göndergesel öğeleri çözme.

**Anahtar kelimeler:** Afazi, niceleyici, adıl, niceleyici yayma, bağlama

## **ABSTRACT**

Pronouns are often found to be effortful in aphasia, an acquired language disorder, with difficulty interpreting to whom a pronoun might refer. In this study, we explored whether Turkish speaking people with aphasia (PWA) present disadvantage while interpreting pronouns and reflexives with and without potential quantified antecedents (i.e., 'Every rabbit / Rabbit is pointing at itself/it/monkey'). A total number of 12 PWA (2 females, age= 59.7, sd=14.55) and 15 age-matched healthy controls were recruited and were 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 judgement task. They were presented with a picture which either matched or mismatched to the sentence contexts, and they were asked to respond. Their accuracy and response times were record and analysed using mixed-effects regression models. Our findings have shown 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 errors interpretation errors in mismatch condition, 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. We suggest our PWA's sentence interpretation difficulty were underlined two forms of separate impairments: interpreting quantifier scope and impairments in resolving pronominal/anaphoric elements.

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

## **1. Introduction**

Aphasia is an acquired language disorder which is often brought on by stroke. Aphasia renders successful communication extremely effortful by impacting virtually all language abilities leading to profound difficulty in speaking fluently, understanding sentences, repeating verbal stimulus. 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 (Blumstein et al., 1983; Choy & Thompson, 2010; Edwards & Varlokosta, 2007; Friederici et al., 1991; Grodzinsky et al., 1993; Ruigendijk et al., 2006, among many others), 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 speaking 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. *Elif understood that Mehmet likes her<sub>i</sub>*). 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<sub>i</sub> likes him<sub>i</sub>*). 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 et al. (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 PWA in their

study performed poorly on referential pronouns than quantified pronouns. In their further study, Grodzinsky and Reinhart (1993) argued that while interpreting referential object pronouns, PWA need to analyse 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 et al. (1993) and showed that their PWA demonstrate an important individual variability regarding their impairment patterns as some PWA performed poorly on pronouns with quantified antecedents than the co-reference condition.

Error patterns observed in Grodzinsky et al. (1993) and Edwards and Varlokosta (2007) suggest that some PWA might have difficulty interpreting 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 as well be prone to quantifier spreading errors (Grodzinsky et al., 1993; Philip & Avrutin, 1998; Saddy, 1995) but see Roca Hoogsteder (2012) who showed that number of quantifier spreading errors are indifferent 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 PWA, but not fluent ones, exhibited an elevated number of quantifier spreading errors by pointing to a picture depicting a picture where one of the cars had no driver as opposed to a picture where all three cars are being driven by different drivers. This type of quantifier interpretation errors are known as non-exhaustive pairing, where participants fails to correctly



interpret intended quantification of ‘every driver’ (see also Drozd & Loosbroek, 2006). Further explanations come from children’s acquisition studies 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.

### *1.1. Reflexive anaphors and object pronouns in Turkish and the current study*

Turkish reflexive form *kendi* ‘oneself’<sup>1</sup> is proposed to comply with the 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 behaviour (Arslan et al., Submitted; Gračanin-Yukseket al., 2017; Knospe, 2019; Özbek & Kahraman, 2016). In (1), for instance, *kendi* is ambiguous between a local interpretation (i.e. ‘Mehmet likes himself’) and long-distance interpretation (i.e. ‘Mehmet likes Elif’). Third-

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<sup>1</sup> 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.

person object pronoun *onu*, by contrast, is syntactically non-variable and can only refer to a long-distance antecedents (see, Underhill, 1976), as illustrated in (2).

- (1) Elif<sub>j</sub> Mehmet'in<sub>k</sub> kendini<sub>j/k</sub> beğendiğini anladı.  
Elif Mehmet.GEN oneself.ACC like.PASTPART.AGR..ACC understand.PST.3SG  
'Elif understood that Mehmet likes oneself.'

