1. **Introduction**

In many languages, a verb agrees with the subject in person, number, gender, case, animacy, and so on. This is called subject-verb agreement (e.g., Corbett 2006). Previous studies have shown that speakers incrementally facilitate the subject-verb agreement in online sentence processing. However, most of the evidence for incremental processing of the subject-verb agreement is provided from the European languages, such as Dutch, English, French, German, Italian, and Spanish (e.g., MacWhinney et al. 1984; Gibson et al. 1996; Nicol et al. 1997; Pearlmuter et al. 1999; Deevy 2000; Hartsuiker et al. 2003; Severen et al. 2008; Wagers et al. 2009; Mancini et al. 2011; Franck et al. 2015). In Asian languages, previous studies could have not paid much attention to this issue because languages such as Japanese and Korean do not have rich syntactic subject-verb agreement systems in terms of number, as in the case of European languages. Unlike Japanese and Korean, Turkish, as a major subject–object–verb (SOV) type Asian language, has a very rich subject-verb agreement system. This enables us to examine how native speakers of an SOV language process the subject-verb agreement in Asian languages. In the current study, to explore the nature of online sentence processing of subject-verb agreement in Asian languages, we conducted a self-paced reading experiment in Turkish. The results of this study show that native speakers of Turkish use the subject-verb (dis)agreement information very effectively to build an argument structure of a sentence, as in the case of many European languages.

The organization of this paper is as follows: In the next section, we briefly review previous studies on online processing of subject-verb agreement. Then, we highlight the importance of Turkish and briefly explain the limited number of experimental studies in Turkish. Section three describes the details of our self-paced reading experiment and reports the results. Section four addresses how the disagreement between the subject and verb causes a processing cost at the initial part of a sentence, but facilitates the later parts of sentence processing in Turkish. Finally, section five concludes with how the subject-verb agreement is also processed incrementally in SOV languages.

2. **Previous studies**

In English, when a subject is a singular noun, it takes the singular form of the verb,
and when it is a plural noun, it takes the plural form of the verb, as shown in (1).

(1)  
a. A student is sleeping.  
b. Students are sleeping.  
c. * A student are sleeping.  
d. * Students is sleeping.

If a singular subject takes the plural form of the verb, or vice versa, the sentence becomes ungrammatical, as in (1c) and (1d). Many languages have this kind of agreement system. From the point of view of human sentence processing, it is assumed the comprehenders, when they hear or read a sentence, need to figure out which items must agree and which do not. This would require computing the syntactic relations among the phrases. Regarding the processing of subject-verb agreement, some researchers argue that comprehenders strongly rely on the (dis)agreement information (e.g., MacWhinney et al. 1984; Peurlmutter et al. 1999; Deely 2000). On the other hand, other researchers argue that the comprehenders may ignore the agreement information in the sentence processing (e.g., Nicol et al. 1997; Ferrellia, 2003; Severens et al. 2008; Wagers et al. 2009).

For example, Nicol et al. (1997) investigated the processing of subject-verb agreement in an online grammaticality judgment task. They manipulated the first and the second nouns in terms of number, as shown below in (2).

(2)  
a. SS: The author of the speech was subsequently well rewarded.  
b. SP: The author of the speeches was subsequently well rewarded.  
c. PP: The authors of the speeches were subsequently well rewarded.  
d. PS: The authors of the speech were subsequently well rewarded.

In the SS condition (2a), a singular noun (speech) follows a singular subject (author). In the SP condition (2b), a plural noun follows a singular subject. In the PP condition (2c), a plural subject is followed by a plural noun, and a singular noun follows a plural subject in the PS condition (2b). Nicol et al. presented these types of sentences to the participants and asked them to judge the grammaticality of the test sentences. The results showed that the response times of the SS condition were statistically faster than the SP condition. On the other hand, there was no statistical difference between the PP and PS conditions. Based on these results, Nicol et al. argued that there was a mismatch effect only when the subject noun is singular, and due to the mismatch (disagreement) between the nouns, the processing cost of the sentences increases. On the other hand, from the results of PP and PS conditions, Nicol et al. argued that there was no mismatch effect and concluded that comprehenders may ignore the agreement information.

