The Impact of Inhibitory Controls on Anticipatory Sentence Processing in L2

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This study investigates the relationship between anticipatory behaviors and inhibitory controls in L2 learners using a visual world paradigm. Thirty-four college students with high-intermediate English proficiency participated in an eye-tracking experiment and a flanker task. The eye-tracking results show that the participants predict upcoming words, thereby incrementally processing English sentences in a similar manner to L1 speakers. The eye-movement patterns indicate that they actively made use of combinatory information extracted from subject and verb and real-world knowledge. The results from a flanker task, as a measurement of inhibitory controls, reveal that the flanker effect of accuracy, but not the flanker effect of RT, is significantly correlated with anticipatory processing. That is, the participants who responded to the flankers more accurately were better and faster in predicting the target object. In short, our study supports the constraint-based accounts for sentence processing in L2 suggesting that inhibitory controls as an index of cognitive functions can be another constraint on predictive sentence processing.

Key words: *L2 sentence processing, anticipatory processing, executive function, inhibitory control, flanker effects, constraint-based models of sentence processing*

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1. Introduction

As language users encounter linguistic material in a sentence, they try to figure out its complex structure (e.g., syllables, phonemes, words) and meaning, utilizing real-world knowledge and conceptual representation stored in memory (Kutas et al., 2011). A great deal of research has proved that this process of sentence comprehension is facilitated by anticipation in nonnative as well as native speakers of English (e.g., Altmann & Mirković, 2009; Borovsky et al., 2012; Kaan, 2014; Noh & Lee, 2016). Many of them have shown that both linguistic (e.g., semantic, morphosyntactic, phonological information) and nonlinguistic (e.g., visual images) cues are simultaneously activated in anticipatory processing. An example of nonlinguistic constraints is the cognitive abilities such as executive functions and working memory. Yet, little is known about the relationship between the cognitive abilities and language comprehension, especially anticipatory processing, in L2 learners. The current study seeks to investigate whether anticipatory L2 sentence processing is correlated with inhibitory controls as a component of cognitive abilities.

1.1 Anticipatory Sentence Processing in L1 speakers

In order to capture the meaning of the linguistic input, language users make use of various types of information at an extremely fast speed and incrementally (Altmann & Mirković, 2009). Incrementality has been considered a basic feature of human sentence processing that accounts for temporal ambiguity resolution (Pickering et al., 2000), sentence comprehension (Altmann & Kamide, 1999), and *anticipatory* processing (Kutas et al., 2011). Anticipation refers to a mental process that generates expectations about forthcoming events ahead of the perceptual input. In language comprehension, anticipation is generated by the simultaneous activation of multiple constraints in processing a sensory input before the actual words are clearly identified. As proposed by Kutas et al. (2011), being able to predict what follows next may not only help human parsers ease the processing of the current material, it also helps them pre-activate subsequent events within hundreds of milliseconds.

In the past decade, a wide range of empirical research has suggested that incremental sentence processing is mediated by the predictive skill and the use of various constraints. Altmann and Kamide (1999), for example, demonstrated the use of the selectional restriction of a verb to predict sentential objects in transitive constructions. Selectional restrictions which are stored in the lexicon specify semantic contents of verb arguments and interact with contextual or real-world knowledge (Warren & McConnell, 2007). In sentences like 'The boy will eat/move the cake', the semantic association between the subject noun and the verb contributes to making predictions about the forthcoming object. Thus, while native English-speaking adults are looking at a visual display of depicted images, their saccadic eye movements to the target object (e.g., a cake) were launched sooner in the *eat* condition than in the *move* condition. This temporal difference in eye movements supports the role of semantic information extracted at the verb in generating expectations about sentential objects. Arai and Keller (2013) also demonstrated that verb-specific syntactic information can lead to different processing patterns. They found greater fixations toward the predicted target in the transitive construction as compared to the intransitive construction. This is because transitive verbs require a direct object while intransitive verbs do not. Participants were aware of this syntactic difference, and, thus they predicted the target entity for transitive verbs better than for intransitive verbs. This result has an important implication that anticipatory skills may relate to the use of syntactic constraints available in a given context (verbal subcategorization in this case).

Along with the use of linguistic constraints (e.g., semantic, syntactic, and phonological cues), nonlinguistic constraints (e.g., visual contexts and paralinguistic cues) are also important when predicting subsequent words during spoken language comprehension (Borovsky & Creel, 2014).[1] Tanenhaus et al. (1995) present an example of the effect of visual context

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[1] Paralinguistic information refers to a type of information delivered by meta-communicative cues such as voice. Borovsky and Creel (2014) showed that anticipatory sentence processing is facilitated by the mental system that combines a voice-mediated agent role (i.e., talker information) into the verb-related semantic information in both native English-speaking children and adults.

