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Facilitatory and inhibitory effects of grammatical agreement: Evidence from readers' eye fixation patterns

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Abstract

The study examined how grammatical agreement affects reading in Finnish. Readers' eye fixation patterns were recorded when they read one of three alternative versions of the same sentences, where the critical difference was the type of preceding word of the target nouns. The preceding word was (a) an agreeing modifier (mainioksi orkesteriksi = 'for an excellent orchestra'), (b) a non-agreeing modifier that was grammatical, unambiguous and synonymous to the agreeing modifier (kelpo orkesteriksi = 'for an excellent orchestra'), or (c) a baseline condition without a modifier (orkesteriksi = 'for an orchestra'). Two different types of agreement were used, a modifier-head agreement and a possessive agreement. The results showed that the agreeing modifiers facilitate and the non-agreeing modifiers inhibit the reading of the target nouns compared to the neutral baseline condition. These effects appeared in the second-pass reading. The pattern was similar between the two agreement structures.

Keywords: Grammatical agreement; Sentence comprehension; Eye movements

1. Introduction

The present study examines the effects of grammatical agreement in reading. By agreement we refer to the linguistic phenomenon of how word forms are grammatically dependent on each other (e.g., the boy walks vs. the boys walk). Agreement may take many forms, such as subject–verb agreement, modifier-head agreement, possessive-head agreement, verb–object agreement, gender agreement, or number agreement.

The effects of grammatical agreement on language processing have been studied by several methods that could be divided into two major groups: *reaction time methods and on-line methods*. The former include methods like naming (Guillelmon & Grosjean, 2001), and lexical decision (Gurjanov, Lukatela, Moscovljević, Savić, & Turvey, 1985; Lukatela, Kostić, Todorović, Carello, & Turvey, 1987; Schriefers, Friederici, & Rose, 1998), the latter include eye tracking studies (Pearlmutter, Garnsey, & Bock, 1999) and event related brain potentials (ERP) studies (Gunter, Friederici, & Schriefvers, 2000; Osterhout & Mobley, 1995). The point Gunter et al. (2000) and Pearlmutter et al. (1999) stress is that by using reaction time methods important information about the time course of agreement processing remains opaque. On-line methods, on the other hand, can increase our knowledge about what happens during the processing the agreement structures and not only about the end result (whether it causes facilitation or inhibition).

Probably the most common arrangement in previous studies has been to compare normal agreement structures to grammatically illegal structures that somehow violate *modifier-head* (Gurjanov et al., 1985; Hyönä & Lindeman, 1994), *possessive-head* (Lukatela et al., 1987), *subject–verb* (Osterhout & Mobley, 1995; Pearlmutter et al., 1999), *verb–object* (MacWhinney & Pleh, 1997; Schriefers et al., 1998), *gender* (Gunter et al., 2000), or *number* (Bock, Eberhard, Cutting, Meyer, & Schriefers, 2001) agreement. However, as Pearlmutter et al. (1999)

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point out, it is difficult to make inferences about normal language processing by using materials that are not clearly grammatical.

The results of most previous studies demonstrate clear agreement effects in processing. For instance, when a head noun is preceded by an agreeing modifier, the head is easier to process compared to a situation where the head is preceded by an illegal, non-agreeing modifier. However, it is not clear from these studies to what extent the phenomenon is facilitative, inhibitory, or both. Without a baseline it is not possible to determine whether grammatical agreement facilitates processing, or whether illegal structures cause interference in processing.

The present study departs from most previous ones in four important ways. First, we included a baseline condition, against which agreeing and non-agreeing structures may be compared. Second, the non-agreeing structures were grammatically legal. Third, two (instead of the usual one) very different agreement types of Finnish were used: modifier-head agreement (MHA) and possessive agreement (PA). Fourth, we studied the phenomenon during normal, continuous reading and used readers' eye-tracking to tap the time course of agreement effects.

