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Electronic Journal of Foreign Language Teaching
2026, Vol. 23, Supplement, pp. 62–75

Exploring Korean Passive Sentence Processing in Chinese L2 Learners: An Eye-Tracking Study

Changkyung Song
(pg6886hj@snu.ac.kr)
Seoul National University, South Korea

Hyeyun Jeong
(tosirihy@snu.ac.kr)
Seoul National University, South Korea

Sixuan Zhu
(zhusixuan@snu.ac.kr)
Seoul National University, South Korea

Hojung Kim
(renata88@snu.ac.kr)
Seoul National University, South Korea

Abstract

This study investigates the processing of Korean passive sentences by 33 native Korean speakers and 37 advanced Chinese learners of Korean, using eye-tracking technology. Passive sentences are challenging because the mapping between thematic roles and syntactic structure does not align, unlike in active sentences where agents typically appear as subjects. In addition, Korean's use of morphological markers and flexible word order further complicates sentence processing. This study explores which sentence constituents impose higher cognitive demands and whether these demands differ between the two groups. It also examines how word order affects sentence processing and whether its impact varies across groups. The results show that Chinese learners, like native speakers, relied on case markers and experienced longer processing times at agent and patient arguments rather than the verb. However, unlike native speakers, who were unaffected by word order changes, learners showed higher cognitive load when processing sentences with scrambled word order. These findings underscore the importance of real-time processing research in understanding how learners' sentence processing differs from that of native speakers, offering insights into second language acquisition.

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Song, C., Jeong, H., Zhu, S., & Kim, H. (2026). Exploring Korean passive sentence processing in Chinese L2 learners: An eye-tracking study. *Electronic Journal of Foreign Language Teaching [e-FLT], 23* (Supplement), 62–75. https://doi.org/10.56040/chsh2316

1 Introduction

Passive sentences are known to be challenging for second language learners due to the differences in case and word order compared to active sentences. In active sentences, the agent typically takes the nominative case while the patient is marked as accusative. However, in passive sentences, the patient is marked as nominative, and the agent appears in the oblique case (Bock & Levelt, 1994; Hyams et al., 2006). Moreover, the agent usually follows the patient, deviating from the usual event structure and thereby increasing cognitive load (O'Grady & Lee, 2005).

As an SOV language, Korean requires integrative processing after the verb is encountered, since the preceding constituents can be unified into a coherent meaning at that point. While active meaning construction may already begin upon encountering preverbal elements, it is the final verb—especially in constructions like the passive—that plays a decisive role in confirming sentence structure and meaning. SOV constructions therefore impose additional processing costs on working memory, as preverbal constituents must be actively maintained until the verb is encountered and integration occurs (Engelhardt et al., 2024). Such cognitive load becomes particularly pronounced in passive constructions, where learners may initially interpret a nominative-marked noun phrase as the agent, only to reanalyze it as the patient upon encountering the final passive verb (Son et al., 2022). Mitsugi (2017) found that in Japanese—a language with an SOV structure similar to Korean—native speakers were able to assign thematic roles using case markers before reaching the verb in the incremental processing process, while learners struggled to use case markers as efficiently to predict these roles. As an agglutinative language with a well-developed system of case particles, Korean allows flexible word order, enabling both the typical patient-agent and the less common agent-patient order in passive sentences. These characteristics of Korean passives may pose challenges for learners whose native language, like Chinese, follows a relatively fixed SVO word order. Chinese learners of Korean present a particularly relevant group for examining passive sentence processing due to the typological distance between Chinese and Korean. Chinese lacks morphological case marking and has relatively rigid word order, making Korean's case-driven and word-order-flexible system especially challenging. This study, therefore, aims to use eye-tracking methods to examine in real time how Chinese learners process Korean passive sentences.

Previous studies have shown conflicting findings regarding how Chinese learners process Korean passive sentences. Jeong (2014) reported that Chinese learners processed dative passive sentences more quickly and accurately than nominative passive sentences. In dative passives, the agent appears and is marked by the particle 에게 (*eykey*) (e.g., 오빠에게 잡혀요 (*oppa-eykey caphyeyo*, "[someone is] caught by the brother")). In contrast, nominative passives include only the patient, marked by the particle 이/가 (*i/ka*) (e.g., 언니가 잡혀요 (*enni-ka caphyeyo*, "the sister is caught [by someone]")). Jeong (2014) interpreted this as possibly due to Chinese learners' reliance on the isomorphic mapping strategy through native language transfer (O'Grady & Lee, 2005) or their incomplete acquisition of the polysemous functions of the nominative particle 이/가 (*i/ka*) in both active and passive contexts, having instead learned only the simpler use of 에게 (*eykey*). In contrast, Kim (2021) reported that learners processed passive sentences with canonical word order—where the patient appears as the first noun—more effectively, highlighting the importance of case markers and verb morphology in processing Korean passives. However, Shin and Park (2023) found that canonical passive sentences required longer processing times, while the acceptability of scrambled sentences was judged to be lower in acceptability judgments. These conflicting findings make it unclear what linguistic cues—such as word order and case marking—learners rely on when processing Korean passive sentences, and whether this differs from native speaker strategies.

Furthermore, these studies employed tasks such as picture-sentence verification, where participants listened to or read a sentence and chose the matching picture, sentence acceptability judgments, collecting judgment outcomes and reaction times. However, these tasks did not directly capture the real-time processing that occurs as learners read sentences. To address these limitations, the present study used eye-tracking to observe online sentence processing. Eye-tracking provides fine-grained temporal data such as fixation durations, regressions, and rereading patterns, allowing researchers to infer how and when readers allocate attention to specific parts of a sentence.

Eye-tracking is particularly suitable for investigating Korean passive constructions because it directly captures regressions, rereading patterns, and fixation allocation, linking structural properties of passives to measurable cognitive effort. Integration is expected to occur incrementally as readers process NP1 and NP2, resulting in longer dwell times and more fixations for passive or scrambled structures, whereas reanalysis is predicted at the verb, increasing regressions from the verb to preceding regions. By connecting specific eye-movement metrics to sentence regions and processing constructs, this method provides a clear framework for observing online sentence processing.