(i.e., the number of referents depicted in a visual scene) on syntactic parsing. When a sentence 'Put the apple on the towel in the box' was spoken in the one-referent condition (with an apple on the towel), participants first looked at the target object (the apple) after hearing *apple*. They then looked at the incorrect goal referent (the towel next to the apple) after hearing *towel,* thus providing evidence of an initial misinterpretation. Only when the second prepositional phrase *in the box* was presented, they realized that the first prepositional phrase *on the towel* is a modifier that specifies the location of the apple. On the other hand, when the ambiguous sentence was given in the two-referent condition (with an apple on the towel and another on the napkin), the participants often looked at both apples during the processing of *the apple on the towel,* indicating that the intended target referent could not be unambiguously identified until the word *towel*. However, they rarely looked at the incorrect goal referent (the empty towel); instead, they looked at the correct goal referent (the box) shortly after hearing *box*. These results support that syntactic processing is encapsulated by referentially relevant nonlinguistic information on a basis of perceptual and mental systems.

The view that language comprehension can be driven by information integration has been relatively well studied, supporting constraint-based models of processing (e.g., MacDonald et al., 1994). Constraint-based models have proposed that language users are able to activate various types of information simultaneously as the sentences are unfolding. Then the activation of multiple constraints can affect sentence comprehension by facilitating or inhibiting the language processing. According to these accounts, sentence comprehension can be referred to as a constraint satisfaction process given that exploiting multiple constraints is required to fully understand a sentence and to construct its most plausible interpretation in a given situation (Rohde & Plaut, 2003). In this regard, integration of previously mentioned items into newly encoded information, thus forming combinatory information, can be a type of constraint in language comprehension.

Many studies have shown that combinatory information is activated in anticipatory processing. For example, Kamide et al. (2003) showed that semantic and morphosyntactic information associated with the verb and nouns is used in anticipatory processing in German. To illustrate, consider

the following sentences in (1).

(1) Den Hasen frisst gleich der Fuchs.
The[ACC] hare eats soon the[NOM] fox.
'The fox will soon eat the hare.'

Given the flexible word-orders in German, a case-maker can determine the syntactic and thematic role of a noun, regardless of its position in the sentence. When the German-speaking participants heard the first noun with an accusative determiner (*den Hasen* "the hare") and the verb *frisst* 'eat' in (1), their eye movements were more oriented to the image of a fox as the Agent before hearing the target *der Fuchs*. By integrating the semantic information conveyed by the verb *frisst* and the first-positioned accusative-marked noun, the participants were capable of successfully anticipating the subject noun phrase. These results suggest that native speakers can integrate linguistic information to make predictions about following referents.

To sum up, previous studies have confirmed that the sentence processing mechanism in L1 is heavily dependent on the integration of several types of cues rapidly and/or simultaneously in order to predict what will come up next. On the whole, the information integration is presumably one of the major characteristics of language comprehension as constraint-based models have claimed. Together with this, anticipation can be a cognitively efficient mechanism to process the incoming input and to retrieve a variety of resources even before they become available.

1.2 Anticipatory Sentence Processing in L2 Speakers

It has been argued that there are similarities and differences in predictive sentence processing between L1 and L2 speakers with respect to the extent to which multiple sources of information are pre-activated and utilized (e.g., Grüter & Rohde, 2013; Hopp, 2015; Kaan, 2014). An account for the differences is the RAGE approach (Reduced Ability to Generate Expectations during language processing; Grüter and Rohde, 2013). RAGE proposes that L2 learners have a *limited* capacity to generate expectations about subsequent words during language comprehension, regardless of what type of resolving cues are available in the given sentence. In a story-

continuation task, Grüter and Rohde (2013) found that advanced Korean and Japanese learners of English were less able to identify intended referents in the reference resolution, as compared with native speakers of English. This observation suggests potential limitations in nonnative predictive processing of sentences. If integrating information is burdensome, it will limit the capability of processing available resources, resulting in less efficient performance in making predictions. Nevertheless, RAGE does not argue that L2 speakers completely lack the ability to anticipate what will appear next. Rather, this model admits that L2 learners can integrate linguistic information while their predictive skills are somewhat restricted, thus engaging in slower and/or less accurate predictions about upcoming words than L1 speakers. It is possible that the discrepancy between L1 and L2 processing is due to the differences in the extent to which different types of information are integrated and utilized in real-time language processing.

There is some supporting evidence for the limited capacity in anticipatory sentence processing in L2. Martin et al. (2013), for example, found that Spanish-English bilinguals predicted upcoming words in L2 sentence reading as native readers but in a slower and less accurate manner compared to native speakers. In their ERP study, late Spanish-English bilinguals did not show the increased N400 effect when encountering unexpected articles.[2] Only a slight increase in the N400 modification was elicited by unexpected than expected nouns with no subsequent modification of the Anterior Positivity component.[3] These results indicate a weaker lexical prediction capacity in L2 learners, relative to L1 speakers, which results from overall slower linguistic processing such as less accurate integration of information or semantic processing. Hopp (2015) also showed a limited pattern of predictive processing in English learners of German. In an eye-tracking study, the L2 learners identified target objects before they encountered corresponding nouns, by combining the lexical semantic information associated with the verb and other nouns. However, their ability to use

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[2] The N400 effect is the brain's response to semantic anomalies while reading or hearing a linguistic material.

