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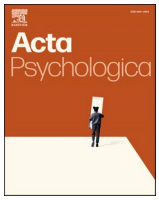

Keep calm and move on: 'Good-enough' processing of clausal constructions in Korean

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ABSTRACT

The good-enough processing account maintains that the human parser favours cognitively less effortful parsing (a heuristic stream) over deep and costly parsing (an algorithmic stream) in real-time processing. This study investigates how the two parsing routes work for sentence comprehension in Korean, an understudied language for this topic, through two self-paced reading experiments. In Experiment 1, focusing on the suffixal passive, native Korean speakers show no significant difference in reading times at the verb region between the verb-initial and verb-final conditions. However, we find a significant by-condition difference in the spill-over region, with longer reading times for the verb-initial condition compared to the verb-final condition. Experiment 2, examining the morphological causative, we find constant reading times across both word-order conditions including at the spill-over region. These findings suggest an interplay between the two parsing routes, with heuristics taking precedence over algorithms when disequilibrium arises. This study's findings also shed light on how the operations of these two parsing streams are modulated by language-specific properties (e.g., word order, case-marking, verbal morphology) during sentence comprehension.

1. Introduction

The human parser is equipped with mechanisms designed to enhance efficiency in language processing by minimising the cognitive load on working memory (O'Grady, 2005). During language processing, the parser encounters various constraints, both linguistic (e.g., mapping form to meaning/function and vice versa, resolving dependency relations) and non-linguistic (e.g., task demands, time constraints, cognitive limitations). Numerous accounts explain how the parser manages these challenges by making decisions to optimise the integration of incoming information for effective processing (Ferreira & Clifton, 1986; Ferreira & Henderson, 1990; Frazier, 1979; Gibson, 1998; Hale, 2001; Levy, 2008; MacDonald, 2013; Rayner et al., 1983; Traxler, 2014). Amongst these accounts, the good-enough processing framework provides a plausible explanation for why misunderstandings and miscommunications occur in language activities. This framework maintains that the parser often chooses the least effortful analysis available at the earliest opportunity to facilitate efficient communication (Christianson, 2016; Ferreira, 2003). For example, Ferreira (2003) demonstrates that people sometimes misinterpret passive constructions by incorrectly assigning thematic roles to event participants (i.e., assigning the agent role to the subject and the theme role to the object. This reflects a reliance on non-structural factors (e.g., language experience, semantic plausibility, world knowledge) during language activities.

Previous research on this framework appears somewhat biased, as it has predominantly examined a narrow range of languages, mainly focusing on (L2-)English (Dwivedi, 2013; Ferreira, 2003; Lim & Christianson, 2013, 2015; Qian et al., 2018; Swets et al., 2008; Tan & Foltz, 2020), leading to an English-centric view (cf. Blasi et al., 2022). A comprehensive understanding of human sentence processing requires systematic investigation across a broader range of languages, including those typologically distinct from English. Some research on non-English languages within this framework has highlighted the robustness of semantic information over structural information (e.g., Stoops et al., 2014 for Russian; Zhou et al., 2018 for Mandarin), but there is a notable scarcity of literature extending this research to languages beyond the predominant ones studied. This raises questions as to whether the processing patterns observed in major languages apply to speakers of underrepresented languages and how speakers of those languages utilise various cues during sentence processing within this framework.

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Including lesser-studied languages and contexts in this line of research can enhance the good-enough processing framework by incorporating diverse linguistic structures and language-specific adaptations not typically found in languages dominant in the field, thereby refining the current understanding of this framework.

This study aims to address this gap by examining Korean, a language that has received limited attention in this context despite its increasing prominence in sentence-processing research (Hwang & Kaiser, 2014; Kim, 1999; Kwon & Sturt, 2019). Korean is an agglutinative, Subject–Object–Verb language in which case particles allow for word-order variations through the scrambling of sentential components (Sohn, 1999). Verbal morphology provides another type of grammatical information crucial for forming clausal constructions. The interplay between word-order scrambling and verbal morphology offers a novel testing ground for examining how the good-enough processing framework—represented by two parsing routes (Section 2)—illuminates Korean speakers' sentence-processing behaviour in conjunction with language-specific properties of clausal constructions (Sections 3 and 4).

2. Heuristic versus algorithmic parsing

The good-enough processing framework posits two parsing routes: algorithmic parsing versus heuristic parsing. The former aims for an accurate analysis based on structural cues from the current input. This route resolves temporal (syntactic) ambiguities by considering various representations on a moment-by-moment basis, whether this be purely structural (Ferreira & Clifton, 1986; Frazier, 1979) or be partly informed by probabilistic knowledge (Hale, 2001; Levy, 2008), and revises a prior analysis when the current material biases against the previously processed information. In contrast to this veridical computations, heuristic parsing offers a faster, less effortful interpretation based on non-structural schemata and usage-based expectations about the incoming input. This route exploits readily accessible options from memory, often resulting in shallow, underspecified representations rather than detailed, structural ones (Christianson, 2016; Ferreira, 2003).

Previous research has shown that these routes do not always operate simultaneously or in parallel. Evidence suggests that the parser often prioritises non-structural forces (i.e., heuristic parsing) while selectively engaging in syntactic computation (i.e., algorithmic parsing) based on the task (Ferreira, 2003; Ferreira & Patson, 2007; Karimi & Ferreira, 2016; Lim & Christianson, 2013). For example, Dwivedi (2013) observed that English speakers tend to favour surface scope interpretations over deep, structure-based processing when resolving ambiguity in quantifier scope, suggesting that heuristic parsing often takes precedence. Similarly, Kharkwal and Stromswold (2014) demonstrated that English speakers prefer heuristic-based analysis when interpreting active and passive sentences, as evidenced by faster reaction times in sentence–video matching tasks when only exposed to active-voice sentences. These findings support the notion that comprehenders sometimes rely more on usage-based knowledge than on detailed structural computations.

The primary role of heuristic parsing over algorithmic parsing is supported by various concepts and models of sentence processing. The online cognitive equilibrium hypothesis (Karimi & Ferreira, 2016) provides a theoretical basis for the heuristic-over-algorithm strategy. This hypothesis assumes that new linguistic items present a cognitive challenge (online disequilibrium), prompting the parser to quickly restore and maintain cognitive equilibrium using less effortful heuristics rather than demanding algorithms. Although heuristic parsing can sometimes lead to misinterpretation (Christianson et al., 2001; Ferreira, 2003), it offers the advantage of achieving cognitive equilibrium with minimal processing demands (Ferreira et al., 2002), thereby aligning with *the principle of least effort* (Jaeger, 2010; Piantadosi et al., 2012; Zipf, 1949). The Late Assignment of Syntactic Theory model (Townsend & Bever, 2001) posits a two-stage mechanism where initial non-syntactic pseudo-parsing, guided by semantic associations and syntactic habits, creates broad-level representations (e.g., Noun–Verb–Noun templates). These broad representations are then refined through detailed, time-consuming structural computations for final syntactic representations. In this model, the parser initially relies on shallow representations before engaging in thorough parsing, which can lead to inconsistencies between pseudo-parsing and true parsing, resulting in misinterpretation (Gibson, 1998; Lewis et al., 2006; Vosse & Kempen, 2000). Given the high demands of real-time processing and noisy linguistic cues (Gibson et al., 2019) within the lossy memory (Christiansen & Chater, 2016), the parser opts for a trade-off between accuracy and efficiency, favouring readily available options unless they significantly distort communicative intents (Jaeger & Tily, 2011; Kleinschmidt & Jaeger, 2015). The parser's operational patterns described here is consistent with how information processing occurs in other cognitive domains (Gigerenzer et al., 1999; Henderson et al., 2001; Metzger & Flanagin, 2013; Volz & Gigerenzer, 2012).

