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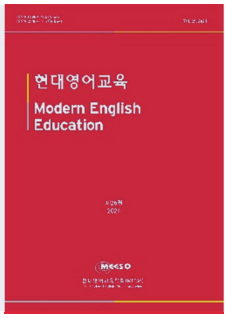

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How Machine Translation Systems Handle Relative Clause Attachment: A Comparative Analysis

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Abstract

The use of machine translators (MTs) in teaching and learning English has increased in recent years. This study investigates how English-to-Korean and Korean-to-English MTs handle relative clause (RC) attachment. A total of 72 sentences—36 English and 36 Korean—were collected from 16 research articles on RC attachment. The collected RC attachment items were categorized into three types: ambiguous, high attachment (HA), and low attachment (LA). English RCs with ambiguity (n=18) were translated into ambiguous Korean RCs; LA preference sentences (n=16) were translated into Korean RCs as LA. However, Korean RCs with ambiguity (n=34) were translated into ambiguous English RCs or HA preference sentences. Results showed that RCs with ambiguity in English and Korean were translated differently into the target language. The main cause of this distinction seemed to be that Korean RCs involving genitive case *-uy* were translated into English RCs using prepositions such as *of* and the genitive *-'s*. These two possible structures resulted in two different outcomes in English: (i) NP-of-NP structures, where ambiguity is preserved, or (ii) NP's NP structures, where only HA preference was possible. These findings suggest that RC attachment is translated differently between the two languages by MTs.

INTRODUCTION

Machine translation (MT) systems have become highly accurate and reliable in recent years; however, their output can still present challenges. This study is an experimental investigation into how ambiguous relative clause (RC) constructions are interpreted in English-to-Korean and Korean-to-English translations. The most frequently used MTs in Korean educational settings are Google Translate (hereafter GT) and Naver Papago (hereafter NP) (C.-E. Kim, 2018, 2021, 2022, 2023; J. Park, 2017). Recent linguistic studies on the outcomes produced by these two MTs have primarily focused on morphosyntactic errors and system malfunctions. Although the use of AI-based tools in language teaching and learning is a subject of debate, their adoption in English classrooms at the secondary level in Korea seems inevitable. Starting in 2025, English textbooks will be fully converted into AI-based Digital Textbooks (AIDT) as part of a digital educational innovation initiative. This major change will first be implemented in subjects such as English, math, and information technology and will later be expanded to other curricula. This aims to support teachers by enabling a more personalized and effective teaching approach. The Ministry of Education's decision to integrate AI tools, including AI-based textbooks, into education highlights the potential of AI to create interactive and personalized learning experiences for EFL learners in Korean secondary schools. After the pandemic, disparities in students' learning abilities worsened, and varying individual learning paces became problematic. AI can offer customized language content, enabling students to easily access materials and receive high-quality feedback. In particular, since AI-based translation tools are readily accessible and can provide instant results, they hold promise for use in language teaching and learning among adult EFL learners. However, research on using these two MTs at the secondary level is relatively scarce despite growing interest in incorporating them into teaching settings. This study underscores the need for further research in this area, as it could offer valuable insights and support for foreign language learning, enhancing student engagement and learning outcomes by providing personalized materials.

The present study hypothesizes that the translation of RC attachment (e.g., Someone shot the servant of the actress [who was on the balcony]), which potentially involves structural ambiguity, may introduce a translation bias in favor of either high or low attachment. Most studies on English RC attachment have shown that native speakers of English tend to prefer low attachment (Carreiras & Clifton, 1993; Dussias, 2003; Frazier, 1987; Frazier & Clifton, 1996). In contrast, several studies have indicated that Korean learners of English are more likely to prefer high attachment (J. H. Kim & Christianson, 2017; B. J. Park, 2010). The main reason for selecting this particular structure for the present study is that previous research on RC attachment has revealed significant cross-linguistic differences, which can pose learning challenges for foreign language learners when there is a mismatch in attachment preferences between their first language (L1) and second language (L2). It is vital to assess how machine MT systems handle RC attachment in English-to-Korean and Korean-to-English translations before incorporating MTs into foreign language learning tools. Therefore, this study examines how two representative MTs, GT and NP, process RC attachment when translating into Korean and English.

