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Trade-off effect in the processing of Korean case-drop sentences: An eye tracking investigation

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Nominative and accusative case markers are frequently dropped in colloquial Korean. Prior studies demonstrate a nominative-accusative asymmetry in frequency and acceptability of case-drop sentences, which correlates well with the implications of the actor identification strategy (AIS) of the extended argument dependency model (eADM). This study investigated the reading of case-drop sentences by native Korean speakers using the eye tracking methodology. While the nominative-accusative asymmetry was only partially observed in the reading time data, our results showed an important trade-off effect in the processing of case-drop sentences: a decrease in reading time on the bare noun phrase (NP) was balanced by an increase in reading time on the case-marked NP. A critical exception to this trade-off effect suggested that extra processing costs can be avoided when the AIS works in an optimal condition.

Keywords: case marking, nominative-accusative asymmetry, Korean, eye tracking, word order, animacy

INTRODUCTION

Although a majority of subject-object-verb (SOV) languages exhibit a case marking system (*1*), universally overt case marking is relatively uncommon among case marking languages (*2*). In many differential case marking (DCM) languages, for example, the use or non-use of overt case marking is strongly modulated by the animacy and/or definiteness of the noun (*3–5*).

The nominative (marks the subject) and accusative (marks the object) case markers are frequently dropped or omitted in colloquial Korean and Japanese. However, unlike differential case marking (DCM) languages, case marker drop is far less predictable in these two languages. Case drop in Korean and Japanese is considered to be "a multi-factor phenomenon that is affected by a variety of pragmatic, semantic, syntactic, and phonological factors" (*4*).

Case markers in Korean are attached after noun phrases (NPs). The nominative case marker is *-ka* or *-i*; the accusative case marker is *-lul* or *-ul*. Below are two sets of examples of case drop in Korean. Sentence (2) is an example of nominative case-drop, where the nominative case marker *-ka* for the subject *Cinwu* (a person) is dropped. Sentence (4) is an example of accusative case-drop, where the accusative case marker *-lul* for the object *Mincay* (a person) is dropped. Although sentences in (2) and (4) each have one missing case marker, both sentences are acceptable.

(1) Cinwu-*ka* khwukhi-*lul* mek-ess-ta
Cinwu-NOM cookie-ACC eat-PST-IND
Cinwu ate the cookie.

(2) **Cinwu-∅** khwukhi-*lul* mek-ess-ta
Cinwu-∅ cookie-ACC eat-PST-IND

(3) Senho-*ka* Mincay-*lul* mil-ess-ta
Senho-NOM Mincay-ACC push-PST-IND
Senho pushed Mincay.

(4) Senho-*ka* **Mincay-∅** mil-ess-ta
Senho-NOM **Mincay-∅** push-PST-IND

Theoretical studies have argued that nominative case-drop can be more restricted in usage than accusative case-drop and the former can lead to ungrammaticality in Korean and Japanese (*6–8*). Previous corpus-based studies have shown that such nominative-accusative asymmetry does exist, and that nominative case-drop (for subjects) is less frequent than accusative case-drop (for objects) in both Korean and Japanese. Lee (*9*) reported that in colloquial Korean, the accusative case marker is dropped 65% of the time while the nominative case marker is dropped only 41% of the time. Furthermore, based on survey results, Yu and Tamaoka (*10*) found that while both accusative and nominative case drops were less acceptable than fully case-marked sentences, accusative case drop was generally more acceptable than nominative case drop, in both subject-object-verb (SOV) and object-subject-verb (OSV) word orders (see **Fig. 1**). Given that the presence of either nominative or accusative case markers allows unambiguous identification of the subject and object in a transitive sentence (*11*, *12*), it is an intriguing question of how such nominative-accusative asymmetry came into existence.

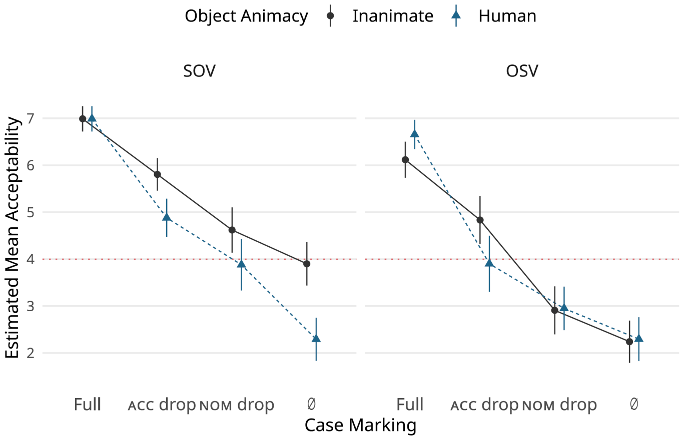

Fig. 1. Estimated acceptability of Korean case-drop sentences (*10*)

The possible underlying cause for the nominative-accusative asymmetry in case drop sentences may be the fundamental asymmetry in the identification of the subject and object during language comprehension (*13–15*). In their neurolinguistic model, the argument dependency model (eADM), Bornkessel-Schlesewsky and Schlesewsky propose the "actor identification strategy" (AIS) as one principal strategy employed by the language processing system to determine the thematic (e.g., actor or undergoer) and syntactic roles (e.g., subject or object) of the arguments in the sentence. The AIS contends that the identification of arguments is fundamentally asymmetrical in that the process is actor-centered (the notions of "actor" and "subject" are equivalent in the context of the present study): the parser seeks to "identify the actor role as quickly and unambiguously as possible" (*14*). Support for

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the AIS has been drawn from experiments on a wide range of languages, including English (*16*), German (*17–19*), Turkish (*20*), and Mandarin Chinese (*21*, *22*).