Usage information, including morpho-syntactic typicality and semantic/pragmatic plausibility, is one major driver of heuristic parsing (Ferreira, 2003; Townsend & Bever, 2001). Language users build linguistic representations from frequent exemplars encountered throughout their lives, which are stored as structured inventories of linguistic repertoires or abstract sets of prefabricated chunks (Ellis, 2002; Tomasello, 2003). These sets of knowledge—clusters of conventionalised form–function pairings (Goldberg, 2019)—emerge and develop as associative connections in long-term memory and serve as automatic chains that ensure faster and less effortful retrieval of relevant linguistic information (Bates & MacWhinney, 1989; Goldberg, 2019). Evidence shows that sentence processing is sensitive to the usage frequency of constructions, which influences the utilisation of linguistic and non-linguistic resources (Ellis, 2002; Levy, 2008; McRae & Matsuki, 2009; Wells et al., 2009) and supports processing efficiency (Boston et al., 2008; Demberg & Keller, 2008). It is thus reasonable to assume that form–function associations reliably and frequently attested in language use, such as typical alignments between thematic roles and case markers in a clause, promote heuristics which are easily accessible from memory, thus contributing to processing efficiency.

Several studies reported the opposing view, asserting that algorithmic parsing is the dominant, and perhaps the only, component of the human parsing mechanism (Bader & Meng, 2018; Meng & Bader, 2021; Paolazzi et al., 2019; Paolazzi et al., 2021). This perspective, however, may not fully justify its rejection of heuristic parsing in language processing. In addition to the variations in task demands across these studies (e.g., plausibility judgment, agent/patient naming, self-paced reading, eye-tracking), the inclusion of different voice types (active vs. passive), each with varying degrees of linguistic complexity, complicates the assessment of how the two parsing routes operate during comprehension. While we do not claim that frequency distinctions between active and passive constructions in previous research are inherently problematic, we contend that these distinctions complicate the precise evaluation of the individual and interactive roles of heuristic and algorithmic parsing, independent of the potential effects of task type or voice type on language users' processing behaviour. This underscores the need for further investigation into how these parsing routes, and the good-enough processing framework more broadly, operate across a wider range of languages—particularly those that are typologically distinct from the major languages previously studied—and across voice types beyond the active–passive distinctions.

In the present study, we investigate the online processing of two types of clausal constructions—suffixal passive (Section 3) and morphological causative (Section 4)—by native Korean speakers under different word-order conditions through self-paced reading experiments. The two construction types are distinctive in the mapping

relations between thematic roles and case markers (e.g., atypical and infrequent pairings in the passive [theme–nominative, agent–dative]; typical and frequent pairings in the causative [agent/causer–nominative, recipient/causee–dative]) but are comparable in their structural composition (e.g., the attachment of a voice suffix to a verb stem and its modulation of valency) and usage frequency.[1] Considering the caveats identified in previous literature, we controlled for voice type so that each target construction maintains consistent linguistic cues for evaluating the operation of the two parsing routes in sentence comprehension. By contrasting verb-final (canonical and frequent) and verb-initial (non-canonical and infrequent) patterns within each voice type (passive; causative), we seek to alleviate the unintended influence of voice contrast (e.g., active versus passive) and associated factors, such as the stark differences in usage frequency between active and passive voices (with actives being far more frequently used than passives), thereby isolating their effects on sentence comprehension. Specifically, we believe that the varying frequencies of the two word-order patterns within each construction type, where canonical word order is substantially more common than scrambled word order, enable us to better illuminate the operation of the two parsing routes.

3. Experiment 1: Suffixal passive construction

Compared to the active voice, the passive voice is marked across languages (Haspelmath, 1990; Siewierska, 2013), and its usage in Korean is notably infrequent (Park, 2021; Woo, 1997). Within the suffixal passive, the canonical word-order pattern—which is frequent in use—involves two arguments, a theme subject and an agent oblique, followed by a passivised verb, as in (1a). The passive morphology, marked by one of four allomorphic variants of verbal suffixes (*−i/hi/li/ki-*) (Choo & Kwak, 2008; Sohn, 1999), is crucial for identifying the sentence's structural properties and reducing the verb's valency (i.e., from two valency slots of a transitive verb to one valency slot of a passivised verb). The verb can be moved to the beginning through scrambling, resulting in a verb-initial pattern—which is infrequent in use—as in (1b). This pattern is found in colloquial Korean to provide clarification, amplify information, or emphasise points (Sohn, 1999).

(1) Example of suffixal passive in Korean: 'The thief was caught by the police.'

a. Verb-final pattern

Totwuk-i	kyengchal-hanthey	cap-hi-ess-ta.
thief-NOM	police-DAT	catch-PSV-PST-SE[2]

b. Verb-initial pattern

Cap-hi-ess-ta	totwuk-i	kyengchal-hanthey.
catch-PSV-PST-SE	thief-NOM	police-DAT

These two passive patterns reveal distinct characteristics in the timing of clausal integration. In the verb-final pattern (1a), although the word order is canonical and frequent, the passive morphology appears late in the sentence, requiring the comprehender to revise the initial analysis made before encountering this cue. In Korean, the nominative-marked [+animate] argument is typically interpreted as an agent, and the dative-marked [+animate] argument as a recipient, supported by strong associations between thematic roles and case markers (Kim & Choi, 2004; Sohn, 1999). Consequently, an initial interpretation of (1a) is that the thief acts on or for the police. However, this initial analysis conflicts with the passive voice indicated by verbal morphology. Upon reaching the verb at the end of the sentence, the comprehender must revise their interpretation as required by the passive morphology, reassigning thematic roles to each argument accordingly. In contrast, the verb-initial pattern (1b) features a non-canonical and infrequent word order where the fronted verb and its morphology provide an early cue. This early cue prevents potential misinterpretations of the arguments' thematic roles since verbal morphology clarifies the sentence structure and guides the subsequent interpretation of the arguments (cf. Pozzan & Trueswell, 2015). Therefore, in (1b), the passivised verb at the beginning of the sentence indicates early on that the nominative-marked entity, the thief, is the theme and the dative-marked entity, the police, is the agent, counteracting typical associations between thematic roles and case markers.