Finnish is a very suitable language for examining effects of agreement for several reasons. First, Finnish has exceptionally strict agreement structures: a modifier like *mainioi**ksi*** agrees with the form of its head word *taloi**ksi*** both in case (ksi) and in number (i = plural), in for instance *mainioi**ksi** taloi**ksi*** '***for** excellent houses*', and a modifier always precedes its head (for more, see e.g., Karlsson, 1977). The case ending is translative (ksi) and it denotes concrete or abstract transition or transmutation.

Second, the agreement relation in possessive structures in Finnish is very different. For instance, the first person plural possessive pronoun '**meidän**' = 'our' accompanied with a possessive clitic '**-mme**' is attached to the head noun (e.g., ***meidän** orkesteri**mme** = '**our** orchestra*') (for more, see Nelson, 1998:185–228). Therefore it is possible to study grammatical agreement in combinations, in which the agreement is either between the modifier and the head noun (*mainio**ksi** orkesteri**ksi** = '**for** an excellent orchestra*') or between the possessive pronoun and the head (e.g., ***meidän** orkesterimme = '**our** orchestra*') The suffix of the declinable modifier in MHA unambiguously constrains the case ending of the head, whereas information about the ending of the head noun in possessive structures comes from a determiner-like possessive pronoun.[1] The suffix is syntactically determined in MHA, whereas the meaning motivates the possessive clitic in PA. Moreover, structures also differ functionally, MHA expresses cohesion between the members of a noun phrase, but PA is somewhat comparable to a subject-predicate agreement (e.g., the boy walk**s**).

Third, there exist about 10 indeclinable modifiers in Finnish that always appear non-inflected and thus do not constrain the grammatical status of the head (e.g., kelpo orkesteri**ksi** = '**for** an excellent orchestra'). Moreover, the possessive modifier 'oma' combines with any of the existing possessive clitics (e.g., **oma** orkesterimme = **our** orchestra vs. **oma** orkesterinne = **your** orchestra). We call these types of modifiers non-agreeing modifiers. Thus, it is possible to compare syntactically and semantically synonymous clause structures, whose only difference is the modifier type (i.e., non-agreeing vs. agreeing).

A no-modifier condition was also included in the experiment to serve as the baseline. Although the no-modifier condition is not totally synonymous to the modifier conditions, its role is important: it allows us to determine whether the presence of an agreeing modifier facilitates the processing of the head noun, or whether the lack of agreement makes non-agreeing structures more demanding to process.

The following hypotheses were entertained. (1) If agreement facilitates processing, the noun preceded by an agreeing modifier should be easier to process than *both* the noun preceded by an non-agreeing modifier and the noun preceded by a word that is not a modifier (a baseline). (2) If the lack of agreement in the non-agreeing modifier condition inhibits processing, then the noun preceded by a non-agreeing modifier should be more difficult to process than the noun in the baseline condition.

2. Method

2.1. Participants

Forty-two native speakers of Finnish (mainly students) participated in the experiment. The age of participants varied between 19 and 34.

2.2. Apparatus

Eye movements were collected by the EYELINK eyetracker manufactured by SR Research (Canada). The eyetracker is an infrared video-based tracking system combined with hyperacuity image processing. There are two cameras mounted on a headband (one for each eye) including two infrared LEDs for illuminating each eye. The headband weighs 450 g in total. The cameras sample pupil location and pupil size at the rate of 250 Hz. Registration can be done either monocularly or binocularly. We performed it for the selected eye

[1] For the sake of simplicity, the determiners will also be called modifiers.

Table 1
Differences between the chosen agreement structures

Agreement type:	modifier-head agreement	possessive agreement
Suffix type:	case ending (-ksi)	possessive clitic (-mme)
Role of the target:	argument or adjunct in the VP	subject in the subject NP
Target position:	at the end of the clause	in the beginning of the clause

Note. VP, verb phrase; NP, nominal phrase.