According to the AIS and the eADM, identification of the actor (subject) is guided by the analysis of an array of "prominence features" (*14*, *15*) which can be regarded as a set of features that a typical actor is expected to possess. For example, a typical actor (subject) is expected to be a human or an animate noun (i.e., a living creature) rather than an inanimate noun; this property of the actor is described as the "+human" or "+animate" feature. The actor (subject) is also preferred to come as the first argument of the sentence rather than appearing after other arguments (e.g., after the object), and this is referred to as "+1st (argument) position". Furthermore, and importantly, in nominative-accusative case marking languages such as Korean, a typical actor (subject) is expected to have the nominative case (e.g., marked by *-ka* or *-i* in Korean), carrying the "+nominative" feature. This expectation of the +nominative feature has a direct implication on the case drop phenomenon in Korean. Because the argument identification process focuses on identifying the actor (subject) both unambiguously and efficiently, and because nominative case marking is one of the critical features that the parser leverages to determine the subject, the lack of overt nominative case marking should pose uncertainty about the subject role of the argument to the parser, and therefore should induce greater processing difficulties. By contrast, accusative case drop should have less impact on sentence processing since the nominative case marker is preserved, enabling the parser to identify the subject efficiently. The asymmetry of nominative and accusative case drops in usage frequency and acceptability in the Korean language may be a result of the intrinsic difference in the case drops in terms of processing difficulty or efficiency.

Few studies have explored the online processing of case-drop sentences in Korean. While the impact of case drop on sentence processing can be deduced from the AIS of the eADM, to our knowledge, the effects of missing the +nominative feature have not yet been examined as extensively as have with other prominence features in the line of eADM-based studies. This could be partially due to the difficulty of manipulating the presence or absence of nominative and accusative case marking independently and systematically in many case marking languages such as German (where case marking information is embedded in articles, and the form varies with noun gender and number) and Turkish (where there is no explicit case marker for the nominative case). The optionality of the nominative and accusative case markers in Korean makes it possible to study the effects of the lack of overt case marking in highly controlled conditions.

The present study investigates the reading of case-drop sentences by native Korean speakers with the eye tracking methodology. We would expect a correlation between the reading time and the results from previous corpus and acceptability studies (*9*, *10*). First, both nominative and accusatives case-drop sentences should be more difficult to process than normal, fully case-marked sentences as the former are less acceptable (processing difficulties should be reflected as relative increases in reaction time or reading time). Second, nominative case-drop sentences should be more difficult to process than their accusative case-drop counterparts as the former are both less frequent and less acceptable than the latter; such prediction is also implied by the AIS. The experimental sentences of this study were simple active sentences that omitted either the nominative case marker or the accusative case marker. Fully case-marked sentences were used as the baseline. The stimuli also varied in object animacy (inanimate and human) and word order (SOV and OSV).

RESULTS

We report the Bayesian analysis of reaction time and eye-tracking reading measures (first fixation duration, gaze duration, and total duration) in the following sections, with a focus on the effects of case marking.

For each unique condition formed by the combination of the categorical predictors, we computed the estimated posterior values with the population-level coefficients (the covariate *trials* was fixed to its mean). Furthermore, we back-transformed the values to the response scale (in milliseconds) to allow more intuitive interpretation. The back-transformed values for reaction time and the fixation duration measures corresponded to the median on the response scale (by taking the exponential of μ: e^{μ}). For contrasts between conditions, however, we calculated the posterior differences (denoted by Δ) in the scale of the model coefficients for simplicity (i.e., the logarithmic scale).

Statistical inference was performed based on posterior summaries. Medians of posterior distributions were used as point estimates. 95% equal-tailed credible intervals (CrI) served as interval estimates (50% CrIs were also illustrated in figures). The posterior probability of an effect being greater or less than zero, denoted as $P(\Delta > 0)$ or $P(\Delta < 0)$, was jointly utilized to determine the existence of the effect. Interpretation of the results is intuitive: evidence for an effect can be concluded if the 95% CrI excluded zero; weak evidence for an effect can be supposed if the 95% CrI covered zero but $P(\Delta > 0)$ or $P(\Delta < 0)$ was considerably high, e.g., being above 95% (*23–26*).

Reaction Time

An overview of the estimated median reaction time (RT) for each condition is shown in **Fig. 2**. To evaluate the effects of case marking, we compared the estimates of the three case marking conditions while holding other categorical predictors at fixed levels. **Fig. 3** summarizes the results of the comparison by presenting the point and interval estimates both visually and numerically; it also provides values of $P(\Delta > 0)$. The posterior probability densities are plotted as colored areas to give a visualization of the posterior distributions.

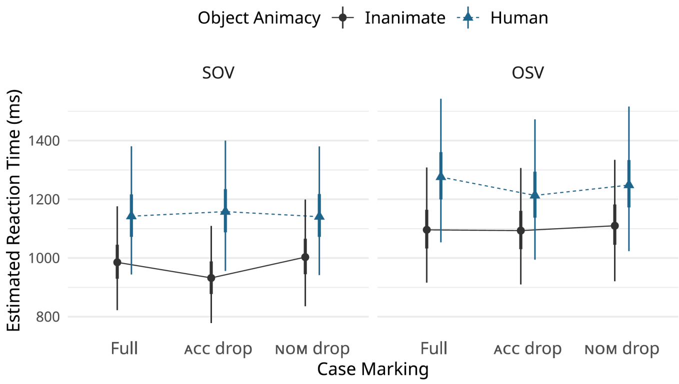

Fig. 2. Estimated median reaction time (ms). Reaction time is back-transformed as medians on the response scale. Points are posterior medians; outer and inner intervals indicate 95% and 50% equal-tailed credible intervals.