[3] The Anterior Positivity reflects a failure of lexical prediction; that is, it can be seen when the lexical representation of a word is against one's expectations.

morphosyntatic cues (i.e., case-markers) was somewhat restricted; even advanced L2 learners could not readily use the case information to figure out the thematic roles of nouns, and, thus, failed to generate expectations about the upcoming object. These results suggest that the L2 learners are able to integrate semantic cues and process sentences in a predictive manner as L1 speakers but that their ability to use morphosyntactic cues are not native-like, and, thus, limits anticipatory processing.

Unlike RAGE, constraint-based models (e.g., MacDonald et al., 1994; Tanenhaus et al., 1995) have suggested that L2 learners can also use various types of constraints in anticipatory processing as native speakers do (e.g., Kaan, 2014; Trenkic et al., 2014). Some experimental studies have presented supporting evidence for the similarities between L1 and L2 sentence processing. An example is found in Foucart et al.'s (2014) ERP study. They reported that bilinguals were able to comprehend L2 sentences in the same manner as L1 speakers. Their three groups (Spanish monolinguals, early and late Spanish bilinguals) showed all similar brain responses to expected and unexpected noun phrases in a reading task; that is, the N400 components were observed by detecting semantic anomalies between a preceding article and a noun. A larger anterior positivity was also found in unexpected rather than expected nouns. These findings thus have an implication that L2 learners, like L1 speakers, actively anticipate upcoming linguistic items by making use of syntactic cues in L2 sentence processing.

In short, previous studies have demonstrated varying patterns of anticipatory processing in L2 without a clear conclusion as of yet. However, there is a strong possibility that L2 learners do indeed anticipate upcoming linguistic materials. Consistent with the constraint-based accounts, predictive sentence processing in L2 should be strongly related to the integration of various linguistic and nonlinguistic cues as reported in Noh and Lee (2016).

2. Executive Functions and Sentence Processing

Predictive L2 sentence processing can be influenced by linguistic constraints such as vocabulary knowledge (Noh & Lee, 2016), proficiency (Hopp, 2015), and nonlinguistic constraints such as frequency information

(Kaan, 2014). Executive functions are another nonlinguistic constraint that has been argued to be highly associated with bilingual language processing. Executive functions (also referred to as cognitive controls) are a set of cognitive processes that are related to attention, working memory, inhibitory controls, and language processing. These cognitive abilities are necessary to select relevant information and monitor various kinds of human behaviors.

When it comes to language processing, executive functions can be crucial elements to the retention and activation of information that is accessible through a memory system. Although little is known about the impact of executive functions on predictive L2 processing, previous studies suggest that executive functions can have an effect on information integration in the way of regulating the access to multiple resources of information and knowledge stored in memory. Ye and Zhou (2009) argue that executive functions—more strictly, inhibitory controls—are employed to resolve conflicts among linguistic or perceptual representations. Also, there is a close connection between developmental progress of executive functions and individuals' ability to overcome their initial misunderstandings. Furthermore, executive functions are engaged in retrieval and selection of appropriate lexical items in language processing. Such cognitive processes can modulate processing L2 sentences in bilinguals (Abutalebi et al., 2008). For example, when bilinguals are faced with a lexical competition in a bilingual context that entails two languages, executive functions may be employed; they must pay attention to the semantic and/or phonological representations in order to choose the appropriate lexical item. In the selection process, executive functions (or inhibitory controls) may regulate the activation of two languages by simultaneously suppressing irrelevant information.

The effects of executive functions on language processing are constantly observed in Vissers et al.'s (2008) research. In a picture-sentence matching task, they found that native speakers of Dutch detected the semantic mismatch between the incoming input and a visual image. The semantic unexpectedness resulted in an early negativity and a late positivity (i.e., a P600 effect).[4] Considering that there was no syntactic violation, the

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[4] The modulation of the P600 amplitude is generally observed as a detection

P600 effect was proposed to reflect a process to check whether the initial sentence processing was correct. This is where executive functions come to play: the cognitive processes detect the semantic mismatch by monitoring perceptually received input on a basis of lexically-stored knowledge in memory.

In relation to bilingual language processing, Bialystock et al. (2008) found an interaction among language skills, executive functions and sentence processing. They examined lexical access in monolinguals and bilinguals and found that bilinguals performed worse than monolinguals in word naming and verbal fluency tasks. However, these group differences disappeared as vocabulary size was considered as a factor for bilinguals. In other words, highly proficient bilinguals who had a large vocabulary size of L2 were almost equivalent to monolinguals in performance, suggesting that having a large vocabulary size can facilitate rapid lexical access. Interestingly, highly proficient bilinguals outperformed monolinguals in a task requiring executive controls. These results propose that bilinguals can have a cognitive advantage, which, in turn, promotes bilinguals to retrieve relevant items (L2 words in this case) very fast (see also Abutalebi et al., 2008).