(usually the right eye) by placing the camera and the two infrared lights 4–6 cm away from the eye. The resolution of eye position is 15 s of arc and the spatial accuracy better than 0.5 degree. Head position with respect to the computer screen is tracked with the help of a head-tracking camera mounted on the centre of the headband at the level of the forehead. Four LEDs are attached to the corners of the computer screen, which are viewed by the head-tracking camera, once the participant sits directly facing the screen. Possible head motion is detected as movements of the four LEDs and is compensated for on-line from the eye position records. The compensation is better than 1 degree over the acceptable range of head motion.

2.3. Materials

Twenty-four Finnish nouns in translative case (**-ksi**) and 24 Finnish nouns with the possessive first person plural clitic (**-mme**) were used as targets in the experiment. In translatives the same case ending is repeated both in the modifier and in the head. On the other hand, the possessive pronoun determines the type of the possessive clitic attached to the headword without echoing an identical ending in the head. The target nouns were embedded in sentences, in which they were preceded either by (a) a non-agreeing modifier, (b) an agreeing modifier, or (c) without a modifier.

To create the non-agreeing condition for the MHA structure, we made use of a few indeclinable modifiers that exist in Finnish (see *a* below); for the agreeing condition, a synonymous adjective was chosen (see *b*). An example sentence triplet is presented below:

(*a*)...johtaja kehui vierailijoita kelpo orkesteri**ksi**, jonka...
(*b*)...johtaja kehui vierailijoita mainio**ksi** orkesteri**ksi**, jonka ...
(*c*)...johtaja kehui vierailijoita orkesteri**ksi**, jonka...
'...the manager praised the visitors **for** an (excellent) orchestra, whose ...'

The possessive pronoun 'meidän' (our) was used as the agreeing modifier in the PA structure (see *b*), while the possessive modifier 'oma' was used in the non-agreeing condition (see *a*). The difference is that the former requires the first person plural possessive clitic (-mme) in the head, whereas the latter does not necessitate any clitic. An example sentence triplet is presented below:

(*a*)...että **oma** kansantulomme ei ole...
(*b*)...että **meidÄn** kansantulomme ei ole...
(*c*)...että kansantulomme ei ole...
'...that **our** national income is not ...'

Each participant read one version of the sentence triplets. Thus, participants read 48 target sentences that were mixed with 104 filler sentences containing variable sentence structures. Three separate blocks of sentences were created that were counterbalanced across participants. The target word never appeared in the beginning nor at the end of a text line.

Table 1 clarifies the differences in the chosen agreement structures.

The meaning of the preceding modifiers was similar in the matched pairs according to a computerised dictionary of Finnish (CD-Perussanakirja, 1997). Moreover, according to the TS-corpus,[2] neither the chosen target words (Laine & Virtanen, 1999) nor the chosen modifier-head combinations (Virtanen & Pajunen, 2000) were very frequent.

2.4. Procedure

Prior to the experiment, the eyetracker was calibrated using a nine-point calibration grid that extended over the entire computer screen. Each target sentence was presented left-justified one at the time roughly on the centre of the monitor. Prior to each sentence, the calibration was checked by presenting a fixation point on the centre–left corner of the screen; if needed, the calibration was automatically corrected.

Participants were instructed to read sentences for comprehension at their own pace. They were further told that periodically they would be asked to paraphrase the last sentence they have just read to make sure that they attended to what they read. However, it was emphasised that the task was to comprehend not to memorise the sentences. Participants were asked to paraphrase the sentence approximately after every ten sentences. The experimental session lasted maximum of 45 min.

3. Results

A $2 \times 3 \times 3$ [(agreement type: MHA vs. PA) $\times$ (modifier type: non-agreeing, agreeing vs. no modifier) $\times$

[2] The TS-corpus is a 22.7 million word token newspaper corpus.