With these in mind, Experiment 1 tested these predictions using a self-paced reading task, where native Korean speakers were presented with suffixal passive constructions in two different word-order conditions as outlined in (1). The asymmetric timings of disambiguation between these patterns allow us to examine how native Korean speakers utilise the two parsing routes—heuristics (word-order canonicity) versus algorithms (revising initial interpretations driven by passive morphology)—in Korean sentence comprehension, given the atypical associations between thematic roles and case markers present in the passive structure. We note that the current study did not manipulate the presence/absence of verbal morphology directly (as in the case of comparing actives and passives; cf. Bader & Meng, 2018; Paolazzi et al., 2019). Instead, our investigation centred on how the presence of verbal morphology affects readers' processing patterns. Incorporating verbal morphology in the target construction is crucial for evaluating how interpretive procedures driven by verbal morphology cues (representing algorithmic parsing, which involves detailed, computationally demanding processing) interplay with word-order effects (representing heuristic parsing, based on usage-based distributional and local cues), while keeping the nature of associations between thematic roles and case markers constant within the construction. The use of verb-initial structures introduces "unexpected scrambling," providing an opportunity for early-appearing verbal morphology cues to guide subsequent interpretation while disentangling word-order canonicity. Such insights would not be achievable by merely comparing active versus passive structures with the verb-finality maintained. We believe the approach we take in our study will more effectively reveal how the good-enough processing framework addresses sentence-processing behaviour amongst native Korean speakers; examining the presence/absence of verbal morphology (and its repercussions) within the experimental design might open another line of inquiry into sentence processing.

3.1. Methods[3]

3.1.1. Participants

We recruited 40 native speakers of Korean (mean age = 23.6; *SD* = 4.1) from a university in South Korea. All participants reported having spoken Korean as their first language since early childhood and had normal or corrected-to-normal vision. None of the participants reported any reading difficulties.

3.1.2. Stimuli

We created 16 Korean suffixal passive sentences, divided into eight verb-final and eight verb-initial patterns. Each sentence included a consistent carrier phrase (e.g., *Nay-ka tul-ess-nuntey*, 'I heard that'), followed by the critical passive structure ('theme–agent–verb' for the verb-final condition; 'verb–theme–agent' for the verb-initial condition) and a temporal adverbial phrase consisting of two words (e.g., *ecey pam-ey*, 'last night'), as illustrated in (2). The sentences were

[1] Normed frequency (per one million words) of sentences with passive or causative suffixes found in the Sejong corpus (annotated with morpheme and semantic information; total word count: 15,674,039): [type frequency] 6.32 passive-suffix sentences and 4.59 causative-suffix sentences, $\chi^2(1) = 0.274$, $p = 0.600$; [token frequency] 76.81 passive-suffix sentences and 55.76 causative-suffix sentences, $\chi^2(1) = 0.274$, $p = 0.067$.

[2] Abbreviations: ACC = accusative case maker; COMP = complementiser; CST = causative suffix; DAT = dative marker; N = noun; NOM = nominative case marker; PST = past tense marker; PSV = passive suffix; REL = relativiser; SE = sentence ender; TIME = time marker; V = verb.

[3] See this repository for the data and code used in this study.

counterbalanced across two lists for the two word-order conditions, with each participant exposed to only one condition. Each sentence was divided into six regions (Rs), with R2, R3, and R4 as the main focus, and R5 included to account for potential spill-over effects due to button-press strategies (e.g., Koornneef & Van Berkum, 2006). The test stimuli were mixed with 60 filler sentences of varying word order, structures, and complexity.

(2) Example of test sentences: Suffixal passive ('I heard that Huyswu was hugged by Mincay last night.')

a. Verb-final condition

[Nay-ka tul-ess-nuntey]$_{R1}$	[Huyswu-ka]$_{R2}$	[Mincay-hanthey]$_{R3}$
I-NOM hear-PST-COMP	Huyswu-NOM	Mincay-DAT
[an-ki-ess-tay]$_{R4}$	[ecey]$_{R5}$	[pam-ey.]$_{R6}$
hug-PSV-PST-SE	yesterday	night-TIME

b. Verb-initial condition

[Nay-ka tul-ess-nuntey]$_{R1}$	[an-ki-ess-tay]$_{R2}$	[Huyswu-ka]$_{R3}$
I-NOM hear-PST-COMP	hug-PSV-PST-SE	Huyswu-NOM
[Mincay-hanthey]$_{R4}$	[ecey]$_{R5}$	[pam-ey.]$_{R6}$
Mincay-DAT	yesterday	night-TIME

Prior to the self-paced reading task, we conducted a norming task to evaluate Korean speakers' general acceptance of the test sentences used in the main experiment. Given that verb-initial sentences were presented without any contextual support for the scrambling, it was crucial to confirm that participants would accept this structure as grammatical, albeit less so than the verb-final sentences. Ten native Korean speakers, who did not participate in the main experiment, assessed the grammaticality of the test sentences on a binary scale (i.e., grammatically correct or incorrect). The mean ratings were 100 % ($SD = 0$) for the verb-final sentences and 93.8 % ($SD = 0.24$) for the verb-initial sentences, indicating that both sentence types were generally accepted as grammatical. The inspectors noted that any rejection of verb-initial sentences was due to a preference issue related to the lack of context rather than a grammatical difference between the two conditions. These results confirmed that our experimental sentences were grammatically acceptable.

3.1.3. Procedure

The self-paced reading task was conducted using *PCIbex* (Zehr & Schwarz, 2018). Research has revealed that data collection via web-based platforms is as reliable as laboratory-based experimentation (Hilbig, 2016; Kim et al., 2019; Slim & Hartsuiker, 2022). We further ensured data quality by inviting participants to a *Zoom* meeting room and supervising their performance in real time. The task employed a non-cumulative moving-window paradigm (Just et al., 1982), with each target sentence appearing region-by-region at the centre of the screen. At the start of each trial, participants saw a series of dashes, and pressing the spacebar revealed words in each region while hiding previously displayed words, allowing participants to process the sentence at their own pace. After each sentence, a comprehension check question appeared to ensure participants attended to the sentence's meaning. Participants answered by selecting one of two options presented below the question. These questions focused on the target event (e.g., *What did the subject do?*), differing from previous studies that typically asked about an agent or a theme to gauge comprehension (e.g., Ferreira, 2003). The responses were used solely for attention checks (cf. Dwivedi, 2013), with an error rate of less than 3 % (see Section 3.1.4). Participants received written instructions and completed three practice items to familiarise themselves with the experimental procedure. The entire task took approximately 25 min per participant.

3.1.4. Analysis

Before conducting the main analysis, we pre-processed the data from the self-paced reading task by excluding (i) trials where participants answered the comprehension question incorrectly (data loss: 2.5 %), (ii) extreme reading times exceeding 5000 ms or below 100 ms (data loss: 0.2 %)[4], and (iii) outliers more than three standard deviations from the mean (data loss: 1.7 %). We then log-transformed the cleaned data to approximate a normal distribution and converted them to residual reading times to account for variability in word length and individual reading speed. For residualisation (following Trueswell et al., 1994), we first generated predicted reading times for each participant using a linear mixed-effects model with word length (i.e., number of syllables) as a fixed effect and *Participant* as a random effect. Residual reading times were calculated by subtracting the predicted reading times from the log-transformed reading times for each participant.

To address our research question more effectively, we compared residual reading times between the verb-final and verb-initial conditions using two separate analyses. In a global analysis, we performed a linear mixed-effects regression (Bates et al., 2015) on the residual RTs for the critical frames corresponding to the passive structure (from R2 to R4) and the spill-over region (R5). This analysis aimed to determine which word-order condition posed a greater processing challenge. We included *Word Order* (verb-final, verb-initial) as a fixed factor in the regression model, as well as random effects of *Participant* and *Item*. The fixed factor was centred around the mean and deviation-coded (assigning −0.5 to the verb-final condition and 0.5 to the verb-initial condition). The models included the maximal random-effects structure supported by the design with uncorrelated random intercepts and slopes for the fixed effect (Barr et al., 2013).