LITERATURE REVIEW

Machine Translation and Language Learning

Using MTs for language learning can benefit learners in various ways, including vocabulary acquisition, translation skills, reading comprehension, and writing. Previous research on AI tools in language learning suggests that personalized learning, which adapts to the learner's affective states and proficiency level, can help bridge learning gaps (Ahn & Chung, 2020; H.-K. Kim & Han, 2021). Additionally, with access to a smartphone or PC, all learners can participate in educational activities, creating a more ubiquitous learning environment.

Among the many AI-based tools available, MTs offer free translation services in over one hundred languages (C.-E. Kim, 2018). MTs have accumulated vast amounts of translation data over nearly 20 years, significantly enhancing their accuracy (C.-E. Kim, 2021, 2023, 2024). As key components of the Fourth Industrial Revolution, AI-based tools for learning and teaching English are becoming central to the English education field. Studies examining MT outcomes have shown that the translated results can serve as reliable materials for learning and teaching.

As opportunities for learning through MT have recently expanded in primary and secondary schools, understanding effective ways to integrate MTs into classrooms is essential for future language teachers. Previous research suggests that learners will need to be skilled in identifying correct data and using MT outputs appropriately (C.-E. Kim, 2022). Learning to use AI-based language tools and creatively applying their outcomes is becoming increasingly important in future language education. Rather than accepting translated outputs without critical thinking, it is widely recommended that learners engage

in a process where they critically evaluate the results and select the most accurate option.

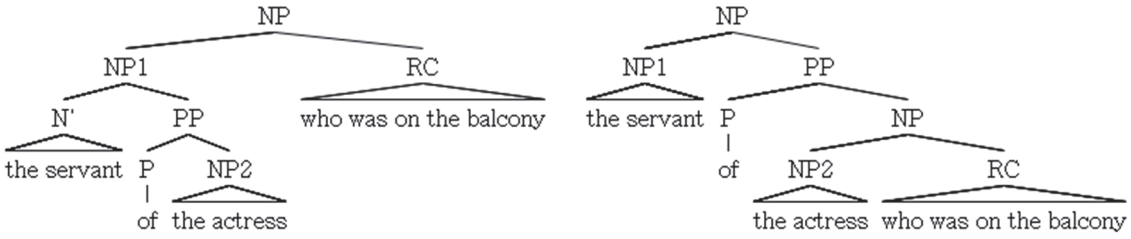
MTs have improved significantly through deep learning-based processes, resulting in enhanced naturalness and grammatical accuracy in their translations (C.-E. Kim, 2022). Although tools like GT and NP have evolved rapidly, they still sometimes produce grammatical or unnatural errors. This is particularly evident when MTs translate Korean case markers into English, where various errors often occur (C.-E. Kim, 2021, 2022, 2023, 2024). Previous studies have emphasized the need for MTs to handle Korean case markers better to improve translation accuracy.

Cross-linguistic Differences in RC Attachment

The ambiguous RC structure, as seen in example (1), has been a focal point of interest across various academic fields for the past few decades. To disambiguate such sentences, two strategies—late closure (Frazier & Clifton, 1996) and recency (Gibson et al., 1996)—have been employed in experimental studies to understand how parsers resolve ambiguous RCs. Late closure is a strategy in syntactic ambiguity resolution in which the human parser prefers to attach new information (e.g., a phrase or clause) to the most recently processed part of the sentence, rather than to earlier parts. This is one of the principles that guide how we initially interpret ambiguous sentences in real-time. On the other hand, under the recency principle**,** when faced with multiple possible attachments for an ambiguous phrase, the parser tends to attach it to the nearest preceding structure. This helps simplify sentence processing by reducing the need to maintain longer dependencies across the sentence. In the tree diagram below as in (2), the RC can be attached to a structurally higher position (NP1) is called high attachment (HA); on the other hand, it also can be attached to NP2 which is lower than NP1, which provoke low attachment (LA) as in (3).

(1) Someone shot [the servant of the actress] who was on the balcony.

(2) The servant was on the balcony. (3) The actress was on the balcony.



Cuetos and Mitchell (1988), who investigated RC attachment, identified different disambiguation strategies in English and Spanish. Their research contributed significantly to understanding cross-linguistic differences in syntactic ambiguity resolution. As shown in example (1), this structure, consisting of complex noun phrases—NP1 of NP2—and an unfolding RC, is ambiguous because the RC may be attached either to the servant of the actress (high NP1) or to the actress (low NP2). Also, from this point, NP1 refers to 'the servant of the actress' and NP2 refers to 'the actress.' Cuetos and Mitchell found that preferences for ambiguous RC attachment can differ across languages. They observed that English speakers preferred lower NP2 attachment 61% of the time, while Spanish speakers preferred higher NP1 attachment 72% of the time. However, recency and late closure strategies predict a preference for low attachment regardless of the language, suggesting that these strategies cannot fully explain their findings.