Taken together, it is obvious that cognitive functions are associated with linguistic abilities and anticipatory processing in both L1 and L2 speakers. To our knowledge, however, the effect of inhibitory controls (as a component of executive functions) on anticipatory sentence processing, especially in bilinguals, are still under investigation. Given this, we investigated whether Korean learners of English can predict upcoming words in L2 sentence processing and in what way inhibitory controls affect the predictive sentence processing in L2.

3. Methods

3.1 Participants
Thirty-four college students with high-intermediate English proficiency

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of syntactic anomalies around 600 ms (Paczynski & Kuperberg, 2012). However, Vissers et al. (2008) observed the P600 effect elicited by semantic anomalies.

participated in the study (mean ages=23.6 years, 19 females). Based on the standard score ranges distributed by the TOEIC committee, only those who had internationally administered scores above 880 in TOEIC or above 90 in TOEFL were included. Taking consideration into an impact of L2 proficiency on anticipatory processing (Hopp, 2015), we only tested L2 learners with high-intermediate proficiency. All participants were native Korean speakers and had less than a year of living experience in an English-speaking country (mean duration=1.8 months). They had no known history of diagnosis or treatment of cognitive/developmental/language problems, and had normal or corrected-to-normal vision and hearing. The participants received monetary compensation for their participation.

3.2 Materials and procedures

To investigate anticipatory processing of L2 sentences and its correlation with the cognitive ability in Korean learners of English, we conducted an eye-tracking experiment and a flanker task.

3.2.1 Visual world eye-tracking experiment

Ten sets of sentence stimuli were used in a visual world eye-tracking experiment. Most of the sentence stimuli were taken from Borovsky et al. (2012) with some modifications to exclude intransitive verbs (see Noh & Lee 2016). All sets of stimuli consisted of four sentences created by crossing two agent nouns (e.g., *baby*, *cow*) with two action verbs (e.g., *eat*, *kick*). In a visual display, corresponding to each stimulus set, there were four images: the Target (semantically related to both an Agent and an Action), the Agent-related competitor (semantically related to an Agent), the Action-related competitor (semantically related to an Action), and the Unrelated competitor (a distractor that is semantically unrelated to both an Agent and an Action).

An example of stimulus sets and its corresponding visual display were presented in Table 1 and Figure 1. For the purpose of eye-movement analysis, we divided each sentence into four regions – Region 0 (Article 1), Region 1 (Agent), Region 2 (Action verb and Article 2), and Region 3 (Target noun). One of the four images in the display should be the Target, depending on which sentence is given as a stimulus. For example, for the

Table 1. An example of a set of sentence stimuli

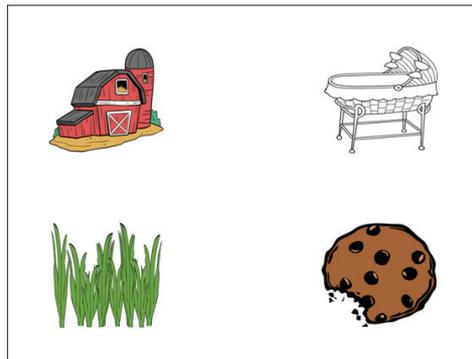| Art1	Agent	Action + Art2	Theme
The	baby	eats the	cookie
The	cow	eats the	grass
The	baby	kicks the	crib
The	cow	kicks the	barn

Figure 1. A visual display

stimulus sentence *The baby eats the cookie*, the image of a cookie is the Target, the most probable object that a *baby* can *eat* among the four objects in the visual scene. It is unlikely for a baby to eat grass in reality, so the grass image is an action-related object in that it is an edible object. A crib is a small bed for a baby or young child, so it is an agent-related object, while a barn is related to neither the Agent *baby* nor the Action *eat*.

The sentences were recorded by a male native speaker of English and sampled at 44,100 Hz. The recorded sentences were edited using Praat software (Boersma, 2002) to normalize the word duration across the same sentential position (Art1: 111ms, Agent: 466ms, Action: 476ms, Art2: 94ms, Theme: 482ms). Five native speakers of English judged whether the recorded and edited sentences were natural. Half of the 40 sentences were randomly run in one of two lists of stimuli. Each image in visual displays was edited to fit within a 280 x 260 pixel and presented with equal

frequency across the lists.

Participants were seated in a comfortable chair in front of a 17" computer screen and viewed the visual stimulus that was presented using the SR Research Eyelink II Experiment Builder software (2011). The participants' eye movements were sampled at 500Hz in a pupil tracking mode and monitored by a head-mounted tracker. A series of calibration and drift-correction were conducted before starting the experiment, and if necessary, these processes were repeated. Then the participants were instructed to listen to the auditory stimuli as they were looking at the four images shown on the screen. At the end of a stimulus sentence, they were asked to answer a comprehension question (e.g., *Does the baby eat the cookie?*) by pressing a Yes- or No-marked button on the keyboard. This last step aimed to check whether the participants paid attention to and understood the experimental sentences. Before starting the experimental trials, three practice items were presented. The entire experiment took approximately 15-20 minutes.