In addition to the global analysis, we conducted a regional analysis focusing on the verb to detect any evidence of reanalysis effects induced by passive morphology in the verb-final condition compared to the verb-initial condition. For this analysis, we fitted another mixed-effects regression model to residual reading times on the verb, examining R4 in the verb-final condition versus R2 in the verb-initial condition. Analogous to the global analysis, the model in the regional analysis included *Word Order* (verb-initial versus verb-final) as a fixed effect (centred and deviation-coded) as well as *Participant* and *Item* as random effects. The maximal random-effects structure included random slopes and random intercepts for both participants and items.

3.2. Predictions

For the verb-final condition, we anticipated slower reading times at R4 and/or R5, as participants would need to revise an initial erroneous interpretation (from agent–recipient to theme–agent) upon encountering the verb and its passive morphology. For the verb-initial condition, if participants proactively and strongly utilise the passive-voice information conveyed by the fronted verb (as an example of algorithmic parsing), we expect constant or reduced reading times as the sentence progresses. This is because the early-appearing passive morphology provides an early disambiguation cue, minimising the need for reanalysis and suppressing typical associations between thematic roles and case markers as the sentence unfolds. This supports algorithmic parsing, highlighting the primary role of structural computations in sentence processing. In contrast, if participants prioritise the canonicity of word order and the typicality of the arguments' thematic roles informed by case markers (as an example of heuristic parsing) over immediate structural analysis prompted by verbal morphology cues, we would anticipate longer processing times throughout the entire passive frame in the verb-initial condition. This arises from (i) the less common use of

[4] This cut-off value was selected to exclude extremely long reading-time values while retaining as many data points as possible, taking into account the overall distribution of the data.

scrambling in context-neutral settings and (ii) the unusual and infrequent pairings between thematic roles and case markers that characterise the passive frame. Both factors are expected to impose a greater cognitive load, resulting in increased processing latencies, despite the fronted verb potentially facilitating early computations of the structural cues present in the remaining passive frame. This supports heuristic parsing, emphasising the primary role of usage-based and/or underspecified representations in sentence processing.

3.3. Results and discussion

Table 1 presents participants' trimmed raw reading times per region. Inspection of the residual reading-time profiles (Fig. 1) indicated a clear numeric trend of longer reading times in the verb-initial condition compared to the verb-final condition across all regions of interest.

Results of the global and regional analyses are summarised in Table 2. The global analysis, which compared reading times across the passive frame (R2 to R4) between the two conditions, showed no main effect of *Word Order*, indicating that participants exhibited comparable reading times between the two conditions. The reading-time difference was pronounced and statistically significant in the spill-over region (R5), indicating a processing challenge in the verb-initial condition. In the regional analysis, focusing specifically on the verb, the statistical model did not reveal a main effect of *Word Order*. This indicates that the time spent by participants on the verb did not significantly differ between the two conditions, irrespective of its position within the sentence.

The results from both global and regional analyses suggest that (i) participants experienced similar levels of processing difficulty in the verb-initial and verb-final conditions, and (ii) there was no additional processing load observed at the verb in the verb-final condition relative to the verb-initial condition. These findings could be interpreted in several ways regarding the operation of two parsing routes. For instance, the fronted verb and its passive morphology may not have provided a significant processing advantage for comprehending passive constructions. Alternatively, participants might have predominantly relied on more frequent and easily accessible schemata (e.g., canonical word order, typical associations between thematic roles and case markers) rather than immediately engaging in the more complex and time-consuming computations associated with verbal morphology cues. Moreover, this routinised processing behaviour within a clause might have extended into clausal integration beyond the clausal boundary. Taken together, these interpretations offer limited evidence supporting the active role of early-appearing verbal morphology cues in processing verb-initial suffixal passive sentences. In other words, the expected benefits of the fronted verbal morphology may not have been sufficient to outweigh the processing advantages of canonical word order, which is more readily retrieved from memory and could mitigate the interpretive challenges posed by the passive morphology at the end of a sentence. This may point to the heuristics-before-algorithm parsing strategy, consistent with the central argument of the good-enough processing framework.

Nonetheless, caution is warranted in drawing definitive conclusions from Experiment 1. The comparable reading times across the two conditions in the passive frame and across the verb regions between the two conditions imply that heuristic parsing might have been counterbalanced by algorithmic parsing, contrary to our predictions and interpretations. In addition, the fronted verb may elicit surprisal effects, potentially heightening the interpretive challenge independently of verb-initiality itself and thereby serving as a confounding factor. Furthermore, our study examined only one construction with two significantly different word-order patterns in terms of cognitive equilibrium, which limits the generalisability of our findings. According to the cognitive equilibrium hypothesis, the parser primarily employs heuristic parsing to manage cognitive challenges during processing (Karimi & Ferreira, 2016). This hypothesis implies that heuristic parsing is less likely when the linguistic input induces minimal disequilibrium. To robustly support conclusions about the two parsing routes, further evidence is needed to show how the parser functions under conditions of potentially lower cognitive disequilibrium in online processing. To address this, we conducted a follow-up experiment using Korean morphological causative constructions, which are expected to induce less cognitive disequilibrium than the suffixal passive.

4. Experiment 2: Morphological causative construction

A morphological causative construction involves three arguments: a subject (causer), an indirect object (causee), and a direct object (theme), as in (3a). The verb conveys a causative meaning through one of the seven allomorphic variants of verbal suffixes (*-i/hi/li/ki/wu/kwu/chwu-*), which also increases the verb's valency slots (Choo & Kwak, 2008; Sohn, 1999). Similar to the suffixal passive, the verb in the morphological causative can be positioned at the start of the sentence, as in (3b).

(3) Example of morphological causative in Korean: 'Yengswu made Minci eat food.'
a. Verb-final pattern
Yengswu-ka Minci-eykey umsik-ul mek-i-ess-ta.

(*continued on next page*)

Table 1
Trimmed raw reading times (standard deviations) in Experiment 1.

Condition	R1	R2	R3	R4	R5	R6
Verb-final		N1-NOM	N2-DAT	V-PSV		
	311.1	348.9	349.0	356.6	353.4	350.7
	(152.0)	(162.4)	(166.4)	(150.4)	(125.5)	(123.6)
Verb-initial		V-PSV	N1-NOM	N2-DAT		
	319.2	368.1	393.3	383.8	407.4	398.7
	(122.8)	(161.5)	(155.5)	(172.3)	(160.2)	(148.1)

Note. The shaded regions (R2 to R4) correspond to the passive frame.