Following their research, many studies have explored attachment preferences, revealing cross-linguistic differences (see J. Park & J.-H. Kim, 2022 for details). For instance, Korean speakers tend to show a preference for high attachment (HA) (Jun & Koike, 2008; Lee & Kwon, 2004). As shown in example (4), because Korean follows a canonical SOV word order, the RC in Korean is a prenominal adjectival clause that could be attached either to *kaswu* (singer), the low NP1, or to *chinkwu* (friend), the high NP2. J. -H. Kim (2010) noted that Korean native speakers generally prefer high attachment as a disambiguation strategy.

(4) 경찰이 내가 만난 가수의 친구를 쐈다 (J.-H. Kim, 2010)

Kyengchal-i	nay-ka mannan	kaswu-uy	chinkwu-lul	sso-ass-ta
Police-NOM	I-NOM meet	singer-GEN	friend-ACC	shoot-PST-DECL

'The police shot the friend of the singer whom I met.'

Various approaches have been proposed to address this ambiguity, including the recency preference and predicate proximity suggested by Gibson et al. (1996) and the construal principle by Frazier & Clifton (1996), both of which have received significant attention in the field of language processing. However, since this study does not aim to identify the most effective solution to structural ambiguity, a detailed discussion of each perspective will not be the focus.

Previous research on MT outputs has emphasized not only the accuracy of MT translations but also the similarity of the processing procedures to those of human parsers (C.-E. Kim, 2018). The first emphasis ensures that the translations produced by MTs are faithful to the meaning and content of the source text, providing accurate and reliable results. Also, the second emphasis is on how closely the processing procedure of MTs resembles those of human parsers. This suggests that researchers are not only concerned with the final translation output but also with how MTs interpret and process sentences in a way similar to human linguistics processing, including how they resolve ambiguities attach clauses, and understand sentence structure.

In this study, the translation outcomes of ambiguous RCs will be analyzed using two MT systems, and the similarities and differences in how English-to-Korean and Korean-to-English translations resolve RC attachment will be investigated.

Research Questions

This study investigates how two MT systems, GT and NP handle ambiguity in translating RC attachment structures between Korean and English. Specifically, it examines how these MTs resolve RC attachment, a structure that varies significantly between the two languages. Sentences will be classified into three categories of RC attachment structures: ambiguous, HA bias, and LA bias. The study will then analyze how each MT system translates English RCs and Korean RCs.

The study aims to address the following research questions:
1. Do the MT systems (GT and NP) show a preference for high or low attachment when translating English RCs?
2. Do the MT systems (GT and NP) show a preference for high or low attachment when translating Korean RCs?

THE STUDY

Target Structure

The three types of RC constructions—HA bias, LA bias, and ambiguous—were used for translation and analysis. Out of 24 papers on English RC ambiguity, only three were selected for analysis. Similarly, among 16 papers on Korean RC ambiguity, six were chosen. These papers were selected from the Korean Citation Index within the last 10 years. In total, nine papers were used to extract sentences for analysis. The selection was based on the presence of meaningful data related to RC attachment. A total of 72 sentences were extracted, with 36 in Korean and 36 in English.

Before addressing the research questions, all 72 sentences were categorized into the three types of RC constructions. Table 1 presents the breakdown of the dataset according to attachment types. For English RCs, 50% of the sentences were ambiguous, 44.44% exhibited low attachment bias, and 5.55% showed high attachment bias. In contrast, for Korean RCs, the majority of sentences were ambiguous, accounting for 94.44%. High and low attachment bias sentences were much less frequent, each representing 2.77% of the dataset.

TABLE 1
Percentages of Types of Attachments in Each Translation

Types of attachment	English to Korean	Korean to English
Ambiguous	50%(18/36)	94.44%(34/36)
High	5.55%(2/36)	2.77%(1/36)
Low	44.44%(16/36)	2.77%(1/36)
Total	100%(36/36)	100%(36/36)

GT and NP were used to translate the English RC attachment sentences into Korean, and the results were categorized accordingly. Additionally, both translation systems were employed to translate the Korean RC attachment sentences into English.