3.2.2 Flanker task

After the eye-tracking experiment, we conducted a flanker task (Eriksen & Eriksen, 1974) to examine inhibitory controls. The flanker task requires suppressing irrelevant items and paying attention to the target, which can be affected by the flanker congruency in the task (Eriksen & Eriksen, 1974; Lange-Malecki & Treue, 2012; Thornton & Vuong, 2004).

There were two conditions by the congruency between the target and surrounding flankers: a congruent condition (with all items in the same direction) and an incongruent condition (with the target in a different direction from the surrounding flankers), as shown in Figure 2. Participants were instructed to fixate on the "+" symbol for 50 ms. Then, a test stimulus was presented for 100 ms and the participants were asked to press the button indicating the direction of the central flanker (i.e., the target) as quickly as they could. A process of fixation and an experimental trial was repeated during the task. After four practice trials, a total of 60 experimental trials were presented. The experimental session consisted of 5 blocks of 12 trials, and the trials varied according to the positions (top, central, bottom) and colors (blue, green, orange, red) of the sequence of flankers. The participants' responses to each trial were recorded for accuracy and reaction
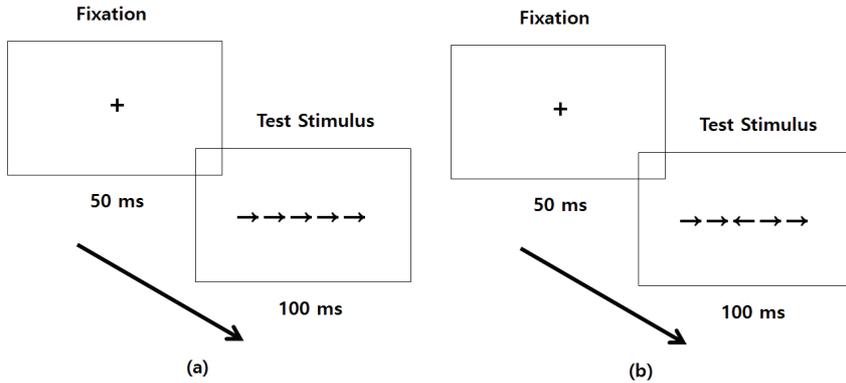
Figure 2. An example of the congruent (a) and incongruent (b) trials in the flanker task

times. All trials were presented in a random order and completed in 5 minutes.

4. Results and Discussion

4.1 Anticipatory L2 Processing

To examine whether Korean learners of English can predict upcoming words as a sentence is unfolding, we first measured the fixating proportions to the four images in each display while the stimulus sentences were spoken. For statistical analyses, we then calculated the mean proportion fixating to the Target and three competitors (i.e., Agent-related, Action-related and Unrelated objects) in each of the four regions (i.e., Region 0 (Art1), Region 1 (Agent), Region 2 (Action + Art2) and Region 3 (Theme = the Target)).

The time-course data in Figure 3 shows the incremental and anticipatory eye movements to the Target and three competitors as the sentence is unfolding. On the whole, looks to the Target increased as the Agent *baby* was spoken. Proportions fixating to the Action-related image started to decrease as the verb *eats* was spoken, whereas those to the Agent-related image continuously increased until the Theme *cookie* was presented.

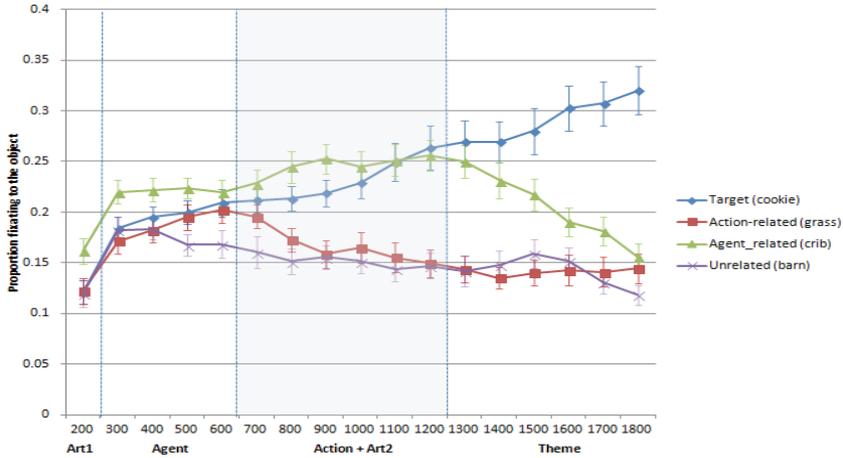Of interest here is to see whether participants made anticipatory looks to

Figure 3. The mean proportion fixating to each of the four images in all participants (n=34) (Vertical lines represent the mean offset of each region)

the Target. Given that anticipatory fixations refer to eye movements toward the Target image before the word corresponding to it is encountered, we only included the eye fixations which occurred after the verb onset in our analyses. This is because L2 learners can exploit combinatory information in predictive processing, as previous research evidenced (Noh & Lee, 2016). In particular, we focused on Region 2 as a critical region, where the semantic information associated with the verb becomes available and combines with the semantic information of the agent noun. A one-way ANOVA was carried out for the mean proportions fixating to the four images in Region 2. Subsequently, we conducted pairwise comparison t-tests to compare the fixation proportions of the Target and other competitors in this region.