In particular, Korean passive constructions distribute semantic information across NP1, NP2, and the passive verb through case markers, and their SOV structure with flexible word order often requires readers to maintain preverbal constituents and revisit earlier elements for reanalysis. Examining NP1, NP2, and the verb as separate regions of interest is therefore theoretically motivated: NP1 carries the nominative case marking the patient, NP2 bears an oblique case marking the agent, and the passive verb completes the argument structure. Prior studies have shown region-specific processing differences across NP1 and NP2, supporting the need to analyze these components individually. This approach, combined with eye-tracking measures, allows us to identify which sentence components trigger processing difficulty or reanalysis and clarifies why these elements induce difficulty.

The present study examines how Chinese learners of Korean and native speakers distribute attention across sentence components in passive constructions, and how sentence type (active vs. passive) and word order (canonical vs. scrambled) affect processing. Active sentence conditions allow the isolation of passivization effects. We do not aim to fully dissociate integration costs from reanalysis, because in Korean passives integration and reanalysis cannot be fully separated and our focus is on capturing overall processing difficulty. Eye-movement measures such as dwell time, fixation count, and regression count reflect cognitive load throughout the passive processing sequence, and previous studies (Clifton et al., 2007; D'Alesio et al., 2025; Gattei et al., 2018; Paolazzi et al., 2022) have shown that these measures effectively capture phenomena related to meaning integration, reanalysis, and overall cognitive effort.

2 Literature review

2.1 Passive constructions in Korean

Passive constructions are often grouped with causative constructions under the grammatical category of voice due to their shared feature of a grammatical shift in subject hierarchy (Yeon, 2011). Shibatani (1985), a typologist, explained that the prototypical feature of passive constructions involves the promotion of the original object from a transitive clause to the subject position, while the original subject is demoted to an oblique. Compared to active sentences, passive sentences thus involve one fewer argument.

Other prototypical features of passive constructions, as outlined by Shibatani (1985), include the following: (1) pragmatically, the agent is defocused; (2) semantically, the subject is affected, and the predicate requires both an agent and a patient; (3) morphologically, the verb carries a passive marker. Passive structures are common in nominative-accusative languages, including Korean, which is also a nominative-accusative language (Whaley, 2008).

The scope of Korean passives includes three major types: suffixal passives (e.g., -이/-히/-리/-기 (*-i/hi/li/ki-*)), periphrastic passives (formed with -아/어지다 (*-a/ecita*)), and lexical passives (formed with inherently passive verbs such as 되다 (*toyta*, "become"), 받다 (*patta*, "receive"), and 당하다 (*tanghata*, "suffer")). However, these passive types differ not only morphosyntactically but also in terms of their processing demands and functional load. In particular, lexical and periphrastic passives often carry additional semantic or aspectual nuances beyond the core grammatical function of passivization, which may confound the interpretation of processing results.

To maintain experimental clarity and control, this study focuses exclusively on suffixal passives, which offer a more structurally transparent and morphologically consistent basis for comparing active and passive constructions. Suffixal passives also allow for more direct alignment with existing psycholinguistic research that investigates the syntactic effects of passivization while minimizing confounds related to lexical semantics or auxiliary constructions. The following examples illustrate the suffixal passive forms employed in this study:

(A) 경찰이 도둑을 잡았다.
(A) kyengchal-i totwuk-ul cap-ass-ta
police-NOM thief-ACC catch-PST-DECL
“The police caught the thief.”

(B) 도둑이 경찰에게 잡혔다.
(B) totwuk-i kyengchal-eykey cap-hi-ess-ta
thief-NOM police-DAT catch-PASS-PST-DECL
“The thief was caught by the police.”

In Example B, a passive suffix (*-hi-*) attaches to the verb 잡다 (*capta*, “to catch”), forming the passive verb 잡히다 (*cap-hi-ta*, “to be caught”). This is one of several passive suffixes in Korean (-이/히/리/기-) (*-i/hi/li/ki-*), which vary depending on the verb.

Another key feature is the use of case markers due to the agglutinative nature of Korean. In Example A, the active sentence, the subject 경찰 (*kyengchal*, “police”) takes the nominative marker -이 (*i*), while the object 도둑 (*totwuk*, “thief”) takes the accusative marker -을 (*eul*). However, in Example B, the object of the active sentence (도둑, “thief”) is promoted to the subject position, receiving the nominative marker -이 (*i*). Meanwhile, the original subject (경찰, “police”) is demoted to an oblique position with the dative marker -에게 (*eykey*). Depending on the animacy of the agent, Korean allows various oblique markers, such as -에게 (*eykey*), -에 (*ey*), or -에 의해 (*ey uyhay*). In this case, -에게 (*eykey*) is used because the agent (경찰, *kyengchal*, “police”) is animate.

These complexities—such as the selection of passive suffixes, case markers, and constraints based on animacy—demand significant cognitive resources when processing passive sentences in Korean.

2.2 Theoretical accounts of passive processing

Typically, agents appear as subjects, patients as direct objects, and recipients as indirect objects. However, in passive constructions, the agent is marked as an oblique argument, which disrupts general cognitive expectations (Bock & Levelt, 1994). This discrepancy has long attracted researchers’ attention to understanding how passive sentences are processed.

For example, Hyams et al. (2006), studying children’s grammatical development, suggested that children initially struggle with passives because they tend to map external arguments (e.g., agents) to the subject position. Based on this observation, they proposed the Canonical Alignment Hypothesis (CAH), which posits that non-canonical mappings in passives result in processing difficulties. VanPatten (2004), focusing on adult second language (L2) learners, introduced the First Noun Principle (FNP). He argued that L2 learners tend to assign the first noun in a sentence as the subject or agent, regardless of its actual thematic role.

The difficulty of processing passives has also been explored in the field of agrammatic aphasia. O’Grady and Lee (2005) questioned the validity of existing models such as the Canonical Order Models (COM) and trace-based theories, specifically the Trace Deletion Hypothesis (TDH) and the Double Dependency Hypothesis (DDH). While these models agree that passive constructions are harder to process than active ones, they offer different explanations. COM attributes the difficulty to the non-canonical order of patient-agent, TDH suggests that passives are challenging due to the presence of noun phrase traces, and DDH argues that multiple dependencies within passive sentences increase processing difficulty. O’Grady and Lee (2005) proposed the Isomorphic Mapping Hypothesis (IMH), which posits that passives are hard to process because the argument order does not reflect the event structure (agent-theme sequence).