Unlike Nicol et al. (1997), Peurlmutter et al. (1999) manipulated the match between the first and second noun, and the grammaticality of the test sentences, as shown in the examples below in (3). In (3a), singular nouns match, and the sentence is grammatical. In (3b), the sentence is grammatical, but the first and second nouns
do not match. In (3c), the first and second nouns match, but the sentence is ungrammatical. In (3d), the sentence is ungrammatical, and the first and second nouns do not match in terms of number.

(3) a. The key to the cabinet was rusty from many years.
b. The key to the cabinets was rusty from many years.
c. *The key to the cabinet were rusty from many years.
d. *The key to the cabinets were rusty from many years.

Peurlmutter et al. conducted a series of self-paced reading and eye-tracking experiments. In these experiments, they compared the reading times of the test sentences illustrated above. The results showed that the verbs were read faster in the match conditions (3a and 3c), irrespective of the grammaticality of the sentences. Ungrammatical sentences (3c and 3d) were read slower after the verbs. Peurlmutter et al. pointed out that the mismatch effect of agreement is observed before the grammaticality effect. Based on this finding, Peurmutte et al. concluded that comprehenders strongly rely on the (dis)agreement information in online sentence processing.

These studies were also replicated in other European languages, like Dutch, French and Spanish. However, previous studies pose some problems. First, there is no clear consensus on the results. The studies above were also replicated in other European languages, such as Dutch, French, and Spanish. However, previous studies pose some problems. First, there is no clear consensus on the results. While some researchers argue that the comprehenders effectively use the (dis)agreement information (MacWhinney et al. 1984; Peurlmutter et al. 1999; Deely 2000), other researchers argue against the effective use of (dis)agreement information (Nicol et al. 1997; Ferreiara 2003, Severens et al. 2008; Wagers et al. 2009). Second, researchers such as Nicol et al. (1997) and Pearlmutter et al. (1999) refer to “subject-verb agreement” in their articles, but what they mainly investigated was the number agreement between the nouns, rather than a noun and a verb. In other words, the subject-verb agreement was not tested purely in some studies. Finally, and more critically, some studies used ungrammatical sentences to examine the online processing of subject-verb agreement (see 3c and 3d). The use of ungrammatical test sentences may confound the results because either subject-verb disagreement or ungrammaticality may affect the results. Thus, it is difficult to rule out the impact of both factors on sentence processing. In this regard, Turkish provides a very important and interesting test case to examine the online processing of subject-verb agreement, as explained below.

Turkish is an SOV language with very rich subject-verb agreement in terms of number, as shown in (4) (e.g., Underhill 1976; Kornfilt 1997; Göksel & Kerslake 2005).

(4) a. *Ben gel-di-m
I come-PST-ISG1
‘I came.’

b.  

\[ \text{Sen} \quad \text{gel-di-n} \]  
\[ \text{You} \quad \text{come-PST-2SG} \]  
\[ \text{‘You came.’} \]

c.  

\[ \text{O} \quad \text{gel-di} \]  
\[ \text{S/he} \quad \text{come-PST-3SG} \]  
\[ \text{‘S/he came.’} \]

d.  

\[ \text{Biz} \quad \text{gel-di-k} \]  
\[ \text{We} \quad \text{come-PST-IPL} \]  
\[ \text{‘We came.’} \]

e.  

\[ \text{Siz} \quad \text{gel-di-niz} \]  
\[ \text{You} \quad \text{come-PST-2PL} \]  
\[ \text{‘You came.’} \]

f.  

\[ \text{Onlar} \quad \text{gel-di-(ler)} \]  
\[ \text{They} \quad \text{come-PST-(3PL)} \]  
\[ \text{‘They came.’} \]

When the subject is a first-person singular noun, the verb obligatorily takes the first-person singular noun suffix \textit{m}, as in (4a). When the subject is a second-person singular noun, the verb takes the second-person singular noun suffix \textit{n}, as in (4b). In the case of the third-person singular noun, there is no overt person suffix in Turkish (see 4c). As for the plural nouns, the verb also takes different person suffixes based on the subject. If a verb takes a different person suffix than the subject, then the sentence becomes ungrammatical. Only in the case of third-person plural noun, the use of person suffixes \textit{ler/lar} is optional. In other words, third-person plural nouns can optionally be used with either the plural or singular form of the verb. (e.g., Underhill 1976; Kornfilt 1997; Göksel & Kerslake 2005).