The results showed that participants looked significantly more at the Target (23%) and the Agent-related (25%) than the Action-related (17%) and the Unrelated (15%) in Region 2, as predicted. The mean proportion of fixation to the Agent-related gradually increased until the target word *cookie* was encountered. Fixations to the Agent-related and the Target started to diverge before the Target onset (1100 ms). A one-way ANOVA revealed that there were significant differences in the mean proportions fixating to the Target and other objects ($F(3,812)=62.177$, $p<.001$). Subsequent pairwise

comparisons showed that anticipatory looks to the Target were significantly different as compared to eye movements to the Action-related and the Unrelated (all $p<.001$). There were also highly significant differences in fixating proportions between the Agent-related and the Action-related ($p<.001$).

These results confirm that L2 learners are capable of making predictions about forthcoming words using combinatory information in L2 sentence processing. More looks to the Target and Agent-related objects indicate that the ability to integrate semantic information is not specific to native speakers of English. Contrary to some previous reports that L2 learners are unable to make predictions, our participants indeed generated expectations to the Target even before the referent was expressed. More precisely, it seems that the L2 learners had no difficulty in activating and integrating lexical-semantic information, which led to successful anticipatory processing. The gradual increase in looks to the Agent-related object supports that the semantic information associated with the Agent is continuously activated until the target word is referred to. At the same time, verb-specific information is retrieved and combined into already activated information, yielding the activation of combinatory information. Meanwhile, a decrease in the proportion fixating to the Action-related object suggests that an integrative strategy restricts the exclusive activation of semantic information from the verb.

It is unexpected that more looks to the Agent-related than other objects were observed as the participants heard the article *the* in Region 0. Given that the article does not convey semantic information relevant to the following noun, hearing it alone should not make any difference in the looks to the four images. Unfortunately there is no clear explanation for this unexpected result yet and thus further investigation is needed to understand the underlying factors.

4.2 The Relation between Anticipatory Processing and Inhibitory Controls

To explore a possible relationship between anticipatory behaviors and inhibitory controls in L2 sentence comprehension, we first calculated mean reaction times (RTs) and mean accuracy of participants' correct responses in

the flanker task. Then, we examined the correlations between anticipatory fixations to the Target in Region 2 and flanker effects of RT and accuracy.

4.2.1 Anticipation and Speed of Inhibitory Controls

Overall, the mean RTs were different according to the congruency of flankers, as shown in Figure 4. Participants responded to the target flanker more quickly in the congruent condition than in the incongruent condition. A paired t-test confirmed that the difference between two configurations was highly significant ($t(577)=5.9779$, $p<.001$). The mean RTs were significantly shorter for congruent trials (571.5 ms) than incongruent trials (764.5 ms), with a flanker effect of RT (192.8 ms, $p<.001$). These results confirm that the congruency of flankers influences participants' performance on the flanker task, as reported in previous findings (e.g., Lange-Malecki & Treue, 2012). That is, in the congruent trials, it is easy to distinguish the direction of the target, yielding a faster response to the target. On the other hand, the incongruent trials require participants to inhibit the activation of surrounding flankers to figure out the target.

The flanker effect of RT is not correlated with anticipatory processing. The Pearson Correlation revealed no significant correlation between the flanker effect of RT and the anticipatory fixations to the Target in Region 2 ($r(202)=-0.098$, $p>.10$). This result implies that the *speed* of inhibitory controls to suppress the activation of irrelevant cues does not affect
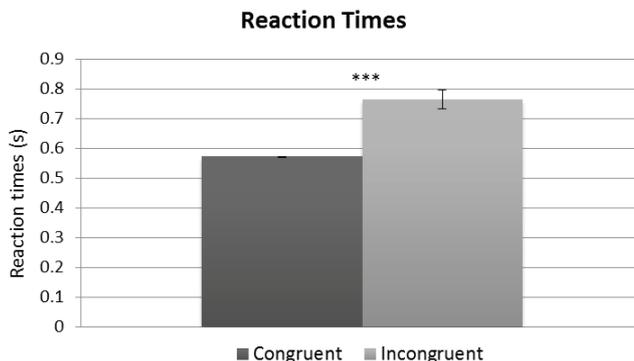

Figure 4. Mean reaction times (RTs) in the flanker task (with SE bars)

anticipatory L2 processing, at least in highly proficient L2 learners.