- (2) Elif<sub>j</sub> Mehmet'in onu<sub>j</sub> beğendiğini anladı.  
Elif Mehmet.GEN she.ACC like.PASTPART.AGR..ACC understand.PST.3SG  
'Elif understood that Mehmet likes oneself.'

Studies on pronouns in Turkish PWA are rather limited. In a conference contribution, Akyüz and Arslan (2021) analysed different pronoun variables in spontaneous speech samples of a group of Turkish PWA and reported that Turkish non-fluent aphasia is rather characterised by an overuse of pronouns in narrative production. In particular, the authors found that overall number of pronouns, pronoun-to-noun and pronoun-to-word ratios (i.e., ratio of pronouns to lexically nominal elements and that of to all words) were inflated as compared to the norms of healthy controls. Turkish PWA showed typical patterns of object/subject personal pronouns within control ranges; however, total number of object and subject dropping instances were excessive compared to controls. These findings are in line with studies that have reported in languages with complex inflectional paradigms, pronouns are often overused as an 'empty category' to be able to compensate for the lack of lexical access (Menn & Obler, 1990). Arslan et al. (Submitted) have conducted eye-movement monitoring studies on groups of Turkish PWA exploring resolution of object pronoun and reflexive conditions in sentence contexts (*Hemşire doktorun onu/kendini/∅ 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 Kurada et. al. (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 bilingual PWAs' impairment. 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 that there is a selectivity for the binding of referent elements to their antecedents in PWAs. This participant performed better in reflexivity than direct object pronouns in Turkish. Kurada et. al.'s (Submitted) data revealed that in general, the participants made more errors when the antecedents were quantified.

In the current study, we examine resolution of 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)?

## **2. Method**

### *2.1.Participants*

A total number of 12 PWA were recruited (2 females, mean *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, Turkey. The PWA had no other neurological or psychiatric disability and were right-handed before stroke. We included PWA with a post-onset time of minimally four months since 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.

[PLACE TABLE 1 HERE ]

## *2.2. Materials*

Verbal materials used under this study were adapted to Turkish from Chien and Wexler's (1990) picture-sentence matching truth-value judgement task, the visual materials were drawn in colour for the purpose of this study. The task included 24 stimulus materials presented in each of the two conditions summing up to 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 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. 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 match condition, the visual depiction exhibits three rabbits every 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).

**[PLACE FIGURE 1 HERE ]**

**[PLACE FIGURE 2 HERE ]**

### *2.3. Procedure*

These verbal and visual materials were programmed using the Super Lab software (Haxby et al., 1993). The participants’ task was to make a judgement 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 on 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 labelled as ‘yes’ when the sentence and picture matched or ‘no’ when the sentence did not match to 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 equal number of trials from both critical conditions presented in a random order.

Procedures described above have been 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.

#### *2.4.Data analysis*

Accuracy data was recorded and analysed 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 occurred haphazardly and the data were log-transformed prior to analysis. Binary accuracy data were logit transformed prior to running 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  $\times$  Quantifier  $\times$  Mismatch; however, due to ceiling performances of

the control group, we have further analysed the PWA group data with the removal of fixed effect of Group and addition of the Condition. Therefore, final model reported included the fixed effects of Mismatch (*Match vs. Mismatch*)  $\times$  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 subset with mismatch sentences as this type of error only occurs in those. Individual PWA data were analysed using the McNemar test in R (McNemar, 1947).

### **3. Results**

#### *3.1. Overall group comparison*

Table 2 demonstrates 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 has shown significant fixed-effect of Group ( $\beta = -2.31, p < .001$ ). 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 ( $\beta = 1.09, p < .001$ ), indicating that both groups performed better on the match as compared to the mismatch conditions. No other effects returned significant. As the control group showed a ceiling performance and there were no significant interaction effects for Group $\times$ Quantifier or for Group $\times$ Mismatch (see full outputs of this model in Appendix 2), we did not further analyse the control group data in relation to accuracy of responses.