As displayed in the top-left quarter of **Fig. 3**, for SOV inanimate-object sentences, the estimated RT in the accusative case-drop condition (ACC *drop*) was faster than the nominative case-drop

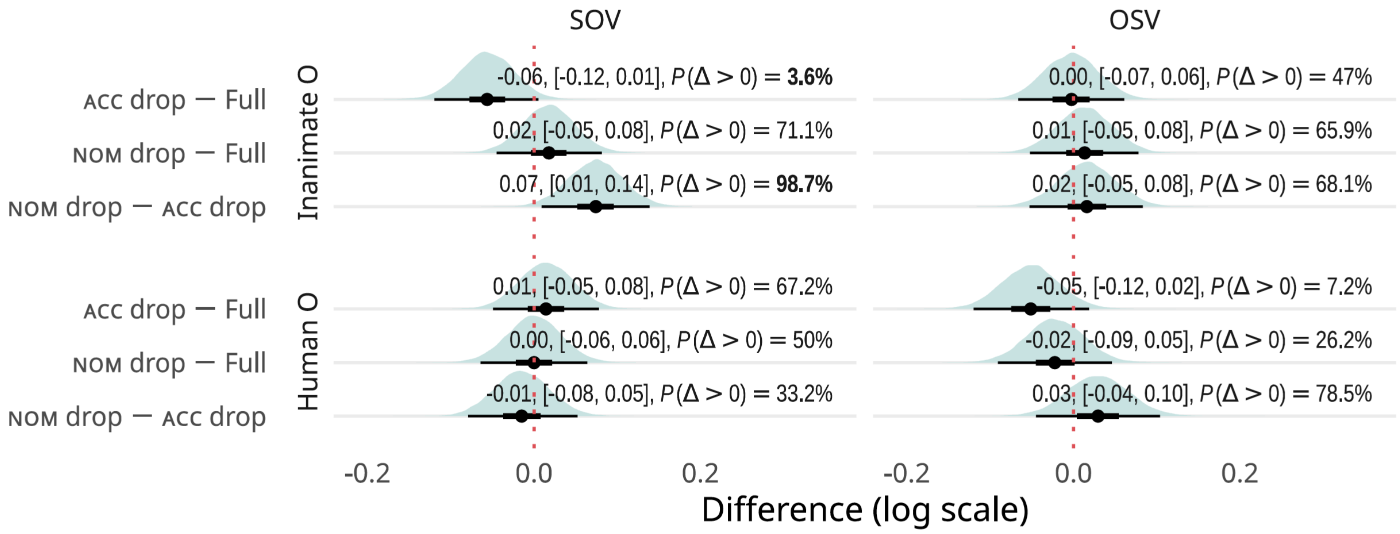

Fig. 3. Estimated differences of case marking conditions in reaction time (log scale). Points are posterior medians; outer and inner intervals indicate 95% and 50% equal-tailed credible intervals (CrI). Numbers over the intervals summarize (1) the posterior median and the 95% CrI, (2) the posterior probability of the difference being greater than zero, as denoted by P (Δ > 0). Probabilities are in bold if P (Δ > 0) ≥ 95% or P (Δ > 0) ≤ 5%.

condition (NOM *drop*), Δ = 0.07, 95% CrI [0.01, 0.14], *P*(NOM *drop* > ACC *drop*) = 98.7%. Moreover, there was also weak evidence that RT in the ACC *drop* condition was faster than the fully case-marked condition (*Full*), Δ = 0.06, 95% CrI [-0.01, 0.12], *P*(*Full* > ACC *drop*) = 96.4%. For reference, the estimated median RT was 932ms, 95% CrI [778, 1109] for ACC *drop*; 985 ms, 95% CrI [822, 1176] for *Full*; and 1003 ms, 95% CrI [835, 1199] for NOM *drop*.

While ACC *drop* was expected to be processed faster than NOM *drop*, it was somewhat surprising that ACC *drop* was processed even faster than the *Full* condition. It was also unexpected that differences between the case marking conditions were only found for SOV inanimate-object sentences. More details on participants' reading behavior were revealed by the reading measures, which could offer explanations for this outcome.

Reading measures

We examine three fixation duration measures: 1. *First fixation duration*, which is the duration of the very first fixation on an area of interest (AOI) in progressive reading; 2. *Gaze duration*, or *first-pass reading time*, which is the accumulated duration of all fixations on an AOI in progressive reading; 3. *Total duration*, which is the summed duration of all fixations on an AOI during the entire reading period. First fixation duration and gaze duration are commonly regarded as early measures of sentence processing, while total duration is regarded as a late measure (*27*, *28*).

First fixation duration

Case-marker drop appeared to have negligible effects on first fixation duration as can be seen from **Supplementary Fig. 1**. Although the case-marked nouns are one character longer than the bare nouns, reading time seemed to be comparable for the case-marked and bare nouns, regardless of word order and object animacy configurations. Summaries of the posterior differences (**Supplementary Fig. 2**) confirmed the observation that no reliable differences existed between the case marking conditions at the first noun phrase (NP1) and the second noun phrase (NP2). There was weak evidence that for OSV human-object sentences, fixation duration on the verb in the ACC *drop* condition might be shorter than that in the *Full* condition (see the bottom-right portion of **Supplementary Fig. 2**). However, we refrain from further interpretation of this result as it was not found in other fixation duration measures.

The result that NPs had similar first fixation duration whether the case marker was presented or not indicates that case-marking information is not taken into account at the very earliest stage of reading. This is understandable as first fixation duration is mainly associated with word recognition (*28*).

Gaze duration

As identified in **Fig. 4**, a particular pattern of reading behavior began to emerge in gaze duration. Using the *Full* condition as a baseline, one can observe that in either the ACC *drop* or the NOM *drop* condition, one of the two NPs tended to receive shorter fixations than the baseline while the other tended to receive longer fixations. More specifically, it was the bare noun that tended to be fixated shorter while the case-marked noun tended to be fixated longer. As an example, refer to the bottom-left quarter of **Fig. 4**, which corresponds to the results of SOV human-object sentences. The NP1 in the ACC *drop* condition was nominative case-marked and its estimated gaze duration was longer than the baseline; meanwhile, the NP2 was a bare noun with the accusative case marker dropped and its estimated gaze duration was shorter than the baseline. This observation can be verified with the posterior summaries by referring to the ACC *drop*—*Full* and NOM *drop*—*Full* contrasts in **Supplementary Fig. 3** (the first two rows in each small panel).