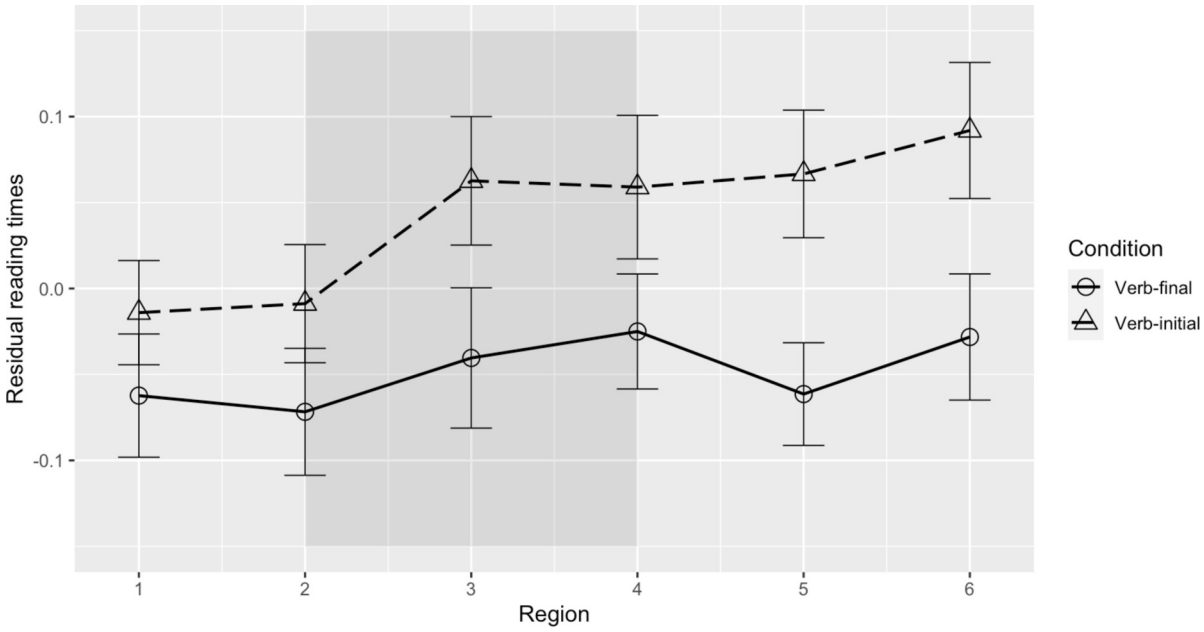

Fig. 1. Residual reading times in Experiment 1. Error bars denote 95 % CIs. The shaded rectangle represents the regions corresponding to the passive frame.

Table 2
Model outcomes of the global and regional analyses in Experiment 1 (α = 0.05).

			ß	*SE*	*t*	*p*
Global analysis	R2 to R4 (critical)	Intercept	–0.012	0.023	–0.553	.581
		Word order	0.086	0.045	1.916	.057
	R5 (spill-over)	Intercept	0.004	0.025	0.156	.876
		Word order	0.132	0.047	2.794	.007**
Regional analysis (R2 in the verb-initial condition vs. R4 in the verb-final condition)		Intercept	–0.016	0.025	–0.653	.518
		Word order	0.017	0.053	0.317	.761

Note. Formula: ResidualRT ~ Word Order + (1 + Word Order | Participant) + (1 + Word Order | Item).

(*continued*)

Yengswu-NOM	Minci-DAT	food-ACC	eat-CST-PST-SE
b. Verb-initial pattern			
Mek-i-ess-ta	Yengswu-ka	Minci-eykey	umsik-ul.
eat-CST-PST-SE	Yengswu-NOM	Minci-DAT	food-ACC

The interpretation of thematic roles in the morphological causative relies on the causative morphology, similar to the suffixal passive. However, the revision process for the morphological causative does not pose considerable challenges compared to the passive morphology. For example, in the canonical and frequent word-order example (2a), the nominative-marked [+animate] argument is understood as a causer (extending the concept of an agent or volitional actor). The dative-marked [+animate] argument is understood as a causee (extending the concept of a recipient), with the dative marker ensuring this by sharing the semantic component—GOAL (Sohn, 1999). While these interpretations are linked to the causative morphology, it does not require the same recalibration of thematic roles as the passive morphology does, nor does it disrupt the typical associations between thematic roles and case markers. Consequently, the challenges posed by verbal morphology in real-time processing of the morphological causative are relatively minimal.

The two morphological causative patterns offer an opportunity to further investigate the two parsing routes in light of the findings from Experiment 1. While these patterns show similar disambiguation timings as observed in the suffixal passive patterns, the morphological causative features different associations between thematic roles and case markers (which are more frequent and expected in language use) and interpretive procedures invited by verbal morphology. To explore this, we conducted another self-paced reading task with the two word-order patterns of the morphological causative, similar to the experimental setting used in Experiment 1.

4.1. Methods

4.1.1. Participants and stimuli

The same native Korean speakers (n = 40) who participated in Experiment 1 took part in this experiment one week to ten days later. We designed 16 test sentences, with an equal split between the verb-final and verb-initial patterns. To facilitate a direct comparison between

Experiments 1 and 2, we structured the target sentences similarly to those in Experiment 1. Specifically, we topicalised the direct object by placing it at the start of the sentence, ensuring that the target frame (R2 to R4) includes a nominative-marked NP, a dative-marked NP, and the verb, as in (4), thereby closely mirroring the structure used in Experiment 1.

(4) Example of test sentences: morphological causative ('That shoe over there, Senhuy made Yengswu wear last night.')

a. Verb-final condition

[Ceki iss-nun sinpal]$_{R1}$,	[Senhuy-ka]$_{R2}$	[Yengswu-hanthey]$_{R3}$
that be-REL shoe	Senhuy-NOM	Yengswu-DAT
[sin-ki-ess-tay]$_{R4}$	[ecey]$_{R5}$	[pam-ey.]$_{R6}$
wear-CST-PST-SE	yesterday	night-TIME

b. Verb-initial condition

[Ceki iss-nun sinpal]$_{R1}$,	[sin-ki-ess-tay]$_{R2}$	[Senhuy-ka]$_{R3}$
that be-REL shoe	wear-CST-PST-SE	Senhuy-NOM
[Yengswu-hanthey]$_{R4}$	[ecey]$_{R5}$	[pam-ey.]$_{R6}$
Yengswu-DAT	yesterday	night-TIME

Participants were randomly assigned to one of two lists, which were counterbalanced for word order between the two conditions (verb-final, verb-initial). Ten native Korean speakers, who did not take part in either Experiment 1 or Experiment 2, assessed the grammaticality of the experimental sentences using a binary scale (i.e., grammatically correct or incorrect). Acceptability ratings were 100 % for sentences in the verb-final condition ($SD = 0$) and 93.8 % for sentences in the verb-initial condition ($SD = 0.24$). The lower rating for the verb-initial condition was attributed to sentences involving scrambling without relevant context. Despite this, the high grammaticality ratings for both conditions indicate that the experimental stimuli were generally deemed grammatical. The test sentences were mixed with 60 fillers featuring various structures.

4.1.2. Procedure and analysis

The procedure for Experiment 2 was identical to that of Experiment 1. Data from the self-paced reading task were processed in the same way as in Experiment 1. We excluded incorrect responses on the comprehension check (data loss: 2.5 %), response times longer than 5000 ms or shorter than 100 ms (data loss: 0.1 %), and those beyond three standard deviations from the mean (data loss: 1.7 %). The remaining data were converted to log-transformed residual reading times.

For statistical modelling, we employed linear mixed-effects regression to analyse the effect of *Word Order* (centred and deviation-coded; verb-final: −0.5, verb-initial: 0.5) on residual reading times in both the single frame corresponding to the causative structure (R2 to R4) and the spill-over region (R5). The model included the maximal random effect structure permitted by the design, including by-participant and by-item random slopes and intercepts for *Word Order* (Barr et al., 2013).