Furthermore, in the case of Korean passives, one major debate concerns how the flexible word order of Korean affects passive processing. Specifically, in Korean, an agent can precede a patient even in passive sentences, raising the question of whether these scrambled word orders cause additional difficulty. Table 1 presents key predictions from various hypotheses. It summarizes the claims regarding processing tendencies for each hypothesis and shows how these claims predict the difficulty of scrambled passives.

Table 1. Summary of key predictions from various hypotheses

Hypothesis	Processing tendencies	Difficulty of scrambled passive
Canonical Alignment Hypothesis (Hyams et al., 2006)	Maps agents to subject positions	Hard
First Noun Principle (VanPatten, 2004)	Assigns first noun as subject/agent	Hard / Easy
Canonical Order Models (Schwartz et al., 1980)	Prefers agent-patient sequence	Easy

Trace Deletion Hypothesis (Grodzinsky, 2000)	Considers first noun as agent	Easy
Double Dependency Hypothesis (Mauner et al., 1993)	Feels difficulty with sentences involving multiple dependencies	Hard
Isomorphic Mapping Hypothesis (O'Grady & Lee, 2005)	Feels difficulty when argument order differs from event structure	Easy / Hard (with suffixal passives)

Examining which hypotheses are supported by studies on Korean passives, Beretta et al. (2001) found that Korean aphasia patients performed poorly on scrambled passives, suggesting that their results support the DDH over the TDH or COM. In contrast, O'Grady and Lee (2005) argued in favor of the IMH, suggesting that the difficulty of scrambled passives depends on the presence of a passive suffix. Specifically, when a passive suffix is present, such as in the suffixal passive 잡히다 (*caphita*, "to be caught"), aphasia patients focus on the passive marker rather than on case markers, which complicates mapping the first noun to its appropriate role. In contrast, passives without a suffix (e.g., 아이에게 개가 맞았다, *ai-eykey kay-ka mac-ass-ta*, "The child was hit by the dog") are easier to process because the argument order mirrors the event structure. Insofar as L2 learners focus more on passive markers of verbs than on case markers, these findings align with research on Japanese, another agglutinative language that relies heavily on case markers. According to Mitsugi (2017), native Japanese speakers use case markers in incremental processing to assign thematic roles before encountering the verb, pre-activating structural representations. However, L2 learners struggle to efficiently use these markers, relying more on the verb's morphological information. Therefore, the processing of Korean passives involves not only challenges related to argument structure and thematic role assignment but also the proper use of word order, case markers, and passive markers as cues.

2.3 Processing of Korean passive sentences by Chinese learners

Previous studies on the processing of Korean passive sentences by Chinese learners have yielded conflicting results. Jeong (2014), using a picture-sentence verification task, found that Korean native speakers processed nominative passive sentences (e.g., 언니가 잡혀요 (*enni-ka cap-hye-yo*, "The sister is caught [by someone]")) more quickly and accurately, whereas Chinese learners tended to process dative passive sentences (e.g., 오빠에게 잡혀요 (*oppa-eykey cap-hye-yo* "[Someone] is caught by the brother")) more effectively. Jeong (2014) interpreted these results in terms of Chinese learners' use of word order and isomorphic mapping strategies, as well as their incomplete acquisition of the nominative marker 이/가 (*i/ka*). However, since arguments were omitted in each passive sentence in this study, it does not sufficiently address the cognitive load typically induced by two arguments or the effect of word order on passive sentences. Therefore, further research is needed to clarify the inconsistent findings with Beretta et al. (2001) and O'Grady and Lee (2005), who reported difficulties in processing scrambled word orders in suffixal passives.

Conversely, Kim (2021) found that Chinese learners processed Korean passive sentences according to word order patterns, where the subject marked by case particles appears as the first noun phrase, rather than based on agent-patient word order. A sentence-reading and picture-selection task revealed that low-proficiency Chinese learners scored significantly lower in recognizing scrambled word-order sentences compared to canonical word-order sentences. This trend was observed across proficiency groups, with high-proficiency learners and native Korean speakers outperforming low-proficiency learners. The findings suggest that learners struggle with scrambled word-order sentences due to influence from their native language, Chinese, which has a relatively fixed arrangement of sentence components. However, a limitation of the study is that it examined the effect of word order without distinguishing between active and passive sentences.

Shin and Park (2023) examined Chinese learners' acceptability judgments and reaction times for Korean passive sentences, with a focus on the Isomorphism Hypothesis and the role of language-specific mechanisms, such as case marking and verbal morphology. Their results showed that learners took longer to judge the acceptability of canonical word order passive sentences compared to scrambled ones, indicating a higher cognitive load for the canonical word order passive sentences. This was interpreted as supporting the Isomorphism Hypothesis, suggesting that processing becomes more challenging when the agent follows the patient, resulting in a non-isomorphic semantic and syntactic structure. However, in terms of acceptability judgments, learners rated non-canonical passive sentences as less acceptable than canonical ones, which contrasted with the reaction time findings.

In summary, Jeong (2014) found that Chinese learners had more difficulty processing passive sentences with canonical word order, while Kim (2021) found that they struggled more with passive sentences that had a scrambled word order. Shin and Park (2023) observed that learners judged passive sentences with canonical word order as more acceptable, although they took longer to process them. Given these conflicting findings, it remains challenging to draw definitive conclusions about the cues that Chinese learners rely on when processing Korean sentences. Furthermore, previous studies used static research tools, such as picture-sentence verification tasks, sentence-reading, and picture-selection tasks, and acceptability judgment tests, which limit direct observation of real-time processing. This study, therefore, aims to observe the real-time processing of Korean passive sentences by Chinese learners using eye-tracking methodology, comparing their patterns with those of native Korean speakers. Specifically, it examines how word order influences processing when reading passive sentences without omitted arguments, analyzed in comparison to active sentences.

Based on the foregoing review, the study addresses the following research questions:

RQ1: Do Chinese learners and Korean native speakers focus on different sentence components in passive sentences?

- Hypothesis 1 (H1):

Chinese learners will rely more on verb information and surface word order to interpret passive sentences, whereas Korean native speakers will allocate more attention to the agent and patient regions, using case markers to assign thematic roles.