This particular pattern was not always clearly manifested in gaze duration when compared to results for total duration (especially for OSV sentences). We examine the pattern in greater detail in the next section.

Total duration

The previously mentioned pattern became more evident in total duration (**Fig. 5**). A "trade-off" in reading time can generally be found between the two NPs in the case-drop conditions: the bare NP was read longer while the case-marked NP was read shorter, in comparison to the baseline (*Full*). The same results in **Fig. 5** are also visualized from an alternative perspective in **Supplementary**

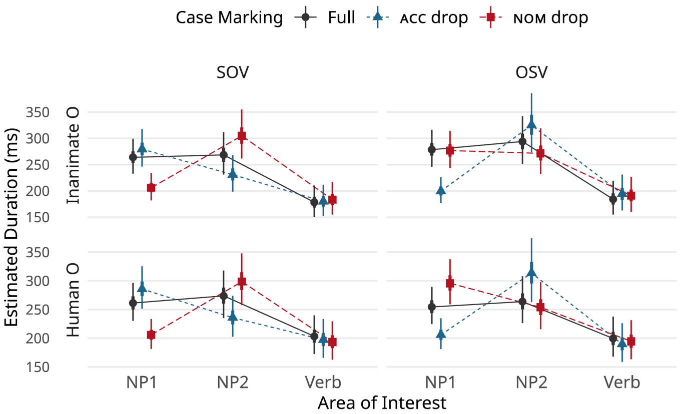

Fig. 4. Estimated median gaze duration (ms). Duration is back-transformed as medians on the response scale. Points are posterior medians; outer and inner intervals indicate 95% and 50% equal-tailed credible intervals.

Fig. 4, where the case marking conditions are used as the x-axes, and the SOV and OSV word orders are compared side-by-side for each of the AOIs (NP1, NP2, Verb). The x-axes of SOV and OSV are matched vertically according to the presence or non-presence of case marker; for both SOV and OSV, the x-axis order is (1) *Full*, (2) NP1-CASE NP2-∅, and (3) NP1-∅ NP2-CASE. **Supplementary Fig. 4** clearly demonstrates that in the case-drop conditions, a noun phrase tended to be read longer when it was case-marked, and it tended to be read shorter when the case marker was dropped, irrespective of the word order.

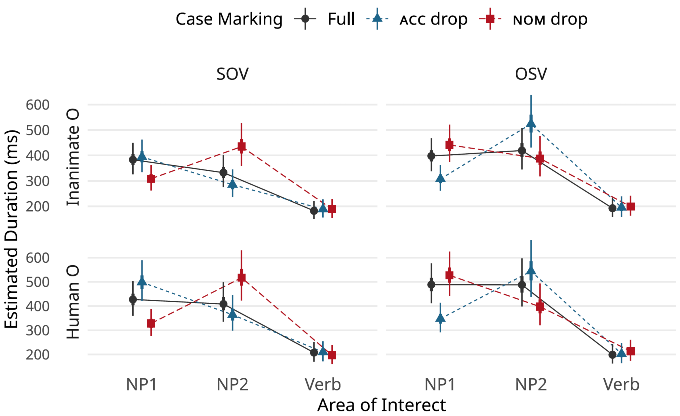

Fig. 5. Estimated median total duration (ms). Duration is back-transformed as medians on the response scale. Points are posterior medians; outer and inner intervals indicate 95% and 50% equal-tailed credible intervals.

There was, however, one obvious exception to this trade-off pattern. As can be seen from the top-left quarter of **Fig. 5** (corresponding to SOV inanimate-object sentences), the total duration of the NP1 in the ACC *drop* condition did not appear to deviate from the baseline *Full* condition. Because the NP1 was nominative cased-marked and the NP2 was a bare noun in the ACC *drop* condition for these sentences (with an "NP1-NOM NP2-∅ Verb" configuration), the NP1 should have been fixated longer relative to the baseline if the trade-off effect existed. However, the estimated total duration of the NP1 in ACC *drop* was 394 ms, 95% CrI [335, 462], which was not reliably different from the baseline (383 ms, 95% CrI [326, 450]), Δ= 0.03, 95% CrI [-0.06, 0.12], *P*(ACC *drop* > *Full*) = 72.7%. By contrast, the estimated duration of the NP2 in ACC *drop* (285 ms, 95% CrI [236, 345]) was indeed shorter than the baseline (332 ms, 95% CrI [276, 402]), Δ = 0.15, 95% CrI [0.06, 0.25], *P*(*Full* > ACC *drop*) = 99.9%. Therefore, it can be concluded that the trade-off effect was absent for the NP1 in the ACC *drop* condition of the SOV inanimate-object sentences. This finding has a direct link with the results of the reaction time data. Recall that for SOV inanimate-object sentences, the reaction time of the ACC *drop* condition was faster than the normal *Full* condition. The explanation for this outcome could be attributed the fact that the NP2 in the ACC *drop* condition was read shorter than *Full*, while the reading time on the NP1 was not inflated, leading to an overall reduction in reaction time.