In addition to this analysis, we combined the data from Experiments 1 and 2 to assess participants' sensitivity to word-order manipulation across the two construction types (i.e., suffixal passive and morphological causative). This combined analysis helps control for potential confounds present in separate analyses of each construction. In each experiment, comparisons were made between verbs in different positions (clause-final versus clause-initial), with systematic differences in the words preceding the verb that could have influenced reading times in the verb region. By integrating data from both experiments, we compared the same pairs of word-order conditions with the only variable being the construction type, allowing for a more direct comparison of reading times on the verb region across conditions. For this analysis, we fitted a linear mixed-effects model to residual reading times in both the critical region (R2 to R4) and the spill-over region (R5), incorporating fixed factors of *Construction* (centred and deviation-coded; passive: −0.5, causative: 0.5) and *Word Order* (centred and deviation-coded; verb-final: −0.5, verb-initial: 0.5), and random effects for *Participant* and *Item*. To address a model convergence error, we simplified the random effects structure by removing by-item random slopes for *Item*.

4.2. Predictions

Since the morphological causative does not require a drastic recalibration of initial interpretations (due to the typical associations between thematic roles and case markers) unlike the suffixal passive, speakers are expected to experience less cognitive load than in Experiment 1. Consequently, reliance on word-order properties might decrease, allowing participants to use information from the fronted verb and its causative morphology more effectively. This would result in shorter reading times for the verb-initial condition compared to the verb-final condition over the causative frame, supporting evidence for algorithmic parsing. Alternatively, if the presumed computational advantage of verb-initiality (as an example of algorithmic parsing) does not substantially outweigh the typicality associated with word order and the mapping relations between thematic roles and case markers (as examples of heuristic parsing), we would observe no considerable difference in reading times between the two conditions, consistent with the findings of Experiment 1. The comparable reading times across both conditions would then indicate a major role of heuristic parsing in processing this construction type, given the reduced complexity of interpretive procedures involving verbal morphology within the causative frame.

4.3. Results and discussion

Table 3 presents participants' trimmed raw reading times in each region. As shown in Fig. 2, participants spent numerically shorter reading times in the verb-initial condition than in the verb-final condition.

Results of the mixed-effects regression are presented in Table 4. The models revealed no significant effect of *Word Order* in either the critical or spill-over regions. Furthermore, comparing reading times at the verb regions across the two conditions (R4 in the verb-final condition; R2 in the verb-initial condition) revealed no main effect of *Word Order* ($\beta = -0.105$, $SE = 0.052$, $p = 0.053$), indicating comparable reading times between the conditions. These findings suggest that the early-arriving morphological cue in the verb-initial condition did not provide substantial processing advantages. Additionally, there was no evidence that the non-canonical word order in the verb-initial condition caused significant processing difficulties for participants.

The outcomes of the full model with combined data from Experiments 1 and 2 are summarised in Table 5. The mixed-effects model fitted to reading times in the critical region (R2 to R4) showed no significant main effects of *Construction*, *Word Order*, or their interaction. In contrast, the model for the spill-over region (R5) revealed a significant interaction between the two factors. As illustrated in Fig. 3 and evident from the analysis of each construction in each experiment, this interaction was attributable to longer reading times in the passive/verb-initial condition compared to the other three conditions. Specifically, considering the potential influence of surprisal effects resulting from verb-initiality in the verb-initial conditions, the asymmetric reading-time patterns observed across the two construction types within the verb-initial condition indicate that verbal morphology cues were penalised differently. This is likely attributable to the typicality of the mapping relations between thematic roles and case markers in the remaining portion of the frame following the processing of the fronted verb.

5. General discussion and conclusion

In two self-paced reading experiments, we investigated how native Korean speakers engage in heuristic versus algorithmic parsing when comprehending Korean suffixal passive and morphological causative constructions. The results differed between the experiments. In

Table 3
Trimmed raw reading times (standard deviations) in Experiment 2.

Condition	Region 1	R2	R3	R4	R5	R6
Verb-final		N-NOM	N-DAT	V-CST		
	335.4	372.6	377.5	397.4	365.8	364.6
	(166.1)	(149.7)	(175.0)	(157.6)	(131.0)	(113.0)
Verb-initial		V-CST	N-NOM	N-DAT		
	323.7	373.2	364.9	360.1	353.6	346.4
	(174.0)	(175.0)	(162.6)	(147.5)	(114.3)	(103.3)

Note. The shaded regions (R2 to R4) correspond to the causative frame.

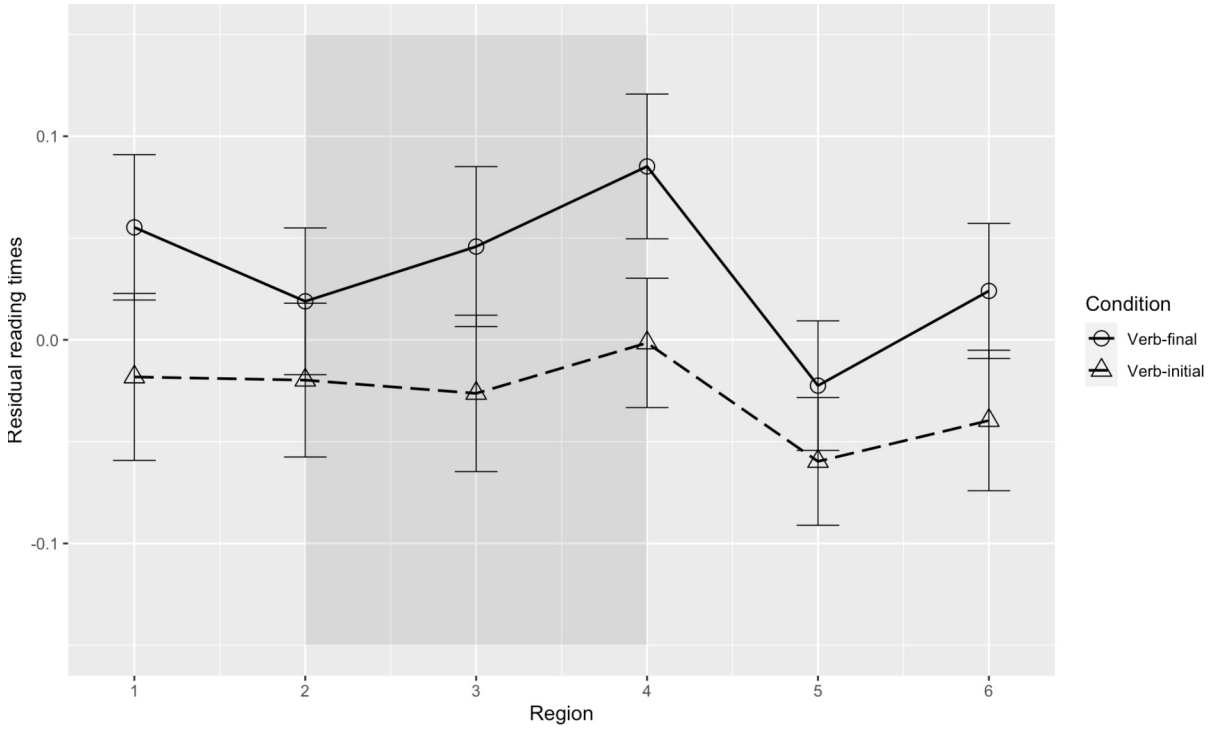

Fig. 2. Residual reading times in Experiment 2. Error bars denote 95 % CIs. The shaded rectangle represents the regions corresponding to the causative frame.