4.2.2 Anticipation and Accuracy in Inhibitory Controls

As shown in Figure 5, there was a highly significant difference in performance rates between the two congruency conditions ($t(577)=18.8693$, $p<.001$). Participants showed more accurate responses to the target flanker in the congruent condition. A paired t-test revealed that the accuracy was higher for congruent (98.94%) than incongruent trials (81.06%), revealing a flanker effect of accuracy (17.88%, $p<.001$). These results indicate that the accuracy in executing inhibitory controls is affected by the flanker configurations that participants have encountered, consistent with some previous findings (e.g., Lange-Malecki & Treue, 2012; Thornton & Vuong, 2004). As discussed earlier, it is more difficult to figure out the target in incongruent configurations than in congruent ones, resulting in better performance in congruent trials.

Interestingly, anticipatory looking behaviors in Region 2 are correlated with the flanker effect of accuracy ($r(202)=-0.204$, $p<.01$), unlike the flanker effect of RT. The negative correlation between anticipatory fixations to the Target and accuracy in the flanker task means that L2 learners who identified target flankers more accurately showed a smaller flanker effect of accuracy, indicating a higher level of inhibitory controls. These results argue that the mechanism of attention-demanding cognitive processes is
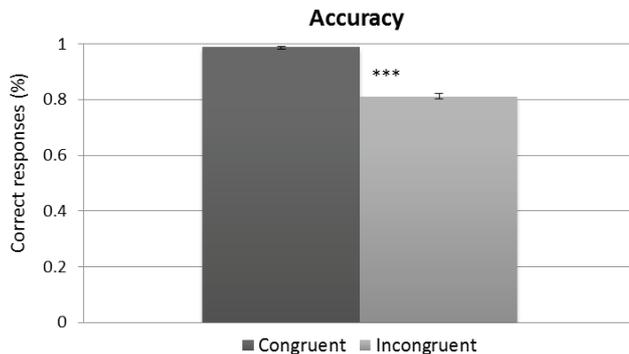

Figure 5. Mean accuracy in the flanker task (with SE bars)

operative in L2 learners to prevent irrelevant items from being activated in the incongruent trials. Furthermore, the strong correlation between anticipatory fixations and the flanker effect of accuracy has an important implication that the ability to facilitate and/or inhibit the activation of input in a precise manner can be crucial to anticipatory sentence processing. In other words, when L2 learners comprehend L2 sentences incrementally by means of the predictive process (Arai & Keller, 2013; Borovsky et al., 2012; Noh & Lee, 2016), cognitive controls can foster the ease of accessing and selecting relevant information in real time.

Taken together, the present study shows how Korean learners of English with high-intermediate proficiency predict upcoming linguistic materials in L2 sentence processing. When the L2 learners hear a verb, they start to combine a previously activated meaning of the agent noun with verb-specific semantic information derived from the lexicon, showing more looks to the Target than other competitors at the verb region. If they make use of the meaning of the verb exclusively, their eye movements toward the Target should be similar to those toward the Action-related object, which is not true. Another interesting result of the current study is that anticipatory processing of L2 sentences can be related to cognitive skills. More precisely, the strategy to select appropriate information and suppress the activation of irrelevant resources can affect the way of integrating multiple constraints in L2 processing (Abutalebi et al., 2007; Bialystock et al., 2008; Ye & Zhou, 2009).

5. Conclusion

This current study demonstrates that nonnative speakers of English do incremental sentence processing as native speakers of English do. Specifically, our Korean learners of English can generate expectations to the upcoming object immediately after hearing the transitive verb while looking at a visual display. To do this, they exploit multiple cues including linguistic constraints (i.e., combinatory semantic information) and nonlinguistic constraints (i.e., visual referents depicted in a display), consistent with the constraint-based models. Thus, our data suggests that integration-dependent predictive processing is not limited in L1 sentence comprehension, but

that L2 sentence predictive processing can occur in a similar manner to L1 processing. It is noteworthy that these results are consistent with RAGE as well, which predicts that highly proficient L2 learners can make predictions about upcoming words in online processing. To decide which model better explains our results, further research is needed to examine whether L2 proficiency levels (as compared to L1) make differences in the latency and/ or accuracy of the anticipatory processing.

Another finding is that the anticipatory processing of L2 sentences is correlated with the cognitive ability in our Korean learners of English. A strong correlation of anticipatory processing with the flanker effect of accuracy, although not with the flanker effect of RT, suggests that the accuracy in implementing cognitive controls can be important to control the interference from irrelevant information during predictive L2 processing, at least in high-intermediate L2 learners. We are currently working on follow-up studies designed to confirm the relationship between cognitive skills and anticipatory processing.

In conclusion, our study found that anticipatory L2 processing can be mediated by the activation of linguistic and nonlinguistic constraints. To restate, L2 learners can process L2 sentences in an anticipatory manner using the combinatory semantic information, and inhibitory controls as a key component of executive functions can be a nonlinguistic constraint on the anticipatory sentence processing.

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References

Abutalebi, J., Annoni, J. M., Zimine, I., Pegna, A. J., Seghier, M. L., et al. 2008. Language control and lexical competition in bilinguals: an event-related fMRI study. *Cerebral Cortex* 18(7), 1496-1505.
Altmann, G. T. M., & Kamide, Y. 1999. Incremental interpretation at verbs:

Restricting the domain of subsequent reference. *Cognition* 73(3), 247-264.