This optionality in the use of third-person plural person suffixes is very important and allows us to exclude the grammaticality issue, which was impossible in previous studies. For example, both \textit{onlar geldi} and \textit{onlar geldiler} in (4f) are grammatical in Turkish. Due to the optional use of the third-person plural suffix, we can avoid using ungrammatical test sentences in Turkish and exclude one critical confounding factor in the sentence processing. Furthermore, we can also interestingly examine a fundamental problem in the sentence processing: whether the existence of subject-verb agreement itself is an obstacle or a facilitator in online sentence processing. Moreover, other major SOV languages, such as Japanese and Korean, do not have a rich subject-verb agreement in terms of number. Therefore, it is difficult to test the processing of this phenomena in SOV languages. Turkish, as a major SOV language, allows us to more deeply understand the nature of subject-verb agreement in
typologically different languages.

In Turkish, a few studies investigated the subject-verb agreement through experimental methodologies (e.g., Aygüneş 2013; Bamyacı et al. 2014). For example, Bamyacı et al. (2014), using an offline questionnaire task, investigated the interaction between the animacy and singularity/plurality of the verb. Bamyacı et al. used human subjects, such as *teacher*; animal subjects, such as *bird*; quasi-animate subjects, such as *plane*; and inanimate subjects, such as *chair*. Then they manipulated the singularity and plurality of the verb. Their results showed that there is an interaction between the animacy and singularity/plurality of the verb. When the subject is a human or animal, the use of either a singular or plural verb is allowed, whereas the plural verb is not allowed when the subject is inanimate or quasi-animate.

Aygüneş (2013) extensively investigated the relationship between the subject-verb agreement and brain responses through event-related potentials (ERPs) in his dissertation. In his experiments, Aygüneş used test sentences, as shown below in (5).

\[
\begin{align*}
(5) & \quad a. & \text{Ben yemeği-i yap-tı-m} \\
& & \text{I meal-ACC cook-PST-1SG} \\
& & \text{’I cooked the meal.’} \\
\hline
& b. & \ast \text{Ben yemeği-i yap-tı-n} \\
& & \text{I meal-ACC cook-PST-2SG} \\
& c. & \ast \text{Ben yemeği-i yap-tı-k} \\
& & \text{I meal-ACC cook-PST-1PL} \\
& & \text{’I cooked the meal.’} \\
& d. & \ast \text{Ben yemeği-i yap-tı-nız} \\
& & \text{I meal-ACC cook-PST-2PL}
\end{align*}
\]

Among these sentences, only (5a) is grammatical. Other sentences are ungrammatical due to a disagreement between the subject and the verb. Aygüneş compared the brain responses between the grammatical and ungrammatical sentences, and found a difference. In the case of ungrammatical sentences, an N400 component was observed. Aygüneş argued that this component may reflect the processing difficulty of subject-verb disagreement and concluded that the grammatical and ungrammatical sentences are processed differently in Turkish.

The above empirical studies shed an important light on some dimensions of the subject-verb agreement phenomena in Turkish. However, there is still a need for empirical studies that investigate the processing of subject-verb agreement from divergent dimensions in Turkish. In the current study, unlike previous studies, we mainly focused on the processing of grammatical test sentences to answer the research questions below.
Research Question 1: Do Turkish native speakers effectively use information obtained from subject-verb (dis)agreement in online sentence processing?

Research Question 2: Is the existence of subject-verb agreement itself an obstacle or a facilitator in the processing of a language?

3. Present study
To answer the research questions above, we conducted a self-paced reading experiment. To do this, we prepared test sentences with three conditions, as shown below in (6).