Table 4
Model outcomes of the analyses in Experiment 2 ($\alpha = 0.05$).

		β	*SE*	*t*	*p*
R2 to R4 (critical)	Intercept	0.013	0.022	0.567	0.571
	Word order	−0.034	0.060	−0.575	0.581
R5 (spill-over)	Intercept	−0.040	0.022	−1.864	0.064
	Word order	−0.042	0.065	−0.646	0.541

Note. Formula: ResidualRT ~ Word Order + (1 + Word Order | Participant) + (1 + Word Order | Item).

Experiment 1, which focused on the suffixal passive, participants spent comparable amounts of time reading both the verb-initial and verb-final conditions, with no significant difference in reading times at the verb region. However, the spill-over region showed a significant reading-time difference, with more time taken for the verb-initial condition compared to the verb-final condition. Experiment 2, which examined the morphological causative, revealed consistent reading-time patterns across the two word-order conditions (even at the spill-over region), which slightly differed from the findings in Experiment 1.

We take these findings across the two experiments as reflecting the interplay between usage-based heuristics and structure-based algorithms, with heuristics taking precedence over algorithms when disequilibrium arises due to cue competition. The online cognitive equilibrium hypothesis posits that speakers rely more on heuristic-based analysis than algorithm-based analysis when the latter is unable to optimise the integration of diverse cues (Karimi & Ferreira, 2016). This is exemplified by the processing patterns observed in the suffixal passive conditions in Experiment 1. To interpret verb-initial passive sentences, the parser must perform a number of concurrent tasks that call upon the integration of multiple cues, including handling scrambled word order (along with possible contextual motivations that licence this non-canonicity), identifying and computing thematic roles using case markers, and reconciling atypical word order with atypical pairings between thematic roles and case markers. On top of that, the parser must resolve conflicting information between the more frequent, canonical

Table 5
Model outputs of the analysis combining data from Experiments 1 and 2 (α = 0.05).

		β	*SE*	*t*	*p*
R2 to R4	Intercept	0.013	0.022	0.567	.571
(critical)	Word order	–0.034	0.060	–0.575	.581
R5	Intercept	–0.040	0.022	–1.864	.064
(spill-over)	Word order	–0.042	0.065	–0.646	.541

Note. Formula: ResidualRT ~ Construction * Word Order + (1 + Construction * Word Order | Participant) + (1 | Item).

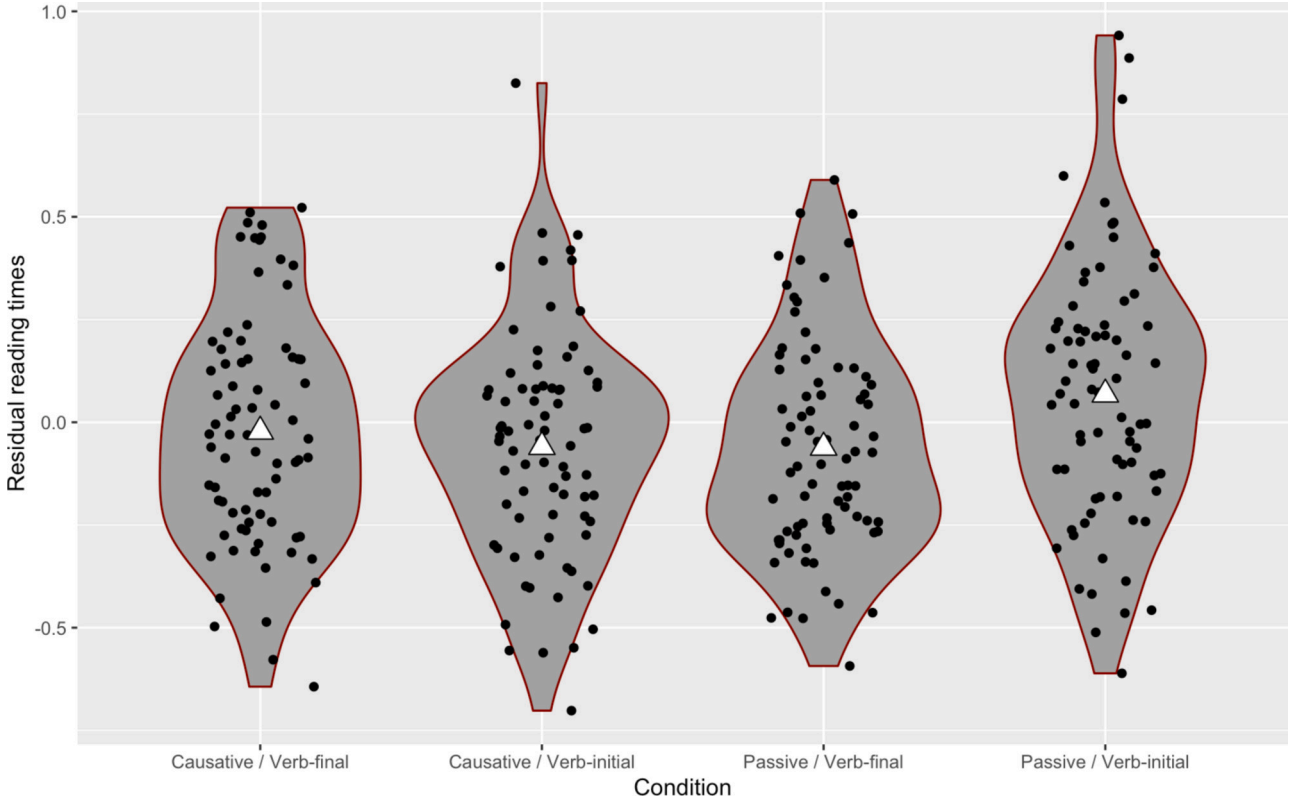

Fig. 3. Residual reading times in the spill-over region (R5) by *Construction* (passive, causative) and *Word Order* (verb-final, verb-initial). The white triangle indicates mean reading time.

alignment between thematic roles and case markers (agent–nominative; recipient–dative) and the less frequent, but correct, alignment between thematic roles and case markers (theme–nominative; agent–dative) required by passive morphology. These complexities induce strong cognitive disequilibrium, causing participants to overlook the potential advantage of an early-arriving morphological cue and continuously increasing their processing burden. In contrast, interpreting verb-final passive sentences is less taxing compared to verb-initial ones due to the word-order canonicity. This canonicity likely reduces processing complexity, enhances cue identification and integration, and facilitates achieving cognitive equilibrium more readily, even though it requires revising initial interpretive commitments at the verb region.

In Experiment 2, for the verb-initial condition, the parser engages in similar tasks as those required for processing the suffixal passive, such as managing non-canonical word order, checking the thematic fit of each argument, and integrating distributional and local cues. However, in contrast to the suffixal passive, the morphological causative does not require drastic recalibration of the associations between thematic roles and case markers due to their established mapping (i.e., agent/causer–nominative, recipient/causee–dative). This characteristic suggests that, given the less demanding nature of interpretive procedures involving this construction type in comparison to the suffixal passive, the within-construction frequency penalty associated with non-canonical word order in the verb-initial condition may have been mitigated by the early-arriving causative morphology to some degree, which facilitated the subsequent interpretation of incoming items until the spill-over region. Therefore, we attribute the observed reading-time patterns in the verb-initial morphological causative condition to the processing of thematic roles (indicated by case markers) linked to verbal morphology, in contrast to the verb-initial suffixal passive condition in Experiment 1.