Procedure

The study aimed to determine the attachment preferences of English translation of English RCs and Korean RCs produced by two different MTs. The English translations of the Korean RC sentences produced by the two MT systems were analyzed to determine whether the structures were ambiguous, high attachment, or low attachment. The same procedure was applied to the translations of English RC sentences. The researcher analyzed the English translations of Korean RC sentences as well as the English RC sentences themselves. Both Korean and English RC sentences were documented in an Excel sheet for systematic coding and analysis. The translations' attachment preferences were evaluated. To ensure reliability, the translations were initially analyzed by a researcher and then rechecked by the author. An initial evaluation of the translations was conducted by a researcher to check whether the translated outcomes were accurate and attachment preferences. This was followed by a recheck performed by the author, ensuring that the findings were robust and validated.

RESULTS

The first analysis assessed how English sentences with ambiguous, HA, and LA preferences were translated into Korean. As indicated in Table 2, for GT, all three sentence types were translated with high semantic accuracy. Specifically, 100% of the 36 English ambiguous sentences translated by GT maintained their ambiguity, and all 16 LA preference sentences were translated as LA preferences. As in Table 3, NP showed similar results: 100% of the 18 ambiguous sentences translated by NP retained their ambiguity, and all 16 LA preference sentences were translated as LA preferences.

TABLE 2
Translation of English RCs Attachment by the GT

English to Korean	Ambiguous	High	Low
Ambiguous (n=18)	100% (18/18)	0% (0/18)	0%(0/18)
High (n=2)	0% (0/2)	100% (2/2)	0%(0/2)
Low (n=16)	0% (0/16)	0% (0/16)	100%(16/16)

TABLE 3
Translation of English RCs Attachment by the NP

English to Korean	Ambiguous	High	Low
Ambiguous (n=18)	100% (18/18)	0% (0/18)	0%(0/18)
High (n=2)	0% (0/2)	100% (2/2)	0%(0/2)
Low (n=16)	0% (0/16)	0% (0/16)	100%(16/16)

The second analysis investigated how Korean sentences with ambiguity, HA preference, and LA preference were translated into English. Of the 34 Korean ambiguous sentences, 55.88% translated by GT remained ambiguous in English, while 44.11% were translated with HA preference, as shown in Table 4. Similarly, with NP, 52.94% of the Korean ambiguous sentences were translated as ambiguous English sentences, and 47.05% were translated with HA preference, as examined in Table 5. Additionally, among the Korean sentences with HA and LA preferences, which were limited to only one of each, both were translated with high accuracy.

TABLE 4
Translations of Korean RCs Attachment by the GT

Korean to English	Ambiguous	High	Low
Ambiguous (n=34)	55.88% (19/34)	44.11% (15/34)	0%(0/34)
High (n=1)	0% (0/1)	100% (1/1)	0%(0/1)
Low (n=11)	0% (0/1)	0% (0/1)	100%(1/1)

TABLE 5
Translations of Korean RCs Attachment by the NP

Korean to English	Ambiguous	High	Low
Ambiguous (n=34)	52.94% (18/34)	47.05% (16/34)	0%(0/34)
High (n=1)	0% (0/1)	100% (1/1)	0% (0/1)
Low (n=11)	0% (0/1)	0% (0/1)	0% (0/1)

To summarize the patterns observed in the translations, ambiguous English RCs are consistently translated as ambiguous in Korean. Conversely, ambiguous Korean RCs are translated into both ambiguous RCs and HA preferences, with rates of 55.55% and 44.11%, respectively, for GT and 52.94% and 47.05% for NP. A detailed analysis of the examples is necessary to fully understand the bias patterns in the translation outcomes of English and Korean RCs produced by these two MT systems.

English RC Attachment

For ambiguous English RCs, such as the example in (5), the relative clause "that was beautiful" can be attached to either NP1, the dress, or NP2, the designer. In the translated data, Korean RCs also exhibited this ambiguity, with the ambiguity persisting in the target language. In (5), the Korean adjective *alumtawun*, meaning "beautiful," can be attached to either *ticaine* (designer) or *tuleysu* (dress), just like in the English sentence. The remaining ambiguity in the translated Korean RCs was 100% across the data.

A prepositional phrase (PP), such as of the designer, can be interpreted as a complement indicating possession. In this context, the NP located to the left is strongly connected to the PP. However, since the prepositional phrase itself does not assign a thematic role, both NPs are possible attachments for the RC.