- Prediction 1 (P1):

In eye-tracking data, Chinese learners will either show less differentiation across regions or relatively more attention to the verb. Korean native speakers, in contrast, will show longer dwell times and more fixations in the agent and patient regions than in the verb region.

RQ2: Do Chinese learners and Korean native speakers differ in sentence processing difficulty depending on sentence type (active/passive) and word order?

- Hypothesis 2 (H2):

Chinese learners will experience greater processing difficulty for passive and scrambled structures than for active and canonical structures, respectively. Korean native speakers will show relatively stable processing patterns across sentence types and word orders.

- Prediction 2 (P2):

Chinese learners will exhibit significantly longer dwell times, more fixations, and more regressions in passive and scrambled sentences than in active and canonical ones. Korean native speakers will show minimal differences in these measures across sentence types and word orders.

3 Methodology

3.1 Participants

This study included a total of 70 participants: 37 Mandarin Chinese-speaking learners of Korean and 33 native Korean speakers. Participants were recruited via university online bulletin boards and Chinese student communities. All participants were adults aged 18 to 35 with corrected vision suitable for eye-tracking experiments. The Mandarin-speaking Korean language learners were selected based on the criterion that both they and their parents were native speakers of Mandarin Chinese. The participants were currently enrolled in graduate programs, universities, or university-affiliated language education institutions in South Korea, and had achieved levels 5-6 on the Test of Proficiency in Korean (TOPIK), which ensured they had studied the passive grammar structures typically introduced at the intermediate level. Native Korean speakers were recruited based on the criteria that both they and their parents were native speakers of Korean and that they had not lived abroad for more than one year before the age of 18. Detailed information regarding the participants' age, gender, and Korean language study duration can be found in Table 2 below.

Table 2. Participant information

Group	N	Gender (male/female)	TOPIK level (level 5/ level 6)	Mean duration of Korean language study (years)
Chinese Korean learner	37	5/32	6/31	6.66
Native Korean speaker	33	16/17	N/A	N/A

3.2 Eye-tracking methodology

In this study, eye-tracking methodology was employed to investigate the processing of Korean passive sentences by Chinese learners of Korean. Eye-tracking is a methodology that records eye movements to analyze attention and cognitive processes. It is useful for exploring cognitive processes that occur in real time, such as language processing, by identifying information processing methods and cognitive load through eye movement patterns, including fixation and saccades (Rayner, 1998). This method has also been widely used in second language research (Conklin & Pellicer-Sánchez, 2016; Dussias, 2010; Godfroid, 2020).

Text-based eye-tracking research has the advantage of recording eye movement data while participants read sentences naturally, as they would in real life (Godfroid, 2020). Unlike self-paced reading (SPR) tasks, eye-tracking allows for regressions and skips, making it a more ecologically valid method by addressing the limitations of SPR, which makes it difficult to observe later integration processes (Paolazzi et al., 2022). This is particularly important in SOV languages such as Korean, where integrative processing is required after encountering the verb for meaning construction (Engelhardt et al., 2024). Therefore, this study selected a text-based eye-tracking methodology to closely observe the sentence processing patterns, including regressions, that occur while learners read Korean passive sentences.

In eye-tracking, various metrics are used to analyze cognitive processes. More difficult texts in reading result in more fixations, longer fixation times, and regressions, while eye movements become shorter (Conklin et al., 2018). This study employs three metrics: dwell time, fixation count, and regression count. Dwell time refers to the duration the eyes remain in the area of interest (AOI), encompassing both fixation and non-fixation times. Generally, a longer dwell time indicates a greater focus of attention (Hu & Aryadoust, 2024). Fixation count measures the number of times the eyes remain in a specific area, commonly employed in sentence processing research focusing on lexical or grammatical areas of interest. This metric serves as an important measure of processing difficulty in conjunction with temporal indicators, complementing the analysis of temporal metrics (Godfroid, 2020). Regression count denotes the number of times the eyes move backward to revisit a previous area, which serves as a significant indicator of difficulties or confusion in lexical, syntactic, or discourse processing, leading to sentence reanalysis (Godfroid, 2020).

3.3 Materials

In this study, nine passive verbs were selected to construct sentence stimuli based on the International Standard Curriculum for Korean Language for level 4 and below. The chosen verbs are 물리다 (*mwullita*, "to be bitten"), 잡히다 (*caphita*, "to be caught"), 먹히다 (*mekhita*, "to be eaten"), 묶이다 (*mwukkita*, "to be tied"), 밀리다 (*millita*, "to be pushed"), 밟히다 (*palphita*, "to be stepped on"), 붙잡히다 (*pwuthcaphita*, "to be caught"), 안기다 (*ankita*, "to be hugged"), and 쫓기다 (*ccochkita*, "to be chased"). Other vocabulary outside of passive verbs was adjusted to level 5 and below according to the Internationally Accepted Korean Language Curriculum (National Institute of the Korean Language, 2017). The reason for adjusting the difficulty of the vocabulary was to prevent the processing patterns of sentences from being influenced by difficult vocabulary that the learners had not yet acquired. Additionally, the selected verbs needed to meet the criteria of having animate nouns as agents and passive subjects and also had to be natural even when used as regular transitive verbs in active sentences.

Target items were created by producing four sentence stimuli for each of the nine passive verbs, modifying them according to sentence type (active, passive) and word order (canonical, scrambled), resulting in a total of 144 sentence stimuli. Modifiers were placed before the subject and object to create a gap between the two noun arguments to accurately track the movement of the pupils. To ensure that a single participant would not read similar sentences repeatedly, the four conditions of each sentence stimulus were divided into a counterbalanced list, randomly assigning participants to one of four sets.

To prevent participants from recognizing the target items, filler items were created in a similar format using the dative marker 에게 (*eykey*) in causative and dative sentences, totaling 36 items—18 causative and 18 active sentences using transitive verbs. Furthermore, to maintain participants' attention on the reading task, comprehension questions were devised for all items to assess their understanding of the sentence content. The ratio of correct answers ("true") to incorrect answers ("false") was kept the same for the comprehension questions, and the questions related to the target items were designed not to include content directly related to the interpretation of the agent and passive subject arguments. In summary, each participant viewed a total of 72 items: 36 target items and 36 filler items. Table 3 below provides examples of the target items used in this study.