**[PLACE TABLE 2 HERE]**

Regarding response times, our initial linear mixed-effects regression model has shown significant fixed effects of Group ( $\beta = 0.28, p < .001$ ), Quantifier ( $\beta = -0.09, p = .03$ ) and Mismatch ( $\beta = -0.08, p = .02$ ). It is conceivable from the output that the PWA's responses were slower than the control group, and overall responses were slower to Mismatch and Quantified conditions than their Match and Non-quantified counterparts. As no other effects returned significant, and as there were no interaction effects with Group (full outputs of this model are given in Appendix 2), we removed control group data from further analyses.

### *3.2. 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. Fixed-effects of Mismatch and anaphoric Conditions together with an interaction between Mismatch and Condition. These indicates 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 the non-quantified subjects.

**[PLACE TABLE 3 HERE]**

A set of post-hoc comparisons using Tukey tests have indicated that the PWA performed more poorly on the mismatch than the match condition with R-expression objects (i.e. *maymun* 'monkey';  $\beta = -1.55, SE = 0.32, z = -4.73, p < .001$ ) object pronoun objects (i.e., *onu* 'him';  $\beta = -1.03, SE = 0.47, z = -2.18, p = .028$ ) but not for reflexives (i.e., *kendi* 'oneself');



$\beta = -0.66$ ,  $SE = 0.38$ ,  $z = -1.72$ ,  $p = .08$ ). The PWA's performance was found to be affected in mismatch conditions than their match counterparts in both quantified ( $\beta = -1.19$ ,  $SE = 0.25$ ,  $z = -4.72$ ,  $p < .001$ ) and non-quantified sentences ( $\beta = -0.76$ ,  $SE = 0.25$ ,  $z = -3.05$ ,  $p = .002$ ). However, this difference was more pronounced in the former.

A further analysis into response times obtained from incorrect responses have shown that the sentences with mismatches evoked longer response times than matching ones in the quantified subjects (5621ms vs. 3504ms;  $\beta = -2117$ ,  $SE = 1004$ ,  $t = -2.108$ ,  $p = .036$ ). However, this difference was not significant in non-quantified subjects (4320 ms vs. 4536 ms;  $\beta = 217$ ,  $SE = 987$ ,  $t = 0.219$ ,  $p = .82$ ). This pattern is visually depicted in Figure 3B.

### *3.3. Quantifier spreading error analysis*

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

**[PLACE FIGURE 3 HERE]**

Greater number of misinterpretation errors in quantified mismatch sentences over match ones has been subject to important individual variability. In 7 individuals, within

quantified subject condition, there were significantly more errors in the mismatch than 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 individual PWA, this difference was not significant. Specifically, in mismatching r-expression conditions (i.e. when one rabbit is pointing itself while the other two pointing at the rabbit in 'Every rabbit/rabbit is pointing at the monkey') 6 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 4 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  $X^2 = \text{null}$ ).

#### **4. 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 have revealed 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 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 poorly to objects with R-expressions than 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 et al. (Submitted). When PWA made errors by clicking on an incorrect depiction of the sentence meaning, these errors evoked longer response times in 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 the PWA took long time to respond to and were less accurate in sentences with r-expressions in comparison to both reflexives and object pronouns. Therefore, 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 as well be prone to quantifier spreading errors (Grodzinsky et al., 1993; Philip & Avrutin, 1998; Saddy, 1995).

Following Grodzinsky et al. (1993), we may have expected our PWA to perform more poorly on referential/non-quantified pronouns than quantified ones. On the contrary, we found significant effects of mismatch in this truth-value judgement task, suggesting that the PWA have no pressing difficulty judging the correct depiction of sentence meaning when the picture and sentence material matched. Nonetheless, the PWA’s increased number of errors in the mismatch condition imply that the PWA’s 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 in Edwards and Varlokosta (2007), who also showed that their PWA performed poorly in mismatch conditions in both reflexives and object pronouns equally similar. Further, Edwards and Varlokosta (2007) showed that their PWA had

