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Investigation of Individual Factors Affecting Second Language Processing

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Abstract
In psycholinguistic research, the interpretation of ambiguous sentences as an area of concern has always received much attention, while less study has been done on factors having the most effect on ambiguous sentence comprehension. This study therefore aims to examine individual factors influencing second language (L2) processing in a sample of 18 adult Persian L2 learners of English and 15 English native speakers, employing both online and offline tasks. The findings from the simple regression model and correlation tests indicated that group effects were significant, showing native speakers' overall faster reading time. Moreover, the results showed that for participants, online processing of L2 relative clause (RC) and offline choice of RC attachment were not significantly affected by working memory, proficiency, and age. However, sentence readers are more likely to choose high attachment (first noun) as an earlier good-enough linguistic representation than to choose low attachment (second noun) to resolve or minimize RC attachment ambiguity online, which is likely modulated by their working memory capacity.
Keywords: L2 relative clause, online processing, offline attachment choice, working memory, proficiency, age

INTRODUCTION

In recent decades, L2 research has provided evidence regarding the impact of individual differences on linguistic and cognitive factors in language processing, specifically in syntactic real-time processing (Dabrowska, 2012; Roberts, 2012). During real-time processing, the parser is occupied with different antecedents to resolve ambiguity. Long syntactic-semantic dependencies also complicate L2 input interpretation. These processing difficulties have led L2 learners to misanalysed temporarily ambiguous sentences (Williams et al., 2001). When such complex processing procedures are at play, sentence processing is assumed to be influenced by working memory, proficiency and age, specifically in less dominant L2 where adult L2 learners process L2 ambiguous sentences incrementally, like native speakers (Roberts, 2012).

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Using experimental methods, recent research has showed L2 learners behave differently concerning both L2 language development and native-like language processing (Dörnyei & Ryan, 2015). It has been found that L2 syntactic processing are influenced by individual factors including working memory (e.g., Caplan, 2016; Karimia & Ferreira, 2016), cognitive capacity (e.g., Kim & Christianson, 2013; Traxler, 2007), Age of Acquisition (AoA) (e.g., Birdsong, 2006; Johnson & Newport, 1989), proficiency (Karimi et al., 2021) and motivation (e.g., Allen, 2010).

Arguably, one of the most demanding sources of processing in syntactic processing is working memory (WM). WM plays a significant role in ambiguous sentence processing with long dependencies. In such constructions, the constituents are first stored in memory and are then retrieved for sentence parsing (Jacob, 2009). Thus, sentence comprehension entails memory capacity in a real-time processing (Caplan, 2016). For example, in (1) as a temporarily ambiguous, or garden-path sentence, the subject of *was,* or the antecedent of *who,* must be recalled somewhere in the sentence where *was,* or *who* appear.

(1) *Someone shot the brother of the actress who was on the balcony.*

In the area of syntactic processing, other notable factors accounting for the observed difference between L2 learners' and natives' syntactic processing are AoA, L2 proficiency, L2 immersion duration, and L2 training duration. Among them, AoA and L2 proficiency seems to be more influencing factors, which demands much attention. Earlier research, for instance, has shown that late L2 learners may in general use syntactic knowledge in both real-time and off-line comprehension, if they have high proficiency (e.g. Hopp, 2006; Wen et al., 2015). However, the question remains why most L2 readers might not able to behave native-like in L2 syntax processing. Prior experimental research has mostly emphasized on each factor separately. The current work, therefore, attempts to examine the effect of all these factors on online syntactic processing. Self-Paced reading (SPR) experiment is conducted on L2 sentence comprehension to test whether L2 RC parsing performance would be differently affected by the individual variables mentioned above.

The area of syntactic processing has been extensively examined in recent years with various experimental methods (i.e. SPR, Event-related potential (ERP) or eye-tracking), sample (i.e. monolingual or bilingual), participants (L2 speakers, L2 learners or native speaker), tools (i.e. off-line and on-line experiments). One of the computerized methods used to probe this topic has been SPR as it provides on-line measures of processing of linguistic units (Jegerski, 2014). In SPR, the reading time for each designated segment (i.e., a word or a phrase) of a sentence designed as an experimental stimulus is recorded to measure sentence interpretation processes across time. In this method, the participants read the stimuli at the pace they can control for each segment. For these functions, it has been widely applied in non-native sentence processing research.

The mixed use of online and offline tasks targeting RC attachment conducted in the present study can shed light on whether WM affects RC attachment in implicit or explicit conditions and whether working memory is assumed to be the only resource for sentence processing.

In the present research, SPR presented the same ambiguous sentences to L2 learners and natives, comparing the reading time between the two groups. These prevalent experimental design and method was employed not only to examine how the reading patterns of L2 sentences in L2 learners is different from differ from those among natives but also to test whether L2 individual factors can predict L2 syntactic processing. In addition to SPR, four instruments that assess individual differences in the linguistic background, language proficiency of L2 learners and short-term memory capacity were administered.