Table 2
Mean fixation times and their standard deviations (in parentheses) for the target word as a function of agreement (MHA vs. PA) and modifier type

Modifier type			
Fixation measure	Non-agreeing modifier	Agreeing modifier	No modifier
MHA and PA structures combined			
Gaze duration	314 (75)	322 (74)	337 (68)
Regression time in	66 (45)	40 (43)	53 (40)
Regression time out	72 (43)	43 (44)	58 (48)
Total fixation time	381 (85)	361 (88)	389 (86)
MHA structure			
Gaze duration	313 (90)	331 (76)	347 (80)
Regression time in	70 (57)	45 (67)	54 (55)
Regression time out	88 (58)	51 (64)	62 (60)
Total fixation time	385 (94)	376 (104)	401 (103)
PA structure			
Gaze duration	315 (94)	312 (90)	326 (74)
Regression time in	62 (70)	35 (45)	51 (57)
Regression time out	57 (55)	35 (49)	54 (65)
Total fixation time	377 (123)	347 (99)	378 (97)

Note. MHA, modifier-head agreement; PA, possessive agreement.

(counterbalancing group)] ANOVA was computed on the data with the first two being within-participants variables and the latter a between-participant variable. In the item analyses, agreement type was a between-item variable and modifier type was a within-item variable. Four-dependent measures were calculated for the target words. They were *gaze duration* (sum of all first-pass fixations until leaving the word), *regression time back* to the target (re-readings of the target word), *regression time out* of the target word, *total fixation time* (gaze duration plus duration of regressions back to the target word). The means and standard deviations are presented in Table 2. The missing data amounted to 2.7%. The cutpoint for regressions to be included in the analysis was the target phrase plus the remaining text line to the right, as modifier-head agreement should produce a local effect, not an effect spanning over the whole sentence.

There were significant main effects of modifier type for the target nouns in *gaze duration* ($F1(2,78) = 3.76$, $p = .03$; $F2(2,92) = 3.48$, $p = .04$), *in regression time* back to the target word ($F1(2,78) = 6.79$, $p < .01$; $F2(2,92) = 4.61$, $p = .01$), in *regression time out* of the target word ($F1(2,78) = 11.0$, $p < .01$; $F2(2,92) = 4.69$, $p = .01$), and *in total fixation time* ($F1(2,78) = 4.20$, $p = .02$; $F2(2,92) = 3.38$, $p = .04$), but no interaction between the modifier and agreement type (all F's $\leqslant 1$), suggesting that the above effects were similar for the two structures.[3] The main effect of agreement type is not relevant, because the target words between the MHA and the PA sets were not matched with each other.

[3] There were *no spill over effects* in the duration of first fixation on the word following the target word.

The main effects were examined further with paired-sample t tests. The t tests for gaze duration showed that the target word preceded by a non-agreeing modifier had significantly shorter fixation times than the target word without a modifier ($t1 = 2.41$, $p = .02$, $t2 = 2.87$, $p < .01$).

The paired sample t test confirmed that significantly longer regression time was spent on reading the target word in non-agreeing than in agreeing modifier clauses ($t1 = 3.11$, $p = .01$, $t2 = 2.90$, $p = .01$). There was also a tendency for the regression times to be longer in the non-modifier than in the no-modifier clauses ($t1 = 1.99$, $p = .05$, $t2 = 1.54$; $p = .13$).

The target word preceded by an agreeing modifier had significantly shorter total fixation times than the target word without a modifier ($t1 = 2.03$, $p = .05$, $t2 = 2.65$, $p = .01$). The agreeing modifier condition was marginally faster than the non-agreeing modifier condition ($t1 = 1.90$, $p = .07$, $t2 = 1.83$, $p = .07$).

The target word preceded by a non-agreeing modifier produced significantly longer regression time out of it than the target word preceded by an agreeing modifier ($t1 = 3.75$, $p < .01$, $t2 = 2.89$, $p < .01$) or the target word without a modifier ($t1 = 2.31$, $p = .03$, $t2 = 1.54$, $p = .13$). Finally, the no-modifier condition produced marginally longer regression times out of the target word than the agreeing modifier condition ($t1 = 1.96$, $p = .06$, $t2 = 1.66$, $p = .10$).

In sum, the results suggest that the time course of reading the target word varied according to the type of the preceding word. Non-agreeing modifiers elicited shorter gaze duration, but more regressions, whereas agreeing modifiers produced the longest gaze duration with the least regression time. This pattern implies that the agreement helps to bind the modifier and head

together when reading the head, thus reducing the need for reprocessing. This was seen also in total fixation times: targets preceded by agreeing modifiers produced shorter total fixation times than either the targets preceded by non-agreeing modifiers or no modifiers.