Table 3. Examples of target items

Verb	Condition	List	Sentences
물리다 (to be bitten)	Active* Canonical	A	까만 고양이가 하얀 쥐를 물었다. kkaman koyangi-ka hayan cwi-lul mwul-ess-ta black cat-NOM white mouse-ACC bite-PAST "The black cat bit the white mouse."
	Active* Scrambled	B	하얀 쥐를 까만 고양이가 물었다. hayan cwi-lul kkaman koyangi-ka mwul-ess-ta white mouse-ACC black cat-NOM bite-PAST "The white mouse was bitten by the black cat."
	Passive* Canonical	C	하얀 쥐가 까만 고양이에게 물렸다. hayan cwi-ka kkaman koyangi-eykey mwul-li-ess-ta white mouse-NOM black cat-DAT bite-PASS-PST "The white mouse was bitten by the black cat."
	Passive* Scrambled	D	까만 고양이에게 하얀 쥐가 물렸다. kkaman koyangi-eykey hayan cwi-ka mwul-li-ess-ta black cat-DAT white mouse-NOM bite-PASS-PST "The white mouse was bitten by the black cat."

Note. The area of interest (AOI) was set into five zones for each word in the sentence: adj-agent, agent, adj-patient, patient, and verb.

3.4 Procedure

This study utilized an SMI RED eye tracker, which operates at a sampling rate of 250 Hz, to record participants' eye movements. Participants were positioned 60 cm away from the monitor displaying the sentence stimuli, with the eye-tracking device attached to the bottom of the monitor.

Prior to beginning the experiment, participants were given instructions on the procedure by the researcher, followed by four practice trials to familiarize them with the task. After completing the practice trials, calibration was conducted to ensure the accuracy of the eye-tracking data before moving on to the main experiment. In each trial, participants first fixated on a "+" symbol presented on the screen for 500 ms. Then they read a Korean sentence that appeared on the screen. Once they had fully understood the sentence, they pressed the space bar on the keyboard, which prompted a comprehension question. Using the mouse, participants then responded to the question by selecting either "Correct" or "Incorrect". There was no time limit for reading the sentences or answering the comprehension questions, and the total duration of the experiment ranged from approximately 15 to 30 minutes.

3.5 Data analysis

Before performing the data analysis, outliers were removed. Data from two Chinese learners with comprehension question accuracy rates below 80% were excluded, resulting in final analyses of data from 35 Chinese learners and 33 native Korean speakers. Additionally, dwell times below 100 ms or above 3000 ms were excluded from the analysis. Data points for dwell time, fixation count, and revisits that fell beyond ±2.5 standard deviations from the group mean were considered outliers and replaced with the mean value. Methods for handling outliers include the accommodating approach, which treats outliers as meaningful data and incorporates them into the analysis, and the discordancy approach, which views outliers as errors or noise, removing or adjusting them (Barnett & Lewis, 1994). In this study, outliers were considered noise and were replaced with the mean value.

Statistical analysis began with an ANOVA and Bonferroni post hoc tests to examine eye movement patterns across the five AOIs in passive sentences for each group. Subsequently, to assess differences in dwell time, fixation count, and regression count metrics specifically within the agent and patient AOIs, which exhibited significant differences from other areas in the initial ANOVA, a linear mixed-effects model was applied. This model included group, word order, and sentence type as fixed effects, with participant and stimulus as random effects, and was followed by a Tukey post hoc test. AOI length and AOI difficulty were added to increase the explanatory power of the model. Interactions among group*word order, group*sentence type, word order*sentence type, and group*word order*sentence type were also analyzed to explore the combined effects of word order and sentence type on processing. The statistical software R was used for all analyses. When fitting a mixed model with the lme4 package in R, the Likelihood Ratio Test (LRT) was used to evaluate the significance of the model. The lmer function estimates the parameters by maximizing the likelihood value. Therefore, the p-values provided in the results were based on the LRT, and the degrees of freedom were estimated using the Satterthwaite method, which adjusts the degrees of freedom to provide a more accurate calculation of p-values. The model equation is presented in the notes of Tables 6, 7, and 8 and includes both the intercept and the slope of the random variables. The random-effects structure for each model was specified as maximal as permitted by the data, including random intercepts and slopes for both participant and item. All models successfully converged without warnings or singular fit issues.

4 Results

4.1 Eye movement patterns in areas of interest (AOI) by group

First, examining the dwell time in the areas of interest (AOIs) for native speakers (NS) and learners (L) in passive constructions reveals the following (see Table 4).

Table 4. Mean dwell time in AOIs of passive by group (ms) (standard deviation)

Name (order)	Adj-agent M(SD)	Agent M(SD)	Adj-patient M(SD)	Patient M(SD)	Verb M(SD)
NS (N = 594)	304.06 (365.76)	927.87 (761.72)	353.76 (455.78)	756.68 (743.79)	316.9 (421.11)
L (N = 630)	993.51 (675.72)	1419.75 (699.67)	1078.02 (704.87)	1309.45 (668.35)	1019.07 (625.64)

Note. NS = Native speaker, L = Learner, 1 = Adjective of the agent area, 2 = Agent area, 3 = Adjective of the patient area, 4 = Patient area, 5 = Verb area.

The average dwell time by group is visualized in Figure 1 below.

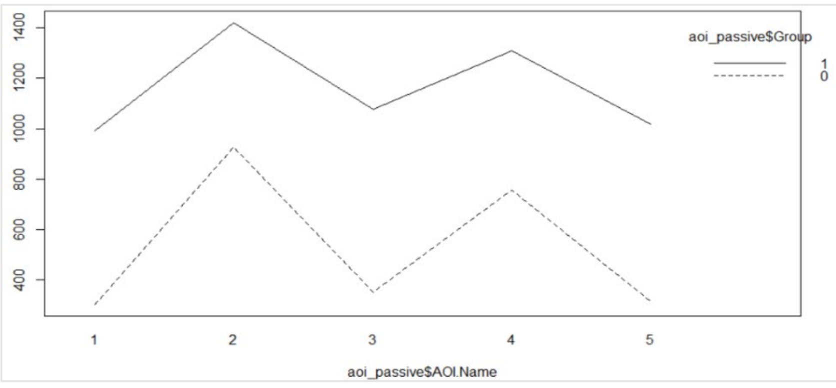

Fig. 1. Mean dwell time in AOIs of passive by group (ms)

Note. Group 0 = Native speaker, Group 1 = Learner, 1 = Adjective of the agent area, 2 = Agent area, 3 = Adjective of the patient area, 4 = Patient area, 5 = Verb area.