(5) English Ambiguous RC into Korean Ambiguous RC
George likes the dress of the designer [that was beautiful.]
GT: 조지는 아름다운 디자이너의 드레스를 좋아했다.
NP: 조지는 아름다운 디자이너의 드레스를 좋아했다.
Coci-num alumtawun ticaine-uy tuleysu-lul cohaha-yss-ta
Geoge-NOM beautiful-RC designer-GEN dress-ACC like-PST-DECL
'George likes the dress of the designer that was beautiful.'

Unlike the Korean RC data, 44.44% of the English RC sentences collected were categorized as having LA bias. This does not necessarily indicate that English RCs inherently show LA bias; rather, it reflects that the collected English RC sentences included a diverse range of ambiguous cases compared to the Korean RCs.

(6) English LA bias into Korean LA bias
Kevin interviewed the coach with the jacket [that looked nice.]
GP: 케빈은 멋있어 보이는 자켓을 입고 코치와 인터뷰했다.
Kheypin-un mesisse poinun cakheys-ul ipko khochi-wa inthepuy-lul hayss-ta
Kevin-NOM nice-looking RC jacket-ACC wear coach-with interview-ACC did-DECL

In example (6), the English sentence with LA bias, "the RC that looked nice," can only be attached to NP2, the jacket, rather than NP1, the coach. This is due to the preposition *with*, which restricts the thematic role of the RC and serves as an adjunct, adding specific meaning to the sentence. In contrast to the preposition *of*, which can be more ambiguous, *with* more clearly attaches to the following RC. Therefore, various prepositions used in ambiguous RCs must be analyzed differently in terms of disambiguation.

A small number of English RCs (n=2) exhibited a high attachment (HA) bias, as shown in example (7). In the English HA bias sentence, "the RC who wears a tuxedo in the show that night," the RC can only be attached to NP1, the father. The clue wears a tuxedo helps to identify that the RC modifies the father. When this sentence is translated into Korean, *kunal pam syo-eyse theksito-lul ip-un* (who wears a tuxedo in the show that night) also attaches to *apeci* (the father), demonstrating that the HA bias remains in the Korean translation.

(7) English HA bias into Korean HA bias
She photographed the father of the actress [who wears a tuxedo in the show that night.]
GP: 그녀는 그날 밤 쇼에서 턱시도를 입은 여배우의 아버지를 촬영했다.
Kunye-nun kunal pam syo-eyse theksito-lul ip-un yepaywu-uy apeci-lul chwalyeng-hayss-ta
She-NOM that night show-LOC tuxedo-ACC wear-RC actress-GEN father-ACC photograph-PST-DECL

Korean RC Attachment

For the ambiguous Korean RCs shown in example (8), the relative clause kenchwukka-uy yenkwu-lul kepwuhan (who rejected the architect's research) can be attached to either NP1, *hoykyeysa* (accountant), or NP2, *wuncenca* (driver). In the translated English sentences, the ambiguity is preserved, meaning that who rejected the architect's research can also be attached to both driver and accountant, just as in the Korean sentences.

However, it is noteworthy that the ambiguity persisted in the English translations with 55.88% for GT and 52.94% for NP of the entire set of ambiguous sentences. Additionally, Korean RCs translated into English RC with HA preference, with rates of 44.11% for GT and 47.05% for NP.

(8) Korean Ambiguous RC into English Ambiguous RC
[건축가의 연구를 거부한] 회계사의 운전사가 그를 위로한다
Kenchwukka-uy yenkwu-lul kepwuhan hoykyeysa-uy wuncenca-ka ku-lul wilohan-ta
Architect-GEN research-ACC reject-RC accountant-GEN driver-NOM he-ACC comfort-Prs.
GP: The driver of the accountant [who rejected the architect's research] comforts him.

In example (9), the RC *cihwica-lul kyeklyehan* (who encouraged the conductor) can be attached to either NP1, *kenchwuka* (architect), or NP2, *wuncenca* (driver). A notable distinction is that while English ambiguity translates into Korean ambiguity 100% of the time, Korean ambiguity can be translated into either an English-ambiguous sentence or HA preference sentence. In this case, the English RC often prefers that the relative clause modifies *driver* rather than *architect.*

For instance, in example (9), GT produced an English sentence that modifies the architect's driver as a phrase with an overall meaning. As discussed previously, English-translated data involving NP-of-NP structures may exhibit structural ambiguity. However, when Korean RCs are translated into English with NP structures, the translation outcomes often display a high attachment preference.