4. Discussion

The present study replicates a number of earlier studies by demonstrating that head nouns preceded by an agreeing modifier are easier to process than those preceded by a non-agreeing modifier. What is new in the present study is that by including a baseline condition we are clearly in the position to determine whether the agreement effect is facilitatory or inhibitory. Moreover, our study also departs from many previous studies in the non-agreeing condition being grammatically legal, which makes the argument solid as for generalisations to the normal agreement processing. Finally, the use of eye-tracking allowed us to tap into the time-course of the agreement effect.

The finding that the results were highly compatible for the two types of agreement structures implies that the results may be generalised to the grammatical agreement phenomenon in general. As MHA is visually and orthographically more salient (i.e., the same inflection is repeated in the modifier and the head) and simpler, one might have expected the grammatical agreement to exert a more immediate effect in processing MHA than PA structures, where the agreement is lexical in nature and thus less salient in the surface level of the text. However, the nature of the effect was very similar for the two structures.

The results showed that agreeing modifiers caused *facilitation* and non-agreeing modifiers created *inhibition* in the processing of the target words compared to the neutral baseline condition. This is partly in contrast to Gurjanov et al. (1985) who interpreted their results to demonstrate that the word primes caused an inhibitory effect. However, they did not have a baseline condition, and therefore their interpretation is not totally valid. The facilitation was seen in the total fixation time and in the regressions out of the target word; both measures indicated that the processing was shortest in the agreeing modifier condition. The effect in the total fixation time comes mainly from the regression time back to the target word, and therefore these regressions showed the same tendency. The inhibition was perceived both in the regressions back to the target and in the regressions out of the target. Thus, both facilitation and inhibition emerged as lagged effects. This compares favourably with Pearlmutter et al. (1999), who make a distinction between two general mechanisms with respect to how agreement is processed: a compute-on-a-fly system where agreement is processed immediately, and a backtracking mechanism that works after the initial parsing. Our results imply that the backtracking procedure is dominant, at least in Finnish.

The results of the present study are also in line with the results of ERP studies: both Gunter et al. (2000) and Osterhout and Mobley (1995) show that grammatical disagreement caused a late P600 (positive wave about 600 ms after target) effect. Especially relevant is the study of Osterhout and Mobley, firstly because they also used an experimental setting, where participants did not need to make any grammatical decision or evaluation, which is comparable to normal silent reading, and secondly because they used subject–verb agreement that is somewhat analogical to PA structures used in the present study. However, there were also differences between these studies: unlike in ERP studies, in our study the whole sentence was available to the participants at once and we also used a more fine-grained manipulation for the non-agreeing condition (i.e., it did not introduce grammatical violations). Despite the methodological differences, these studies converge on showing that grammatical agreement exerts a relatively late effect in processing.

Lukatela et al. (1987) conclude in their article concerning the grammatical congruency effect in lexical decision that "the nature and time course of the processing details that determine grammatical conformity remain, however, largely implicit" (p. 41). We think that by using the eye fixation registration and a baseline condition our study clarifies how the agreement structures influence the process of normal reading.

Gaze duration reflecting the immediate effects produced somewhat puzzling results, for one might expect longer gazes for the target word when it is preceded by a non-agreeing modifier than when it preceded by a word that is not a modifier, but the results showed that the gazes were reliably shorter in a non-agreeing condition. A plausible explanation is that readers quickly go out of the target word, because they realise the incoherence that is caused by the lack of agreement between the modifier and the head. This explanation is supported by the fact that the non-agreeing condition elicits more regressions out of the target word than the no-modifier condition. As for example Liversedge, Paterson, and Pickering (1998) point out, it is indeed possible that the gaze duration for more difficult structures may be shorter than for less difficult structures and that the processing difficulty only shows up in the reinspective fixations.

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