Fig. 6 details the comparison of the case marking conditions. Focusing on the ACC *drop*−*Full* and NOM *drop*−*Full* contrasts (the first two rows in each small panel) for the NP1 and NP2, we can confirm that the trade-off effect was generally true in most cases except for the aforementioned ACC *drop* condition of the SOV inanimate-object sentences. It should be noted that there were also two minor "exceptions". The trade-off effect was somewhat weaker for the NP1 in the NOM *drop* condition of OSV human-object sentences (with an "NP1-ACC NP2-∅ Verb" configuration); the NP1 here should be read longer than the baseline but the effect was weak, Δ = 0.08, 95% CrI [-0.02, 0.17], *P*(Δ > 0) = 94.2% (see the second panel from the top-right of **Fig. 6**). The trade-off effect was also somewhat weaker for the NP2 in the NOM *drop* condition of OSV inanimate-object sentences (with an "NP1-ACC NP2-∅ Verb" configuration); the NP2 here should be read shorter than the baseline but the effect was weak, Δ = -0.08, 95% CrI [-0.18, 0.03], *P*(Δ > 0) = 7.2% or *P*(Δ < 0) = 92.8% (see the third panel from the top-right of **Fig. 6**). Because the overall tendency was still visible and the values of *P*(Δ > 0) or *P*(Δ < 0) were still reasonably high, we assume that the trade-off effect was weakly maintained in those two cases.

As with the results of gaze duration (**Supplementary Fig. 3**), no credible difference in reading time can be found between the case marking conditions for the final verb.

DISCUSSION

The trade-off effect

We first recap the prevalent pattern in our results before discussing the theoretical implications. The present study revealed a trade-off effect in the processing of Korean case-drop sentences by native Korean speakers. Results of total fixation duration demonstrated that reading time was generally reduced for the bare noun phrase (NP) and increased for the case-marked NP (relative to the fully case-marked condition) during the whole reading period (see **Fig. 5** and **Supplementary Fig. 4**). For sentences with an "NP1-ACC NP2-∅ Verb" or "NP1-NOM NP2-∅ Verb" configuration, the case-marked NP1 was generally fixated longer than in the fully case-marked condition, and the case-less NP2 was fixated shorter. In the same vein, for sentences with an "NP1-∅ NP2-ACC Verb" or "NP1-∅ NP2-NOM Verb" configuration, the case-marked NP2 was generally fixated longer than in the fully case-marked condition, and the case-less NP1 was fixated shorter. This trade-off effect was detectable at an early stage of processing (in gaze duration), although the effect in OSV sentences became more evident only when it was measured at a later stage (in total duration). The trade-off effect also explains why reaction time did not reliably differ between case-drop sentences and fully case-marked sentences in most situations: a decrease in reading time on the bare NP was balanced by an increase in reading time on the case-marked NP.

However, there was a critical exception to the trade-off effect.

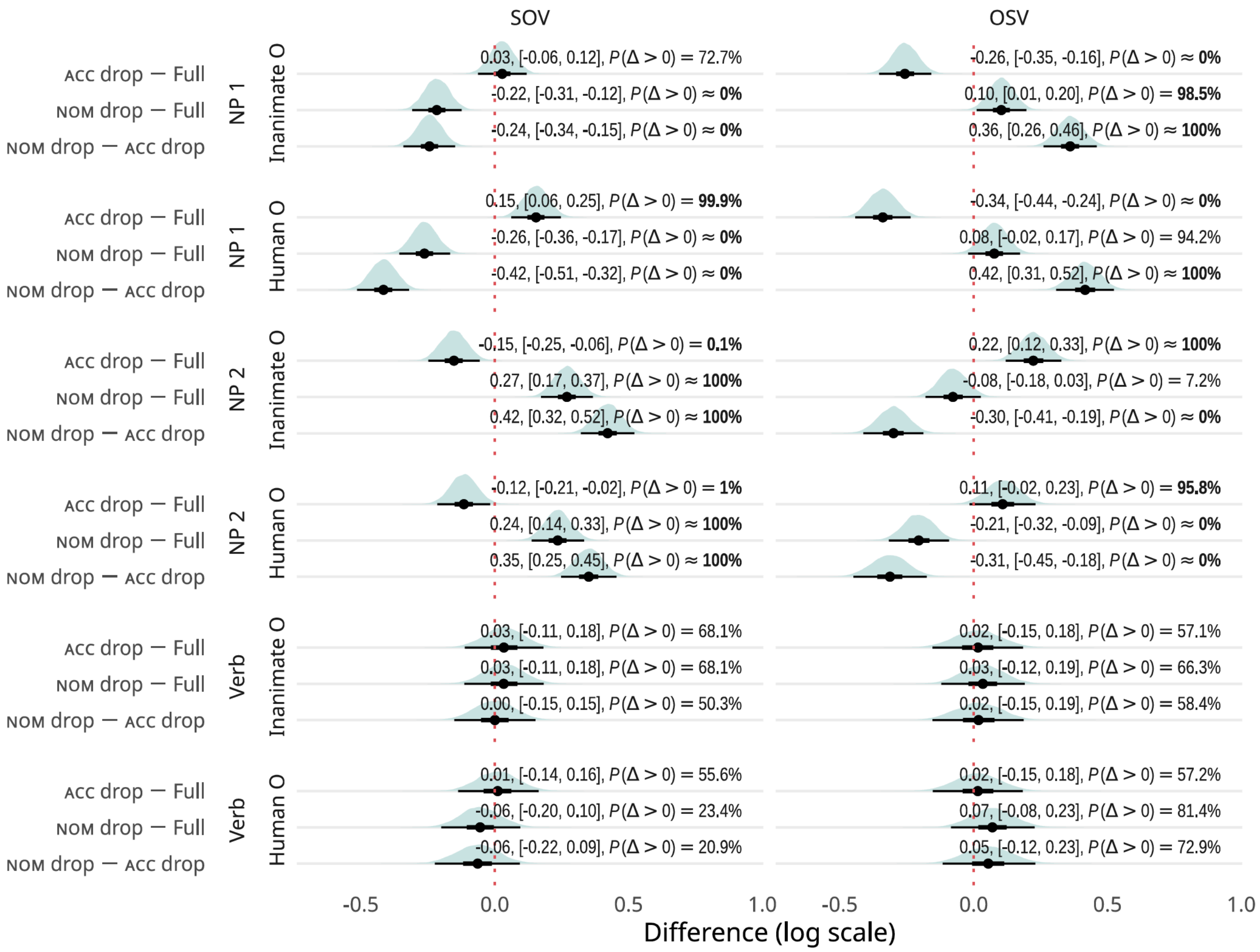

Fig. 6. Estimated differences of case marking conditions in total duration (log scale). Points are posterior medians; outer and inner intervals indicate 95% and 50% equal-tailed credible intervals (CrI). Numbers over the intervals summarize (1) the posterior median and the 95% CrI, (2) the posterior probability of the difference being greater than zero, as denoted by $P(\Delta > 0)$. Probabilities are in bold if $P(\Delta > 0) \geq 95\%$ or $P(\Delta > 0) \leq 5\%$.