3.1 Materials

(6)  
(a) Match subject
Komutan geç kalktı diye asker-ler çok kızdı  
Commander late got up that soldier-3PL very got angry  
‘The soldiers got very angry because the commander got up late.’

(b) Match non-subject
Komutan geç kalktı diye asker-ler-e çok kızdı  
Commander late got up that soldier-3PL-DAT very got angry  
‘The commander got very angry because the soldiers got up late.’

(c) Mismatch non-subject
Komutan geç kalktı-ler diye asker-ler-e çok kızdı  
Commander late got up-3PL that soldier-3PL-DAT very got angry  
‘The commander got very angry because the soldiers got up late.’

In the Match subject condition (6a), the sentence initial noun komutan is the subject of the embedded verb kalktı and matches the embedded verb in terms of number. In the Match non-subject condition (6b), the initial noun matches the embedded verb in terms of number, but it is the subject of the matrix verb kızdı, not the embedded verb. In the Mismatch non-subject condition (6c), the sentence initial noun does not match the embedded verb with third-person plural form, and it is the subject of the matrix verb. The Match non-subject and the Mismatch non-subject conditions have the same meaning.

3.2 Predictions
If the participants are sensitive to subject-verb agreement in Turkish, a mismatch effect would be observed at the embedded verb, and the Mismatch non-subject (6c) condition would be read slower than the Match subject (6a) and Match non-subject (6b) conditions at the embedded verb. If the participants neglect the subject-verb agreement in online sentence processing, there would be no significant difference at the embedded verb among the three conditions. In addition, if a mismatch effect facilitates the processing of later parts of the sentence, the Mismatch non-subject
condition would be read faster than the Match non-subject condition because the mismatch signals that the sentence initial noun cannot be the subject of the embedded verb, and hence, there should be another subject for that verb. On the other hand, if the disagreement between the subject and the verb always causes a processing cost, the later part of the sentence should be read slower in the Mismatch non-subject condition than in the Match subject and Match non-subject conditions.

3.3 Procedure and participants
To test these predictions, we prepared 24 sets of three conditions. Thus, we had 72 test sentences in total. These sentences were followed by a context in relation with another experimental study. In addition to test sentences, 48 filler sentences were prepared to hide the purpose of the study from the participants during the experiment session. Before conducting the experiment, the semantic/pragmatic plausibility of the events described in the test sentences were confirmed in a norming study. Hence, semantically and/or pragmatically unbiased test sentences were used in the experiment.

The test sentences were divided into three lists using a Latin square design. Thirty-five Turkish native speakers participated in the experiment. They were all graduate or undergraduate students at Çanakkale Onsekiz Mart University in Turkey (mean age: 23.6, SD = 3.84). Sentences were presented on a laptop computer with Linger 2.94 (developed by Douglas Rohde) by a non-cumulative word-by-word self-paced reading task. To guarantee the sentences were read carefully and comprehended appropriately, yes–no questions were asked after presenting each sentence, and prior to the experiment, a practice session was conducted with six sentences.

3.4 Results
Prior to statistical analyses on the reading times, the accuracy rates of the three conditions were compared. In the Match subject condition, the participants correctly answered 91% of the questions. In the Match non-subject condition, the accuracy rate was 92%, and in the Mismatch non-subject condition, it was 93%. The statistical analysis based on linear mixed effects (LME) was not significant ($\beta = -0.03$, SE = .01, $t = -0.13$). This shows that the participants accurately comprehended the test sentences, and there was no significant difference among the three conditions. Before conducting statistical analysis on the reading times, we excluded data points shorter than 150 milliseconds (ms) and longer than 4000 ms from the analysis. This affected 0.5% of the overall data. After trimming outliers, we replaced any data point more than 3 standard deviations (SD) from the mean reading times with boundary values. This approximately affected 2% of the remaining data. The mean reading times of each word in the three conditions are shown in Figure 1 below.