Altmann, G. T. M., & Mirković, J. 2009. Incrementality and prediction in human sentence processing. *Cognitive science* 33(4), 583-609.

Arai, M., & Keller, F. 2013. The use of verb-specific information for prediction in sentence processing. *Language and Cognitive Processes* 28(4), 525-560.

Bialystock, E., Craik, F. I. M., & Luk, G. 2008. Lexical access in bilinguals: Effects of vocabulary size and executive control. *Journal of Neurolinguistics* 21(6), 522-538.

Boersma, P. P. G. 2002. Praat, a system for doing phonetics by computer. *Glot international* 5.

Borovsky, A., & Creel, S. C. 2014. Children and adults integrate talker and verb information in online processing. *Developmental psychology* 50(5), 1600.

Borovsky, A., Elman, J. L., & Fernald, A. 2012. Knowing a lot for one's age: Vocabulary skill and not age is associated with anticipatory incremental sentence interpretation in children and adults. *Journal of Experimental Child Psychology* 112(4), 417-436.

Eriksen, B. A., & Eriksen, C. W. 1974. Effects of noise letters upon the identification of a target letter in a nonsearch task. *Attention, Perception, & Psychophysics* 16(1), 143-149.

Foucart, A., Martin, C. D., Moreno, E. M., & Costa, A. 2014. Can bilinguals see it coming? Word anticipation in L2 sentence reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 40(5), 1461.

Grüter, T., & Rohde, H. 2013. L2 processing is affected by RAGE: Evidence from reference resolution. *the 12th conference on Generative Approaches to Second Language Acquisition (GASLA)*.

Hopp, H. 2015. Semantics and morphosyntax in predictive L2 sentence processing. *International Review of Applied Linguistics in Language Teaching* 53(3), 277-306.

Kaan, E. 2014. Predictive sentence processing in L2 and L1: What is different?. *Linguistic Approaches to Bilingualism* 4(2), 257-282.

Kamide, Y., Scheepers, C., & Altmann, G. T. M. 2003. Integration of syntactic and semantic information in predictive processing: Cross-linguistic evidence from German and English. *Journal of Psycholinguistic research* 32(1), 37-55.

Kutas, M., DeLong, K. A., & Smith, N. J. 2011. A look around at what lies ahead: Prediction and predictability in language processing. In M. Bar (Ed.), *Predictions in the brain: Using out past to generate a future*, 190-207, Oxford: Oxford University Press.

Lange-Malecki, B., & Treue, T. 2012. A flanker effect for moving visual stimuli. *Vision research* 62, 134-138.

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. 1994. The lexical nature

of syntactic ambiguity resolution. *Psychological review* 101(4), 676.

Martin, C. D., Thierry, G., Kuipers, J. R., Boutonnet, B., Foucart, A., & Costa, A. 2013. Bilinguals reading in their second language do not predict upcoming words as native speakers do. *Journal of Memory and Language* 69(4), 574-588.

Noh, Y., & Lee, M. 2016. Effects of vocabulary size on anticipatory sentence processing in Korean learners of English. *Korean Journal of Linguistics* 41(3), 359-378.

Paczynski, M., & Kuperberg, G. R. 2012. Multiple influences of semantic memory on sentence processing: Distinct effects of semantic relatedness on violations of real-world event/state knowledge and animacy selection restrictions. *Journal of memory and language* 67(4), 426-448.

Pickering, M. J., Traxler, M. J., & Crocker, M. W. 2000. Ambiguity resolution in sentence processing: Evidence against frequency-based accounts. *Journal of memory and language* 43(3), 447-475.

Rohde, D. L. T., & Plaut, D. C. 2003. Connectionist models of language processing. *Cognitive Studies* 10(1), 10-28.

Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M., & Sedivy, J. C. 1995. Integration of visual and linguistic information in spoken language comprehension. *Science* 268(5217), 1632.

Team, R. Core. 2013. R: A language and environment for statistical computing. R foundation for statistical computing. Vienna, Austria. URL http://www. R-project.org/.

Thornton, I. M., & Vuong, Q. C. 2004. Incidental processing of biological motion. *Current Biology* 14(12), 1084-1089.

Trenkic, D., Mirković, J., & Altmann, G. T. M. 2014. Real-time grammar processing by native and non-native speakers: Constructions unique to the second language. *Bilingualism: Language and Cognition* 17(2), 237-257.

Vissers, C. T. W., Kolk, H. H., Van De Meerendonk, N., & Chwilla, D. J. 2008. Monitoring in language perception: evidence from ERPs in a picture-sentence matching task. *Neuropsychologia* 46(4), 967-982.

Warren, T., & McConnell, K. 2007. Investigating effects of selectional restriction violations and plausibility violation severity on eye-movements in reading. *Psychonomic bulletin & review* 14(4), 770-775.

Ye, Z., & Zhou, X. 2009. Executive control in language processing. *Neuroscience & Biobehavioral Reviews* 33(8), 1168-1177.