Both native speakers and learners exhibited longer dwell times in the agent (2) and patient (4) regions compared to the adjective regions for the agent (1), patient (3), and the verb region (5). An analysis of variance (ANOVA for heterogeneity) showed significant differences in dwell times across AOIs for native speakers ($F(4, 1457.8) = 122.68, p < .001, \eta^2 = 0.17$), which was also true for learners ($F(4, 1571.7) = 49.20, p < .001, \eta^2 = 0.06$).

Post-hoc Bonferroni analyses indicated that for native speakers, the differences between the agent region (2) and other regions (1, 3, 4, 5) were all significant (2-1, p < .001; 2-3, p < .001; 2-4, p < .001; 2-5, p < .001). The patient region (4) also showed significant differences from the other regions (1, 2, 3, 5) (4-1, p < .001; 4-2, p < .001; 4-3, p < .001; 4-5, p < .001). For learners, the agent region (2) exhibited significant differences from all other regions (1, 3, 5) except for the patient region (4) (2-1, p < .001; 2-3, p < .001; 2-5, p < .001). The patient region (4) also showed significant differences from the other regions (1, 3, 5) except for the agent region (2) (4-1, p < .001; 4-3, p < .001; 4-5, p < .001).

Therefore, since the agent and patient regions had significantly greater dwell times than the other regions, further analysis focused on these two areas.

4.2 Eye movement patterns by group based on sentence type and word order

The results of examining eye movement patterns by group according to sentence type and word order are as follows: for dwell time, fixation count, and regression count, learners showed higher values than native speakers in the group comparison, passive sentences had higher values than active sentences in the sentence type comparison, and scrambled word order had higher values than canonical word order in the word order comparison. This is summarized in Table 5.

Table 5. Average dwell time, fixation count, and revisit count by group based on sentence type and word order

		Dwell time (ms) M(SD)	Fixation count M(SD)	Regression count M(SD)
NS (N = 594)	Act*Can	646.64 (537.13)	2.63 (1.68)	1.04 (1.18)
	Act*Scr	700.68 (577.49)	2.83 (1.99)	1.16 (1.11)
	Pass*Can	816.51 (650.75)	3.24 (2.16)	1.32 (1.29)
	Pass*Scr	868.04 (850.48)	3.47 (3.08)	1.52 (1.74)
L (N = 630)	Act*Can	1121.97 (637.68)	4.23 (2.27)	2.06 (1.46)
	Act*Scr	1295.83 (685.55)	4.81 (2.28)	2.5 (1.52)
	Pass*Can	1324.26 (657.68)	4.86 (2.35)	2.43 (1.56)
	Pass*Scr	1404.94 (711.7)	5.1 (2.45)	2.73 (1.65)

Note. NS = Native speaker, L = Learner, Act = Active, Pass = Passive, Can = Canonical order, Scr = Scrambled order, M = Mean, SD = Standard deviation.

The effect of group, sentence type, and word order was examined using a linear mixed-effects model. The main effects of the group (p < .001) and sentence type (p=.021 < .05) on dwell time were significant. The interaction between group and word order was significant for dwell time (p = .039 < .05). Tukey's post hoc analysis revealed that the effect of word order was not significant for native speakers (estimate = -55.6, SE = 37.5, z = -1.483, p = 0.44 > .05). However, for learners, the effect of word order was significant (estimate = -129.1, SE = 36.6, z = -3.527, p = .003 < .05), indicating an increase of 117.17 (ms) in dwell time when scrambled word order was used. These results are summarized in Table 6, and the model and the explained variance can be found in the notes to the table.

The main effects of the group (p < .001) and sentence type (p=.024 < .05) on fixation count were significant. A significant interaction between group and word order was also found for fixation count (p = .042 < .05). Tukey's post hoc analysis showed that the effect of word order was not significant for native speakers (estimate = -0.210, SE = 0.129, z = -1.628, p = 0.36 > .05). In contrast, the effect of word order was significant for learners (estimate = -0.393, SE = 0.126, z = -3.117, p = .009 < .01), suggesting an increase of approximately 0.37 fixations for scrambled word order. These results are summarized in Table 7 and the models, and the explained variance can be found in the notes to the table.

Furthermore, the main effects of group (p < .001) and sentence type (p=.049 < .05) on regression count were significant. The interaction between group and word order was significant for regression count (p = .016 < .05). Tukey's post hoc analysis indicated that the effect of word order was not significant for native speakers (estimate = -0.153, SE = 0.0874, z = -1.747, p = 0.30 > .05). However, the effect of word order was highly significant for learners (estimate = -0.366, SE = 0.0853, z = -4.296, p < .0001), indicating an increase of approximately 0.32 regression counts for scrambled word order. These results are summarized in Table 8, and the model and the explained variance can be found in the notes to the table.

Table 6. Summary of the linear mixed-effects model for dwell time

	Fixed effects					Random effects		
	Estimates	Std. error	CI	t	p		Variance	Std. dev.
(Intercept)	215.18	69.3	79.33 – 351.03	3.11	0.002	σ^2 (Residual)	312671.4	559.17
Group	477.48	69.79	340.67 – 614.30	6.84	<0.001	τ_{00} Participant (Intercept)	65343.5	255.62
Word order	57.93	47.03	-34.27 – 150.13	1.23	0.218	τ_{00} Stimulus (Intercept)	14415.6	120.06
Sentence type	115.87	50.21	17.44 – 214.30	2.31	0.021	τ_{11} Participant.sentence.type	29746.4	172.47
AOI length	117.58	12.8	92.50 – 142.67	9.19	<0.001	τ_{11} Participant.word.order	20015.2	141.47
AOI difficulty	34.02	9.36	15.66 – 52.38	3.63	<0.001	τ_{11} Participant.sentence.type:word.order	18650.1	136.57
Group*word order	117.17	56.79	5.84 – 228.50	2.06	0.039	τ_{11} Stimulus.AOI.length	507.5	22.53
Group*sentence type	29.52	61.63	-91.29 – 150.34	0.48	0.632	τ_{11} Stimulus.AOI.difficulty	2628.2	51.27
Word order*sentence type	-4.67	61.02	-124.30 – 114.96	-0.08	0.939	τ_{11} Stimulus.AOI.length:AOI.difficulty	259.6	16.11
Group*word order* sentence type	-87.31	72.05	-228.55 – 53.94	-1.21	0.226			