For the statistical analysis, an LME was employed. The reading times were assigned as a dependent variable, the conditions as the fixed effects, and the
participants and the items as the random effects in the model (Baayen, 2008). The analyses were conducted on the maximal model (Barr et al., 2013). In the sentence initial position, there was no statistical difference ($\beta = -18.96$, SE = 29.16, $t = -0.65$). At the second word of the test sentences, the statistical analysis showed no significant difference ($\beta = 38.26$, SE = 23.11, $t = 1.66$). At the embedded verb position, which is one of the critical regions, there was a significant difference among the three conditions. ($\beta = 101.1$, SE = 39.45, $t = 2.56$). Pairwise comparisons showed that the embedded verb in the Mismatch non-subject condition was read slower than the Match subject ($t = 2.14$) and the Mismatch subject ($t = 2.52$) conditions. Between the Match subject and Mismatch subject conditions there was no significant difference.

One may assume that the difference observed at the embedded verb position would be due to the word length (character number) of the plural verb compared to the singular verbs. In order to test this possibility, we conducted additional analysis on the residual reading times, which takes the character number into consideration. The tendency was the same. Therefore, it can be said that the difference observed at the embedded verb position is not due to the word length. At the following word, where diye always appeared, there was no significant difference among the three conditions ($\beta = 42.96$, SE = 25.58, $t = 1.68$). At the fifth region, where a dative or nominative noun (i.e., askerler/e) appears, there was no significant difference ($\beta = 43.74$, SE = 36.19, $t = 1.21$). At the adverb, which appeared in front of the matrix verb, there was also no statistical difference ($\beta = 42.96$, SE = 25.58, $t = 1.68$). At the sentence final matrix verb position, there was a significant difference among the three conditions ($\beta = 309.09$, SE = 127.18, $t = 2.43$). Pairwise comparisons showed that the matrix verb in the Match non-subject condition was read slower than the
Match subject \((t = 2.67)\) and the Mismatch non-subject \((t = 3.10)\) conditions.

4. Discussion

The results show that the Mismatch non-subject condition was read slower than the Match subject and the Match non-subject conditions at the embedded verb. This tendency changed at the matrix verb, and the Match non-subject condition was read slower than other two conditions. In other regions, there was no significant difference among the three conditions. These results suggest that the disagreement between the subject and verb influenced the sentence processing in Turkish.

As for the embedded verb, we predicted that, if the participants are sensitive to subject-verb agreement in Turkish, a mismatch effect would be observed, and the Mismatch non-subject condition would be read slower than the Match subject and Match non-subject conditions. On the other hand, if the participants neglect the subject-verb agreement, there would be no significant difference among the three conditions. The results showed that the plural verbs were read slower than singular verbs. As pointed out in the Results section, this difference is not due to the word length, which supports the former prediction above. Therefore, we can say that the disagreement between the subject and the verb caused a processing cost in Turkish. This is probably due to a surprisal effect because the participants were not expecting a plural verb after a singular subject (Levy 2008). After encountering a plural verb, the participants might have changed their initial parsing preferences and then started to build a new argument structure. To do this, they need to posit a plural noun elsewhere in sentence and assign the sentence initial noun phrase (NP) as the argument of another verb. Computing these operations is costly compared to the Match subject and Match non-subject conditions because there is no need to change initial parsing preferences at the embedded verb in these conditions. This result is in line with the previous studies in European languages, such as MacWhinney et al. (1984), Peurlmutter et al. (1999) and Deely (2000). Furthermore, this result also supports the previous findings in Turkish. Ayguneş (2013) reported that subject-verb disagreement elicits an N400 component in Turkish. The present reading time data also showed that the subject-verb disagreement causes a longer reading time, which reflects the processing cost. Taken together, these suggest that Turkish native speakers are sensitive to the subject-verb agreement, and they do not ignore the information obtained from disagreement in online sentence processing.