For SOV inanimate-object sentences, accusative case-drop (sentence configuration: NP1[human]-NOM NP2[inanimate]-∅ Verb) caused decreased reading time on the case-less NP2 while reading time on the case-marked NP1 was not increased accordingly. This unusual absence of processing trade-off was correlated with a reduction in overall reaction time: SOV inanimate-object sentences in the accusative case-drop condition tended to have slightly faster reaction time than in the fully case-marked condition. The accusative case-drop condition also had reasonably faster reaction time than the nominative case-drop condition.

Role identification strategies in the reading of case-drop sentences

Only a very sparse correlation was found between the results of the present study and previous findings in frequency and acceptability (*9*, *10*). While case-drop sentences were expected to be processed more slowly than fully case-marked sentences because of their inferior acceptability, it turned out that in most cases, the overall reaction time of the case-drop sentences and fully case-marked sentences did not differ reliably (due to the trade-off effect summarized above). Furthermore, we expected that nominative case-drop sentences should be more difficult to process than their accusative case-drop counterparts. This prediction was on the one hand based on the previous frequency and acceptability data, and on the other hand based on the assumption of the actor identification strategy (AIS) (*13*–*15*) that the identification of arguments is fundamentally centered on the actor (subject) rather than on the undergoer (object). Despite the convergence of the AIS and previous empirical data, our second prediction was only attested in a single scenario, namely, the case of SOV inanimate-object sentences. As discussed below, we interpret the trade-off effect and its crucial exception as reflecting some important strategies for the online comprehension of case-drop sentences, although some aspects of the observations may be specific to reading.

The trade-off effect suggests that the uncertainty in identifying the role of the bare NP (subject or object) can be compensated for by further referring to the case-marked NP. Case marking can assist the parser to determine the thematic and syntactic roles of the NPs before encountering the verb (*13*, *29*–*31*). In Korean, case marking information is reported to be the predominant factor in resolving the roles of the arguments in transitive sentences (*12*). The bare NP in the case-drop sentences lacked explicit case marking, therefore it could give rise to uncertainty about the NP's role. Additionally, the bare NP was consistently estimated to be read for less time than its case-marked counterpart in the fully case-marked condition. Such difference in reading time is probably a reflection of the cost for processing the case information carried by the case marker. The increase in reading time on the case-marked NP of the case-drop sentences should reflect a compensating strategy: the uncertainty about the role of the bare NP was resolved by further referring to the case marking information of the other NP (and the NP's role as indicated by the case information). Because there are only two arguments (subject and object) in a simple transitive sentence, the role of one argument can always be deduced from the role of the other. Our results suggest that the parser's strategy to consolidate its decision on the role of the bare NP is approached by referring to and reconfirming the role of the case-marked NP.

Surprisingly, the processing trade-offs caused by nominative and accusative case drops during real-time reading were apparently symmetric in that the two types of case drop eventually resulted in comparable overall reaction time in most cases. However, it would be too early to conclude that the prevalence of the trade-off effect might be a challenge to the actor identification strategy (AIS), which assumes a fundamental asymmetry in the identification of the subject and object roles. To appropriately interpret our results, we need to further discuss the crucial exception to the trade-off effect where a nominative-accusative asymmetry did exist (in SOV inanimate-object sentences).

In and only in SOV inanimate-object sentences, the trade-off effect was absent for the accusative case-drop condition, which had an "NP1[human]-NOM NP2[inanimate]-∅ Verb" configuration (see the top-left quarter of **Fig. 5**). On the other hand, the trade-off effect was evident for the nominative case drop counterpart, which had an "NP1[human]-∅ NP2[inanimate]-ACC Verb" configuration. With the word order and animacy factors being held constant and case marking being the only variable, we consider this sharp contrast of nominative case drop and accusative case drop as a manifestation of the subject-object (or actor-undergoer) asymmetry in argument role identification (*13–15*). The absence of the trade-off effect in the accusative case-drop condition indicates that the argument identification process in this situation was so efficient that the compensating strategy that would cost extra reading time on the case-marked NP (here, the nominative case-marked NP1) was completely avoided.

This processing advantage of accusative case drop over nominative case drop in the SOV inanimate-object sentences can be explained by the fact that the accusative case-drop condition (NP1[human]-NOM NP2[inanimate]-∅ Verb) can offer an optimal configuration for the actor identification strategy (AIS) to work. The AIS aims to identify the actor (subject) as quickly and unambiguously as possible, and one crucial corollary of the AIS is that the two arguments would compete for the actor (subject) role if both of them carry some prominence features, leading to a decline of processing efficiency (*13–15*). The accusative case-drop condition of the SOV inanimate-object sentences had two key advantages that allowed the AIS to work in the most efficient way among all the case-drop sentences. Recall the sentence configuration of this condition: "NP1[human]-NOM NP2[inanimate]-∅ Verb". First, the subject (i.e., NP1) in this particular condition is highly typical, bearing major prominence features that a typical subject (or actor) is supposed to have: +1st argument position, +human, and +nominative (the subject appears as the first argument of the sentence, is a human noun, and is nominative case-marked). Second, and importantly, there is *no* competition from the other NP (i.e., NP2). The NP2 (the object) in this particular condition possesses exactly none of the prominence features that would signal the subject: it is a case-less inanimate noun that comes as the second argument of the sentence. Therefore, because the NP1 was highly typical for the subject, and because there was entirely no competition for the subject role from the other NP (i.e., NP2), the parser must enjoy extremely high confidence about the subject role of the NP1. After encountering the NP2, the parser must have also deduced the object role of the NP2 with great certainty, and it thus bypassed the now-superfluous procedure of further referring to the case-marked NP, eliminating the trade-off effect. As a striking result, the lack of accusative case marking of the inanimate NP2 did not hinder sentence processing at all, and it even suggested a possibly faster reaction time than the fully case-marked baseline.