increased difficulty in variables with quantified antecedents than non-quantified antecedents, similar to our PWA. Our data differed from those in Edwards and Varlokosta (2007) in that they found greater number of errors in reflexive anaphors in sentences with quantified subjects. On the contrary, we found 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-Yukseket al., 2017; Knospe, 2019; Özbek & Kahraman, 2016). In essence, PWA’s greater number of misinterpretation errors in mismatch and quantified antecedents put 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 large 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 6 out of 12 PWA. The presence of quantifier spreading errors were 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 & Sauermaun, 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 et al., (1993); however, it seems to us that truth-value judgment tasks impose certain meta-linguistic domain general cognitive processes that 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 addressed this shortcoming using an eye-movement monitoring experiment with visually-depicted antecedent selection task (Arslan et al., Submitted). This study showed that in fact Turkish PWA's responses are biased towards first-mentioned entities (i.e., a form 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 points to *him*). However, at present, we are not able to contemplate whether those quantifier spreading errors extend to over-exhaustive search errors reported in Sekerina and Sauermaun (2015), such as, 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 is the lack of visual attention and the reduction of other relevant cognitive resources such as visual and verbal working memory. We are only able to contemplate on this without further individual measures of working memory

and attention from our PWA. It is worthwhile that a future study examines quantifier spreading errors in aphasia with greater details of cognitive profiles of participants.

In conclusion, 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 pronoun and reflexives than those with r-expressions. Therefore, a clear conclusion we can arrive 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 impairments in resolving pronominal/anaphoric elements, which seems to have a similar impact on both pronouns and reflexive variables.

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**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.** Statistical outputs from overall models reported under subsection ‘3.1. overall group comparison’

	<i>Accuracy</i>				<i>Response times</i>			
	$\beta$	SE	$z$	$p$	$\beta$	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 $\times$ Quantifier	-0.08	0.19	-0.43	.66	-0.04	0.02	-1.76	.07
Group $\times$ Mismatch	-0.51	0.19	-2.64	.008	0.02	0.02	0.93	.34
Quantifier $\times$ Mismatch	-0.19	0.21	-0.93	.34	-0.01	0.03	-0.48	.63
Group $\times$ Quantifier $\times$ Mismatch	0.07	0.19	0.38	.70	-0.01	0.02	-0.58	.55

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

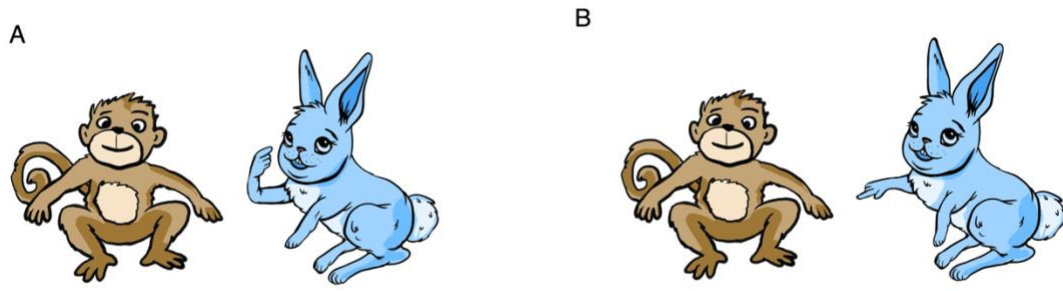
<b>Participant</b>	<b>Age</b>	<b>Gender</b>	<b>Education (years)</b>	<b>MPO</b>
01IY	19	M	11	20
02AI	49	M	8	20
03ŞK	52	F	13	25
04AB	58	M	5	23
05HB	59	F	8	6
06MY	59	M	5	28
07NT	60	M	5	9
08MÇ	70	M	5	27
09VG	71	M	5	4
10ZI	73	M	11	19
11RG	78	M	5	9
12MT	62	M	11	13

**Table 2.** Mean proportions of accurate responses and response times in milliseconds per condition to the end-of-trial truth-value judgement task. Standard deviations are shown in parentheses.