In the following part, I will discuss the key theoretical views regarding the effect of these factors and the SPR findings, which have been so far released, since the role of each L2 factor is still debatable and different assumptions have been raised to account for their special effect on L2 syntactic processing.

Individual factors in L2 processing

Several interpretations have been reported to account for the possible causes of difference between natives' and non-native readers' L2 sentence processing. L2 learners may show low processing, either as a result of low working memory span (Jacob, 2009; Caplan, 2016) or as an effect of other related factors such as age or lower levels of proficiency (Hopp, 2015).

Working memory

While short-term memory (STM) refers to the capacity for holding a mall amount of information accessible for a short time, working memory (WM) is where the input is organized, stored and analyzed (Baddeley, 2010 as cited in Mascio, 2017). WM contributes to storing the input in a short interval and to simultaneously processing this input for performing tasks entailing cognitive abilities, specifically in language processing (Baddeley,1986; Omaki, 2005). WM as a cognitive individual ability, can thus potentially affect L2 sentence processing and learning results (Juffs & Harrington, 2011; Kim & Christianson, 2013; Traxler, 2007). WM also plays a large part in L2 input comprehension, learners' attention regulation (Indrarathne & Kormos, 2017), and encoding the processed input into long-term memory while processing input (Baddeley's model, 2012; Mascio, 2017). However, more broadly, memory systems, input encoding, retrieval process, and manipulating information are supervised by central executive (CE) functions (Baddeley, 2003, 2015). Chun et al. (2011) argue that WM in general, has significant effect in memory-demanding tasks and attentional processes. As Williams (2006) argued, L2 learners who have enough cognitive capacities may parse like native speakers and L2 learners with inadequate span may not be successful in online processing while simultaneously doing a memory-demanding task. Some computations such as short-term storing of information recovered from long-term memory when processing, are also performed in WM. The influence of WM therefore demands much attention to examine.

The role of WM is more prominent when processing the clauses with structurally and semantically long-distance dependencies, which require more cognitive capacity to assign syntactic relations. The interpretation of such structures involves more capacity and hence requires high memory span in real-time measures. For example, in (2), the subject of *studied or* the antecedents of *who* need to be recalled at the point where RC occurs.

(2) *The lecturer called the boy of the manager who was talking on the phone at the university campus.*

In this example of the garden-path sentence, L2 learner recalls three possible noun phrases for RC (*who*) and choose one of them after reanalysis. There are two conditions complicating processing. One is dependency between the antecedent and the host RC, involving more processing capacity across time; the other is the processing cost of the RC attachment choice, demanding further parsing resources.

Concerning the processing in (2), it is clear that a lot of data should be kept in WM to recall later, so while low working-memory individuals might find it difficult to process, processing the same task for high working-memory individuals seems to be easier. The effect of individual factors is sometimes so significant that Jacob (2009) assumed that WM span can neutralize the role of other affecting factors such as L1 influence. They also play a large part in selecting RC attachment by participants, specifically when low working-memory L2 learners cannot store the first noun phrases (s) for a long time in their buffer and retrieve it later.

Gibson (2000) believed that working memory span is vital in language comprehension. It is assumed to be necessary in (a) *storing* of the constituent, and (b) *integrating* an incoming word into the syntactic structure built thus far, which result in sentence comprehension. Working-memory span is thus believed to play a determining role in RC attachment parsing (Jacob, 2009), For instance, in (2), if *the boy* fades away from WM when RC is being read, there is only *the manager,* still available to attach to the relative clause. If that is the case, low WM span cause L2 speakers to choose low attachment, although their native language prefers high attachment. On the other hand, high WM capacity enables participants to store an input such as *the boy* until they reach RC and recall, as L1 influence.

Relying on the experiments used to determine WM capacity, the type of materials, the learner's proficiency and acquisition age, prior empirical research have revealed inconsistent findings. Since working memory is regarded as a variable in most psycholinguistic studies on sentence processing, appropriate way of measuring working memory capacity has always been a matter of concern. L2 studies, for instance, by Juffs (2004, 2005), have employed measures of Daneman and Carpenter's (1980) reading span test. Juffs (2004) examined the impact of WM capacity during parsing garden-path sentences. The results revealed non- significant correlation between time-course of reading and WM span, although the readers with low-memory span showed slower reading times that those with high-memory span. Similarly, Juffs (2005) tested the effect of WM span in parsing sentences with long-distance dependency and found no significant difference in reading times or RC attachment preference to be attributed to memory span.

In contrast, Swets et al. (2007) indicated that RC attachment choices are affected by a participant's WM span, in that participants with higher spans preferred to select an RC attachment different from participants with lower spans.