By contrast, the nominative case-drop condition of the SOV inanimate-object sentences (with an "NP1[human]-∅ NP2[inanimate]-ACC Verb" configuration) was obviously suboptimal for the AIS to achieve its aim of efficiently identifying the subject. Although there was no competition from the NP2 (as it did not carry any prominence features), NP1 deviated from a typical subject in a significant fashion: lacking the +nominative feature. To resolve the uncertainty about the subject role of the NP1, reading time on the NP2 was increased (the trade-off effect). The asymmetry of the nominative case-drop condition and the accusative case-drop condition provides evidence that the lack of overt nominative case marking (for the subject) would cause greater processing difficulties to the parser than the lack of overt accusative case marking (for the object), which echoes the actor (subject)-centered assumption of the AIS.

Now we consider why the effects of nominative and accusative case drops were apparently symmetric in other parts of our results (i.e., all OSV sentences, and the SOV human-object sentences). We would like to propose that these results might not necessarily be counterexamples to the actor identification strategy (AIS), especially regarding the potential methodology-specific issues. We speculate that the trade-off effect might take over whenever the AIS was not allowed to work at its best efficiency. For example, the non-canonical OSV sentences are not optimal, as the object NP always occupies the first argument position, and accordingly, the subject always lacks the "+1st argument position" feature. The SOV sentences with human objects are suboptimal as well because the objects always bear the "+human" feature, which would cause competition for the subject (actor) role. We further speculate that the trade-off effect might be specific to the reading paradigm of our eye tracking experiment, in which participants can preview contiguous regions (*27*) and are free to re-read any part of the sentence. The trade-off effect would not be possible if the sentence is presented word-by-word as with the self-paced reading paradigm and many event-related potential (ERP) studies. When reading case-drop sentences with a suboptimal configuration, the parser might adopt a straightforward strategy to benefit from free-reading: just look more at the case-marked NP whose role is promised to be identifiable, and then the uncertainty about the bare NP's role should be resolved (the compensating strategy). The trade-off effect by this straightforward strategy might have overridden the more fine-grained nominative-accusative asymmetry in case-drop sentences. This speculation is admittedly rudimentary and tentative, and definitely requires further validation.

Future research

The actor identification strategy's (AIS's) assumption that the argument role identification process is fundamentally asymmetric between the actor (subject) and the undergoer (object) is consistent with usage frequency and acceptability data of Korean case-drop sentences. Although the present study revealed important processing strategies in the reading of Korean case-drop sentences, our prediction that nominative case-drop sentences would be more difficult to process than accusative case-drop sentences was only partially supported. Methodology-specific strategies used by the participants might be responsible for the inconsistencies between the reading data and previous findings. Our results therefore call for validation with different experimental paradigms. As the majority of empirical evidence for the AIS is accumulated from electrophysiological experiments based on the eADM (*13–15*, *32*), further work is planned to investigate the processing of Korean case-drop sentences with ERP experiments.

MATERIALS AND METHODS

Experimental Design

The present experiment was designed to investigate the effects of nominative and accusative case-drops on Korean sentence processing. The experimental items were comprised of 96 stimuli and 96 filler sentences. All stimuli were simple active sentences consisted of two nouns and one verb. Three areas of interest (AOIs) were defined for each stimulus sentence: region of the first noun phrase (NP1), region of the second noun phrase (NP2), and region of the final verb (Verb).

The stimuli were derived from 16 original SOV sentences by manipulating case marking and word order. All subjects of the original sentences were commonly used Korean given names. The objects for half (8) of the original sentences were inanimate nouns, and for the other half were human given names. Three case marking conditions (including the original sentence) were created by dropping either the nominative or the accusative case marker: (1) the fully case-marked condition (*Full*), which was also the baseline; (2) the accusative case-drop condition (ACC *drop*); and (3) the nominative case-drop condition (NOM *drop*). OSV sentences were derived from the original SOV sentences. As above, the 96 stimuli can be cross-classified by three factors: *object animacy* (2 conditions), *case marking* (3 conditions), and *word order* (2 conditions).

Additionally, the nouns in the stimuli all ended with vowels; therefore, the nominative and accusative case markers appeared only in the forms of *–ka* (nominative) and *–lul* (accusative). The phonological form of the nominative and accusative case markers in Korean depends on the last phoneme of the noun phrase preceding the case marker. The forms *–ka* (nominative) and *–lul* (accusative) are used after vowels, while *–i* (nominative) and *– ul* (accusative) are used after consonants.

The length of the nouns was controlled so that only two-*hangul* (or two-character) words were used (e.g., 쿠키 *khwukhi* “cookie”). The verbs in the stimuli were in the past tense, and all had a length of three characters (e.g., 팔았다 *phal-ass-ta* “sold”).