Note. Formula: Dwell.Time.ms. ~ Group * word.order * sentence.type + AOI.length + AOI.difficulty + (1 + sentence.type * word.order | Participant) + (1 + AOI.length * AOI.difficulty | Stimulus), marginal R^2 = 0.22, participant ICC = 0.17, stimulus ICC = 0.04, observations = 4896, N of stimuli = 144, N of participant = 68

Table 7. Summary of the linear mixed-effects model for fixation counts

Fixed effects						Random effects		
	Estimates	Std. error	CI	t	p		Variance	Std. dev.
(Intercept)	0.84	0.23	0.38 – 1.29	3.59	<0.001	σ^2 (Residual)	3.9	1.97
Group	1.61	0.22	1.18 – 2.04	7.3	<0.001	τ_{00} Participant (Intercept)	0.61	0.78
Word order	0.23	0.15	-0.06 – 0.52	1.56	0.118	τ_{00} Stimulus (Intercept)	2.22	1.49
Sentence type	0.38	0.17	0.05 – 0.71	2.25	0.024	τ_{11} Participant.sentence.type	0.32	0.57
AOI length	0.55	0.05	0.45 – 0.64	11.08	<0.001	τ_{11} Participant.word.order	0.13	0.36
AOI difficulty	0.06	0.03	-0.00 – 0.13	1.92	0.055	τ_{11} Participant.sentence.type:word.order	0.27	0.52
Group*word order	0.37	0.18	0.01 – 0.73	2.03	0.042	τ_{11} Stimulus.AOI.length	0.14	0.37
Group*sentence type	0.02	0.21	-0.40 – 0.43	0.07	0.942	τ_{11} Stimulus.AOI.difficulty	0.65	0.81
Word order*sentence type	-0.04	0.21	-0.46 – 0.38	-0.18	0.854	τ_{11} Stimulus.AOI.length:AOI.difficulty	0.05	0.22
Group*word order* sentence type	-0.37	0.26	-0.88 – 0.13	-1.44	0.149			

Note. Formula: Fixation.Count. ~ Group * word.order * sentence.type + AOI.length + AOI.difficulty + (1 + sentence.type * word.order | Participant) + (1 + AOI.length * AOI.difficulty | Stimulus), marginal R^2 = 0.21, participant ICC = 0.09, stimulus ICC = 0.33, Observations = 4896, N of stimuli = 144, N of participant = 68

Table 8. Summary of the linear mixed-effects model for regression counts

	Fixed effects					Random effects		
	Estimates	Std. error	CI	t	p		Variance	Std. dev.
(Intercept)	0.51	0.16	0.20 – 0.82	3.2	0.001	σ^2 (Residual)	1.65	1.28
Group	1.02	0.15	0.73 – 1.32	6.8	<0.001	τ_{00} Participant (Intercept)	0.29	0.54
Word order	0.12	0.11	-0.09 – 0.33	1.14	0.256	τ_{00} Stimulus (Intercept)	1.2	1.1
Sentence type	0.21	0.1	0.00 – 0.41	1.97	0.049	τ_{11} Participant.sentence.type	0.09	0.3
AOI length	0.17	0.03	0.10 – 0.23	5.15	<0.001	τ_{11} Participant.word.order	0.11	0.33
AOI difficulty	0.01	0.02	-0.03 – 0.05	0.62	0.536	τ_{11} Participant.sentence.type:word.order	0.2	0.45
Group* word order	0.32	0.13	0.06 – 0.57	2.41	0.016	τ_{11} Stimulus.AOI.length	0.09	0.3
Group*sentence type	0.08	0.13	-0.17 – 0.33	0.64	0.524	τ_{11} Stimulus.AOI.difficulty	0.26	0.51
Word order*sentence type	0.06	0.15	-0.23 – 0.35	0.41	0.681	τ_{11} Stimulus.AOI.length:AOI.difficulty	0.02	0.14
Group*word order* sentence type	-0.2	0.18	-0.56 – 0.15	-1.12	0.261			

Note. Formula: Regression.Count ~ Group * word.order * sentence.type + AOI.length + AOI.difficulty + (1 + sentence.type * word.order | Participant) + (1 + AOI.length * AOI.difficulty | Stimulus), marginal R^2 = 0.2, participant ICC = 0.09, stimulus ICC = 0.38, observations = 4896, N of stimuli = 144, N of participant = 68

5 Discussion and conclusion

This study compared the differences in processing passive and active sentences with varying word orders between Chinese learners of Korean and native Korean speakers. The discussion focuses on addressing the two research questions raised earlier.

The first research question explored which components of passive sentences Chinese learners and Korean native speakers focused on. Both groups exhibited more eye movements in the agent and patient regions than in the verb region. In a study on Japanese passive sentences—in an SOV language similar to Korean—Mitsugi (2017) found that native Japanese speakers used case markers to pre-assign thematic roles, enabling incremental processing before reaching the verb. In contrast, L2 learners tended to rely more on verb information than on case markers. However, this study observed that advanced Chinese-speaking L2 learners, like native speakers, paid greater attention to the agent and patient regions than to the verb and effectively processed Korean passive sentences using case markers. Since this study integrated early and late measurement methods, further research is needed to separate early and late processing stages to determine whether Chinese learners of Korean can predict thematic roles in passive sentences using case markers before reaching the verb. Additionally, it would be beneficial to expand the research to examine whether intermediate learners show processing patterns similar to those of advanced learners.