(9) Korean Ambiguous RCs into HA bias
과학자가 [지휘자를 격려한] 건축가의 운전사를 위로한다
Kwahakca-ka cihwica-lul kyeklyehan kenchwuka-uy wuncenca-lul wilohan-ta
Scientist-NOM conductor-ACC encourage-RC architect-GEN driver-ACC comfort-Prs.
GT: The scientist comforts the architect's driver [who encouraged the conductor]

DISCUSSION AND CONCLUSION

It is crucial to examine the ambiguity of relative clause (RC) attachments and how they are disambiguated. Despite the importance of this issue, no existing research analyzes the outcomes of RC attachments specifically for the two MT systems, GT and NP. The purpose of this study is to investigate how these MTs handle the ambiguity in English and Korean RC attachments. All three types of RC attachments—ambiguous, HA, and LA bias—were translated using both MTs to examine their patterns of ambiguity resolution.

First, for the 34 English RCs analyzed, both MTs translated the ambiguous English RCs (n=18) into ambiguous Korean RCs with high accuracy: GT at 100% and NP at 100%. For LA bias sentences (n=16), both MTs showed a 100% rate for translating LA preference. For HA bias sentences (n=2), the rate was also 100% for both GT and NP.

Second, for the 36 Korean RCs analyzed, both MTs translated the ambiguous Korean RCs (n=34) into ambiguous English RCs at the following rates: GT at 55.88% and NP at 52.94%. Additionally, ambiguous Korean RCs were translated into LA preferences at rates of 44.11% for GT and 47.05% for NP. When Korean RCs with ambiguity are processed by the MTs, they can be translated into (i) NP-of-NP structures, where the ambiguity is preserved in English, or (ii) NP's NP structures, where only an HA preference is possible. According to Papadopoulou & Clashen (2006), a preposition can cause RCs to

have unique lexical biases, which affects the parsing of ambiguous sentences. In particular, compared to other prepositions, *of,* a functional preposition marking genitive case, makes different RC attachment preferences. The difference in how RC attachment preferences are influenced by different prepositions such as with and of have been examined in previous literature on syntax and psycholinguistics. Since the preposition with typically indicated a relationship involving accomplishment or possession, sentences with *with* often lead to high attachment preferences, were the RCs are more likely to attach to the NP that is more related. However, the preposition of generally indicates a possessive relationship or a partitive sense. Thus sentences with of tend to lead to LA preferences, favoring attachment to the most recent noun.

Third, despite showing ambiguous patterns depending on the language, the MTs produced accurate translation results. In other words, they generated appropriate translations in the target language forms.

Fourth, the outcomes from the MTs resemble those of human language processing mechanisms, as discussed by C.-E. Kim (2016). The process of translating sentences from English to Korean or vice versa using MTs demonstrates a similarity to human parsing, producing target structures that reflect how humans might handle ambiguity. The fact that ambiguous Korean RCs are translated into either ambiguous English RCs or HA preference sentences suggests that, in natural language production, human parsers have multiple options for expressing the same meanings. This aligns with findings in previous literature on AI-based MT outcomes.

In summary, ambiguous English RCs are fully translated into ambiguous Korean RCs, whereas ambiguous Korean RCs are translated into both ambiguous English RCs and HA preference sentences. MTs successfully handle RCs with ambiguity in both Korean-to-English and English-to-Korean translations. Previous research on MTs has often focused on grammatical errors and their causes; however, none have specifically addressed RC ambiguity and its resolution through MTs. This study concludes that the two MTs have effectively learned and stored extensive information about RC structures in both English and Korean, leading to accurate translation results.

In foreign language education, applying MTs can help learners understand structurally complex sentences. Despite the improvements in translation accuracy, it is crucial for English as a Foreign Language (EFL) learners to critically evaluate and select the most appropriate translations from multiple options. In particular, RC attachment sentences have structural ambiguity; however, EFL learners without experience processing complex structures cannot notice the possibility of two different interpretations from one form. As the trials of using AI-based translation systems increase among language learners, educators need to understand the possible outcomes in the current systems and provoke learners to make cautious decisions when choosing translated findings. Also, MTs develop the translation process for particular modes, such as language learning shortly, and reflect the fact that two languages have dissimilar translation processes respectively.

However, this study has some limitations. Since data were collected from various sources, the sentences were not strictly controlled for animacy issues. To enhance the reliability of translation data for RCs with ambiguity in both languages, future research should use controlled sentences that account for potential affective factors influencing ambiguity resolution.

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