Procedure

Participants’ eye-movements during reading were recorded by an SR Research EyeLink 1000 eye-tracker (right-eye monocular tracking, 1000Hz sampling rate). A total of 192 items were divided into six blocks, each containing 16 stimuli and 16 fillers. The presentation order of blocks and trials was randomized, and variants of the same original sentence never appeared in the same block. Rest breaks were provided between blocks. A nine-point calibration was performed before each block. Drift-checking was performed prior to each trial, during which participants’ gaze was directed to a fixation dot located at the beginning of the upcoming sentence.

For each trial, participants read the whole sentence silently at their own pace and pressed the “Yes” button on a gamepad when finished (with a timeout after 10 seconds). To keep the participants focused, a comprehension task was given after 1/4 of the trials at random intervals. In the task, a verification sentence was displayed, and participants were required to judge whether it agreed with the previously read sentence by pressing the “Yes” or “No” button on the gamepad. For example, the sentence *Hyenci put on the coat* was followed by an incorrect verification sentence *Hyenci took off the coat*. Half of the verification sentences were incorrect, and the locus of disagreement was either the subject, the object, or the verb (or an adverbial expression in some of the filler sentences). Participants went through a practice session of 8 trials before the experiment.

The experiment was presented on a 21.5-inch LCD monitor at a refresh rate of 120Hz. The screen resolution was set to 1024×768 pixels. All experimental items were displayed on a single line, in Malgun Gothic font with a 30-pixel size. Each item was left-aligned with an 80-pixel offset and was centered vertically. Participants were seated at a distance of approximately 80 cm from the monitor, with their head stabilized by a chin rest. One *hangul* (Korean character) corresponded to approximately 0.75-degree of visual angle under the above settings.

Participants

Thirty native Korean speakers (20 males and 10 females) participated in the experiment and were included in the final data analysis. The participants all had normal or corrected-to-normal vision. Their mean age was 26 years, ranging from 20.0 to 38.2 years (SD = 4.4). At the time of the experiment, most of the participants were students at Nagoya University, Japan; two participants were non-student residents in Nagoya city. Participants were informed of the experimental procedure, and written consent was obtained before the experiment.

Four additional participants took part in the experiment but were excluded from data analysis. One participant was rejected due to relatively poor accuracy in the comprehension task (81%). The other three participants were rejected because they skipped the first noun phrase (NP1) at very high frequencies during first-pass reading (33%, 43%, and 69% of the time, respectively).

Statistical Analysis

Data cleaning

Fixation data cleaning was performed prior to analysis. Fixations shorter than 80 ms were merged to a directly adjacent fixation if the adjacent fixation was longer than 80 ms and their horizontal distance was within 0.5-degree visual angle. After the merging, all fixations shorter than 80 ms or longer than 800 ms were removed (1,801 or 9.8% of the original 18,341 data points).

Reaction time was analyzed in addition to the eye tracking data. Outliers that exceeded three median absolute deviations (*33*) in logarithmic scale for each unique condition were excluded (18 or 0.6% of the total 2,880 data points).

Hierarchical regression modeling

The data of reaction time, first fixation duration, gaze duration, and total duration were analyzed using hierarchical Bayesian regression models (*34*) using Stan (*35*, *36*) and R. For the fixation duration measures, the population-level predictors included four categorical predictors: *AOI*, *case marking*, *object animacy*, *word order*, as well as all their interactions, resulting in a $3 \times 3 \times 2 \times 2$ design. Furthermore, the number of preceding trials (*trials*) was included as a covariate. Regressors for the categorical predictors and their interactions were created with treatment coding. The numeric regressor *trials* were centered and scaled to have a mean of zero and a standard deviation (SD) of 0.5 (*37*). The intercept and the slopes for all regressors were allowed to vary by participants; the intercept and the slopes for *AOI*'s regressors were also allowed to vary by items (i.e., stimuli). This model structure corresponds to the maximal random effects structure proposed by Barr, Levy, Scheepers & Tily (*38*). For the analysis of reaction time, the same model structure was applied except that *AOI* was not included.

Likelihoods, priors, and posterior sampling

Visual inspection showed that the distributions of reaction time and the various fixation duration measures were heavily right-skewed. Log-normal likelihoods were used in the models as the Box-Cox procedure suggested logarithmic transformation of these data to attain approximate normality (*39*).

Weakly informative priors were specified for the model parameters (*37*, *40*). Internal to the models, a population-level grand-mean intercept was estimated with centered regressors, and the real intercept was restored afterward. The grand-mean intercept was given a Student's t prior centered at the mean of the response variable, with $\nu = 3$ and a scale of 10 times of the data SD (in log scale). The population-level slopes were given Student's t priors centered at zero, with $\nu = 3$ and a scale of 2.5 times of the data SD (in log scale). For the by-participant and by-item varying intercepts and slopes, multivariate normal priors centered at zero were specified to allow for possible correlations between the varying coefficients. The variance-covariance matrices were decomposed into a vector of scale parameters and a correlation matrix. The Cholesky factors of the correlation matrices were given LKJ priors with $\eta = 2$, which moderately favor lower correlations *a priori* (*41*). Finally, the scale parameters of the multivariate normal priors and the log-normal likelihood were given exponential priors with a rate (λ) being the reciprocal of the data SD (in log scale).

For each model, the joint posterior distribution was sampled by running eight Monte Carlo Markov chains, each with 3,000 iterations (including 1,000 warm-ups). All fitted results were successfully validated with $\widehat{R}$ (*42*) and diagnostics specific to Stan's Hamiltonian Monte Carlo sampler (*43*).

SUPPLEMENTARY MATERIALS

Supplementary materials for this article are available at http://www.humanbab.net/qfy-content/uploads/2020/06/2020010203SM.pdf
Supplementary Fig. 1. Estimated median first fixation duration (ms).
Supplementary Fig. 2. Estimated differences of case marking conditions in first fixation duration (log scale).
Supplementary Fig. 3. Estimated differences of case marking conditions in gaze duration (log scale).
Supplementary Fig. 4. Estimated median total duration (ms), alternative perspective.

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