The second research question examined the effect of sentence type and word order on each group's processing. Results from the linear mixed-effects model showed that both groups had significantly longer dwell times, more fixations, and more regressions when processing passive sentences compared to active sentences. However, responses to word order differed between groups: native Korean speakers showed no significant differences based on word order, while Chinese learners of Korean experienced greater cognitive load with non-canonical word orders. This suggests that learners are more sensitive to the position of the nominative marker, finding scrambled word orders more challenging. According to the Canonical Order Model and the TDH introduced in Section 2, scrambled passive sentences—where the first noun serves as the agent—should theoretically be easier to process than canonical passive sentences. However, learners seemed to experience greater difficulty because the nominative marker appears later in the sentence. O'Grady and Lee (2005) suggested that processing scrambled passives becomes challenging for Korean aphasia patients when they focus on the passive suffix and then map the first noun phrase as the theme. However, this study found that even advanced learners, despite focusing on the agent and patient regions where case markers appear rather than on the passive verb itself, still encountered difficulties with scrambled word orders. This suggests that these hypotheses alone may not fully account for the sentence processing patterns of Chinese learners of Korean.

Additionally, compared to previous studies on the processing of Korean passive sentences by Chinese learners, the results of this study align with those of Kim (2021) but contrast with those of Jeong (2014) and Shin and Park (2023). Jeong (2014) analyzed single-argument passive sentences with either the agent or patient omitted, possibly explaining the differences from this study, where passive sentences containing both arguments were used. Meanwhile, Shin and Park (2023) found that learners rated canonical passive sentences as more acceptable than non-canonical ones, but also showed longer reaction times when judging canonical passives. This may indicate a greater cognitive load for canonical passives; however, it is also possible that learners quickly processed scrambled passives with low acceptability by immediately recognizing them as incorrect, while engaging in more cognitive processing for the acceptable canonical passives. In addition, variations in participants' proficiency levels across studies may account for the differences in findings. Jeong (2014) included intermediate and advanced learners, while Shin and Park (2023) included learners ranging from beginner to advanced levels. In contrast, this study focused solely on advanced learners, suggesting that those with higher proficiency in processing Korean passive sentences may be more sensitive to nominative markers and word order.

However, one limitation of the present study lies in the lack of an independent proficiency measure. Although participants' TOPIK levels were used as a general indication of their Korean proficiency, no separate test was administered immediately prior to the main experiment. Thus, proficiency was not included as a continuous variable in the statistical analysis. This limitation constrains the precision with which the role of L2 proficiency in sentence processing can be interpreted. Future studies are encouraged to include independent and fine-grained measures of proficiency to better capture its potential effects. Despite this limitation, the current findings still provide preliminary insights into how learners at intermediate to advanced levels, as determined by their TOPIK proficiency scores, process Korean passive constructions.

Furthermore, this study offers several implications for second language research. First, it highlights the need for a deeper exploration of the roles that thematic roles and case markers play in processing passive sentences. While VanPatten's (2004) First Noun Principle and the Canonical Alignment Hypothesis by Hyams et al. (2006) help explain the challenges second language learners encounter with typical passive sentences, these theories fall short of fully accounting for the differences in difficulty between canonical and non-canonical word orders in languages like Korean, where agent-patient order is flexible. Thus, further research across different languages and proficiency levels is needed to determine whether mismatches in thematic roles or case markers impose a greater cognitive load.

Second, this study emphasizes the importance of task type. The eye-tracking sentence reading task employed in this study produced results that differed from those of the picture-sentence verification task in Jeong (2014) and the acceptability judgment task in Shin and Park (2023). This suggests that task selection can influence outcomes in second language processing research. It is crucial to analyze how task complexity and cognitive demands affect processing strategies, and further studies should compare results using a variety of tasks simultaneously.

Third, research is needed to explore the impact of proficiency on processing patterns. It is important to investigate how learners' processing patterns change as their language abilities develop. For instance, in this study, advanced Chinese learners demonstrated a tendency to use case markers effectively, similar to native speakers. In contrast, beginner and intermediate learners may still rely on isomorphic cues from event structure instead of case markers, which could lead to difficulties in processing passive sentences.

Fourth, in second language education, it is essential to expose learners to a variety of passive structures, including non-canonical word orders, to foster their implicit knowledge of passive constructions. Teaching diverse sentence structures that reflect the flexible word order of Korean can be beneficial, and this approach can also be applied to the instruction of other languages with flexible word orders, such as Japanese and Turkish.

Finally, second language processing research is crucial for understanding how the differences in processing between native speakers and learners account for the different final outcomes that learners achieve compared to native speakers, as well as the slower and less stable development of L2 learners (Hopp, 2022). While learners' language processing remains an opaque process that is difficult to assess externally, studies employing real-time observation methods, such as eye-tracking, can illuminate this process and provide deeper insights into second language acquisition.

Abbreviations

NOM Nominative
ACC Accusative
DAT Dative
PST Past Tense
PASS Passive
DECL Declarative

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About the Authors

Changkyung Song (https://orcid.org/0009-0005-0049-5335) holds a Master's degree in Korean Language Education from Seoul National University. She is currently a teaching assistant and a doctoral candidate in the Department of Korean Language Education, College of Education at Seoul National University. Her research interests focus on second language acquisition, instructional methods for language learning, and cognitive processes involved in second language processing, especially in the context of Korean as an additional language.

Hyeyun Jeong (https://orcid.org/0000-0002-2383-5911) is a Ph.D. candidate in the Department of Korean Language Education at Seoul National University, where she also received her M.A. Her research interests center on second language acquisition, with a particular focus on cognitive language processing, as well as second language assessment, especially the development and validation of language assessment tools. She is also interested in expanding her research into multilingual and inclusive educational contexts for diverse learner populations.

Sixuan Zhu (https://orcid.org/0009-0009-9720-0861) received a Master's degree in Korean Language Education from Seoul National University. Her research lies at the intersection of second language acquisition, cognitive language processing, and corpus-based studies, particularly in relation to Korean language education and the acquisition of Korean as an additional language.

Hojung Kim (https://orcid.org/0000-0002-3055-7366) is Professor in the Department of Korean Language Education at Seoul National University. She is also an affiliated researcher at the Korean Language Education Research Institute and the Learning Sciences Research Institute at SNU. Her research centers on second and third language acquisition, specifically focusing on L2/L3 Korean processing, development, and assessment.