It should be noted, however, that no robust differences were found in

reading times between the two word-order conditions in each construction type, both in global analyses (R2 to R4) and local analyses (R4 in the verb-final condition versus R2 in the verb-initial condition). These results suggest that the processing advantage provided by the early occurrence of verbal morphology was not sufficient to (i) outweigh the disadvantage of processing scrambled word order and (ii) compete with the advantage of processing canonical word order. One possible explanation for this outcome is the reduced role of a verb (and its morphology) in processing Korean sentences. Previous research has shown that, for speakers of verb-final languages such as Korean and Japanese, case-marking information becomes a more reliable cue than verb semantics for comprehension, allowing speakers to construct a mental model of the described event or engage in proactive processing even without the verb (Frenck-Mestre et al., 2019; Kamide et al., 2003; Kim, 1999). Consequently, it is plausible that our participants paid less attention to information from the verb (and verbal morphology) compared to case-marking information, leading to similar reading times across the two word-order conditions in both experiments. If this interpretation is valid, it sheds light on how language-specific properties (e.g., word order, case-marking, and verbal morphology in Korean) interact with general language-processing frameworks (e.g., the good-enough processing framework in this study). This invites the need for further research incorporating a range of lesser-studied languages and diverse usage contexts.

The possibility that the parser prioritises heuristic parsing over algorithmic parsing as a result of increased disequilibrium is further supported by the significant interaction observed in the composite analysis of the two experiments at the spill-over region (R5). Our experiments contrasted construction types based on the alignment between thematic roles and case markers (suffixal passive: theme–nominative and agent–dative; morphological causative: causer/agent–nominative and causee/recipient–dative), which are closely linked to the necessary computations from verbal morphology (verb-final: revision of initial interpretation; verb-initial: guidance of subsequent interpretation). Given these experimental settings, the suffixal passive/verb-initial condition likely required more effortful processing compared to the corresponding morphological causative condition at this region. Processing this region involves (i) evaluating accumulated input (including the non-canonicity of word order), (ii) implementing necessary modifications, and (iii) integrating computed information for complete clausal interpretation. Considering that the two construction types in this study present differing levels of computational challenges—the interpretive procedures driven by verbal morphology and the mapping relations between thematic roles and case markers, participants may have been more influenced by the non-canonicity of word order and the atypical associations between thematic roles and case markers (both of which conflict with heuristics) rather than by verb-initiality (which supports algorithmic computations) in the suffixal passive. This effect was not observed in the morphological causative.[4]

Overall, the findings of this study highlight the dynamic use of two parsing routes by native Korean speakers. We found (i) a preference for heuristic parsing over algorithmic parsing in the comprehension of the two clausal constructions, and (ii) an interaction between both parsing routes, modulated by construction-specific cues and usage factors in processing these structures. These results support the good-enough processing framework which argues that the parser utilises both heuristic and algorithmic approaches to maintain cognitive equilibrium during real-time task execution (Christianson, 2016; Ferreira, 2003; Karimi & Ferreira, 2016). In addition, our findings align with multi-stream models of sentence comprehension and processing (Kuperberg, 2007; Townsend & Bever, 2001; van Herten et al., 2006), which contend that the two parsing routes function both independently and interactively. More broadly, this study appeals to the general principles of human information processing that prioritise efficiency in handling current input in real time (Jaeger & Tily, 2011; O'Grady, 2015).

To clarify, we do not rule out the possibility that the participants used verb morphology for processing the suffixal passive, acknowledging that both heuristic and algorithmic parsing can be activated (see Section 2). While we do not reject the algorithmic parsing route played in sentence processing (cf. Bader & Meng, 2018; Meng & Bader, 2021; Paolazzi et al., 2019; Paolazzi et al., 2021), we propose is a heuristic-before-algorithm strategy, where the parser opts for a computationally simpler and more efficient mechanism in states of cognitive disequilibrium. The processing patterns observed in native Korean speakers for the suffixal passive suggest that heuristics may offer a computational advantage, facilitating quicker restoration and maintenance of cognitive equilibrium during sentence comprehension.[5] Our experimental setting effectively demonstrated this aspect, primarily documented amongst (L2-)English speakers (Dwivedi, 2013; Ferreira, 2003; Kharkwal & Stromswold, 2014; Lim & Christianson, 2015; Qian et al., 2018; Tan & Foltz, 2020), thus suggesting that the same kind of strategy can apply to sentence processing in Korean.

As a final remark, considering the limitations of the current study, we acknowledge that the findings and implications of this study should be replicated and validated through further research. For example, the topicalisation used in Experiment 2 (see Section 4.1.1) could have unintentionally influenced participants' performance. Specifically, compared to the general conversation initiator at R1 in Experiment 1, the case-less noun at R1 in Experiment 2 might have provided a more conducive context for processing the fronted verb, potentially reducing surprisal or disequilibrium in processing R2 for the verb-initial condition. Although this treatment was necessary to ensure comparability between the two experiments, the differing compositions of R1 could have affected the interpretation of the results. We hope that future studies can identify similar clausal constructions with minimal structural differences and replicate our findings. In addition, we made every effort to ensure data quality (see Footnote 3) and experienced a relatively low rate of data loss (see Sections 3.1.4 and 4.1.2), the number of items and native speaker participants was relatively small. Hence, increasing both the number of items and the sample size could enhance the statistical power of the results. Nevertheless, we believe the implications of this study offer a more nuanced understanding of how the two parsing routes operating within the good-enough processing framework address sentence-processing patterns in lesser-studied languages, revealing the degree to which language-specific adaptations—such as word order, case-marking, and verbal morphology in the case of Korean—inform sentence processing in these languages.

CRediT authorship contribution statement

Gyu-Ho Shin: Writing – review & editing, Writing – original draft,

[5] One reviewer proposed an alternative account for interpreting the findings of the two experiments through a gap-hunting strategy:In Experiment 1, when a verb is fronted, participants must engage in gap-hunting at the clause-final position, a requirement absent in the verb-final condition. Consequently, longer reading times were observed at the post-gap location (spill-over) where the verb is allocated immediately after the gap. In Experiment 2, the verb may again be fronted or not, and the direct object is always fronted. Thus, in both word-order conditions, participants must locate a gap for either the object alone or for the combination of the object and the verb. The absence of differences between these conditions could simply indicate that the gap-hunting process is equally recruited in both scenarios; hunting for an object gap is no more difficult than hunting for an object gap accompanied by its verb.While this approach appears to emphasise word order facts and may not clearly take into account the mapping relations between thematic roles and case markers—an essential aspect of heuristic parsing that we deliberately manipulated across our experiments—we concede that it may explain the current data as reasonably as our own approach. In this respect, future work would need to provide alternative methods to more effectively demonstrate evidence for heuristic parsing via the mapping relations between thematic roles and case markers at the interface of interpretive procedures driven by verbal morphology.

Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Chanyoung Lee:** Writing – review & editing, Resources, Project administration, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2025.104726.

Data availability

The data and code of this study are shared via an open-access repository (the link is provided in the manuscript).

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