One natural question is then whether a subject-verb disagreement is always costly or whether it helps comprehenders to build the argument structure and interpret the meaning of the sentences. As for the later parts of the test sentences, we predicted that, if a mismatch effect facilitates the sentence processing, the Mismatch non-subject condition would be read faster than the Match non-subject condition because the subject-verb disagreement signals that the sentence initial NP cannot be the subject of the embedded verb; hence, another plural NP should be the subject of that verb. On the other hand, if the mismatch effect always causes a processing cost, the later part of the sentences should be read slower in the Mismatch non-subject condition compared to the Match subject and Match non-subject conditions. The
results showed that the matrix verbs in the Match non-subject condition were read slower than the Mismatch non-subject and Match subject conditions. This result is in line with our former prediction. In other words, this finding suggests that the disagreement between the subject and the verb facilitated the processing of later parts of the sentences. As we argued above, when the comprehenders realize that the singular NP cannot be the argument of the plural verb at the embedded verb position, they would have changed their initial parsing preferences and posited a plural NP. Then they would have assigned the sentence initial NP as the subject of the matrix verb. In the Match non-subject condition, the comprehenders do not need to change their initial parsing preferences at the embedded verb, but when they encounter plural dative NP (i.e., askerlere) and/or the matrix verb, they would have changed their initial interpretations and assigned dative NP as the argument of the embedded verb and assigned the sentence initial NP as the argument of the matrix verb as well. Such computation of the syntactic relations among the phrases might have caused a processing cost at the matrix verb position. It is generally accepted that the mismatch effects are costly in the sentence processing. However, some studies showed that the mismatch effects may facilitate the sentence processing. The current study also shows that, to some extent, a mismatch effect may facilitate the sentence processing (e.g., Miyamoto & Takahashi 2002; Wagers et al. 2009).

Overall, the results at the embedded and matrix verb positions show that the disagreement between the subject and the verb causes a processing cost at the initial part of the sentences, but this facilitates the processing of later parts of the sentences. Taken together, the current findings suggest that Turkish native speakers are sensitive to the subject-verb (dis)agreement and use this information very effectively to incrementally build an argument structure of a sentence, as in the case of European languages.

5. Conclusions

In the Introduction, we pointed out that the previous studies in Asian languages could have not paid much attention to the online processing of subject-verb agreement because of the lack of number agreement. In addition, we also argued that many studies used ungrammatical sentences and tested the number agreement between the nouns rather than a subject-verb agreement. Then, we pointed out that Turkish, as an SOV type Asian language, provides a very important test case to explore the online processing of subject-verb agreement due to optional use of a third-person plural suffix attached to the verb. Based on these motivations, we set up two research questions: (a) Do Turkish native speakers effectively use information obtained from subject-verb (dis)agreement in online sentence processing? (b) Is the existence of subject-verb agreement itself an obstacle or a facilitator in the processing of a language?

As an answer to the first question, the results of the self-paced reading experiment suggest that Turkish native speakers are sensitive to the subject-verb (dis)agreement and effectively use the information obtained from a disagreement between the subject and the verb. As for the answer to the second question, the
results suggest that the subject-verb disagreement causes a processing cost at the position where a mismatch occurs, but this facilitates the processing of later parts of the sentence. Therefore, it cannot simply be said that the subject-verb disagreement is always an obstacle in online sentence processing. Overall, eliminating the ungrammaticality issue, the current study provides new data and evidence for the online processing of the subject-verb agreement and suggests that the subject-verb agreement is processed incrementally in SOV type Asian languages, as in the case of European languages.

In the current study, we only focused on the processing of third-person agreement in Turkish. The investigation of the first- and second-person (dis)agreement and animacy effects is left for future studies.

Notes
*
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1 The following abbreviations have been used in the glosses: ACC: Accusative; DAT: Dative; PST: Past; 1SG: First person singular; 2SG: Second person singular; 3SG: Third person singular; 1PL: First person plural; 2PL: Second person plural; 3PL: Third person plural.
2 This is not to say that there is no subject-verb agreement in Japanese and Korean. These languages also have the subject-verb agreement, but there is no distinction between singular/plural verb morphology as in Turkish and European languages, and the subject-verb agreement phenomenon has more pragmatic characteristics rather than syntactic characteristics (Kwon & Stuart 2016; Ivana & Sakai 2007).
3 The free software can be downloaded from http://tedlab.mit.edu/%7Edr/Linger/
4 In LME, the p value is not generated automatically. When t value is higher than 2, it is assumed that the difference is significant (Baayen, 2008).

References