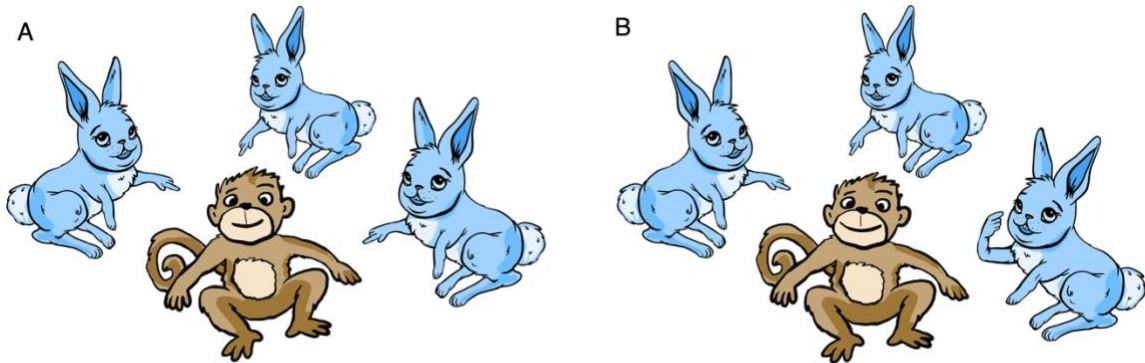
	Non-quantified subjects		Quantified subjects	
	Match	Mismatch	Match	Mismatch
<b><i>Accuracy</i></b>				
Aphasia $\bar{x}$	0.73 (0.44)	0.55 (0.49)	0.73 (0.44)	0.45 (0.50)
Control $\bar{x}$	0.99 (0.07)	0.93 (0.24)	0.99 (0.07)	0.86 (0.34)
<b><i>Response times</i></b>				
Aphasia $\bar{x}$	3441 (3913)	3866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

**Table 3.** Statistical outputs from generalized mixed-effects regression model on PWA’s end-of-trial response data.

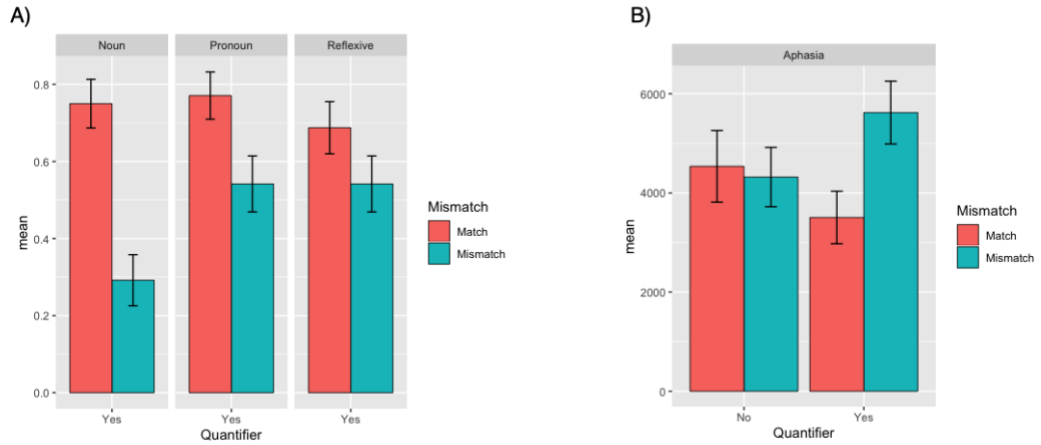
	<i>Accuracy</i>				<i>Response times</i>			
	$\beta$	SE	$z$	$p$	$\beta$	SE	$t$	$p$
Intercept	0.23	0.23	1.01	.31	7.85	0.22	35.46	<.001
Mismatch	0.78	0.16	4.83	<.001	-0.12	0.06	-1.93	.05
Condition (Pronoun)	0.52	0.22	2.30	.021	-0.01	0.09	-0.12	.90
Condition (Reflexive)	0.45	0.22	2.03	.042	-0.14	0.09	-1.58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



**Figure 1.** An example visual depiction for (a) reflexive: ‘Rabbit is pointing at itself’ and (b) object pronoun condition: ‘Rabbit is pointing at him/it’.



**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’.



**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).