King and Just (1991) carried out a self-pace dreading task, in which participants were asked to read each segment of a sentence by pressing the button, and recall the last word of sentences in each sentence set. Employing Daneman and Carpenter's (1980) reading span test, they showed the participants' reading span size and evaluated both groups' performances, those with a high span and those with a low span. King and Just found that the high-spans show shorter reading times than the low-spans when parsing object RC, These results supported the claim that individuals with low spans experience more processing cost than those with high spans whilst parsing structurally complex sentences. The findings from a self-paced reading by Williams (2006) showed an influence of WM span on online processing in Korean, Chinese and German L2 learners of English. The results from his study revealed that learners with high WM behaved like native speakers.

In addition to reading span task, backward digit span (BDS) as one of the most common tests, specifically in measuring short-term memory (Hester et al., 2004; Richardson, 2007), was introduced to assess memory span. This kind of test is derived from backward recall of digit sequences. As in traditional description, memory span refers to the longest sequence of a series of items we can retrieve at once. It comes from short-term memory and acts like a storage following each presentation (Daneman & Carpenter, 1980). The memory tests thus refer to the most amount information a person can encode, store and retrieve. In addition to memory capacity, the way people understand sentences in their second language can be affected by factors, such as the start time of learning (Weber-Fox and Neville, 1996) and level of being proficient (Rossi et al.,2006).

Age of Acquisition (AoA)

There are evidence showing a negative relationship between the age of L2 learning and the achievement in L2 learning (Singleton and Ryan, 2004), specifically within language sub-branches such as syntax (De Keyser, 2000). The lower age the learners at which start learning, the higher level of ultimate attainment they will reach. AoA effects are believed to be due to a reciprocal exchange between the L1 and the L2 during the lifetime (Zhao and Li, 2010). These factors may be caused by differences in experiences, social and educational backgrounds, thinking abilities, and levels of motivation between adults and children (Hyltenstam and Abrahamsson,2003) or biological changes such as the process of becoming more dominant in one side of the brain that happens during puberty, increase in estrogen or testosterone (Ullman, 2005), which can have a significant influence on the L2 final attainment, interplaying with the factors related to the experience (Knudsen, 2004).

The critical period hypothesis is the most debated theory proposed on this issue, which holds that there is a specific time when the brain is more open to learning a second language during early life. All researchers have reached a consensus that receiving second language input at a later time is mostly connected to achieving a lower level of proficiency in that language. However, some people are still concerned about if the critical period might be applied to learning a second language (Birdsong, 2006; VanHove, 2013). The process of learning L2 grammar and syntactic processing have often been believed to be modulated by the effects of age of Learning (Newport et al., 2001; Ullman, 2004). Regarding the domain of L2 syntax, prior studies have reported that most people who begin learning a second language before the critical period show native-like syntactic performances. However, after the critical period, most L2 speakers' performance is different from that of the natives (De Keyser et al., 2010).

Proficiency

The level of being proficient is another key factor affecting L2 RC attachment processing to examine. The impact of proficiency on L2 processing has been highlighted by declarative/procedural model (Ullman, 2001), which describes proficiency as the overall amount of L2 exposure and exercise (Ullman, 2001), which is closely associated with the age of learning (Ullman, 2005). This model explains L2 speakers, during language learning, relay on declarative/lexical memory after shifting from a limited procedural/grammatical system and use more lexical and semantic signals with less dependence on syntactic processing procedures. This change can be flexible as L2 proficiency increases (Ullman, 2005). While L2 learners with low-proficiency would employ more the declarative system for syntactic parsing through learning and remembering difficult grammar patterns complete phrases or groups of w ords, for high-proficiency L2 speakers, the procedural framework plays a more noteworthy part in parsing syntactic structure (Steinhauer et al., 2009). Steinhauer and his colleagues argue that, L2 learners with low-proficiency recall possible linguistic reliances and their grammatical parsing relies on frequency measures (Davidson and Indefrey, 2009a). When proficiency boosts, L2 learners begin revealing the underlying grammatical patterns of the L2, leading to the occurrence of grammar use and application of practical rules.

It is argued that the parsing differences between people learning a second language and natives can be due to the level of L2 knowledge (e.g., Hopp, 2010). Diverging from native-like performance with misanalysis, L2 learners with lower proficiency are less able to interpret structurally complex L2 input than native speakers (Jackson, 2008), and might show difficulty in processing the structures with long dependencies than native speakers (Jackson & Dussias, 2008).

The effect of individual differences in proficiency have been examined by similar tasks. For instance, in a self-paced reading by Jackson and van Hell (2011), it was found that Dutch learners of English with low proficiency showed processing difficulty for subject RCs, while the learners with high proficiency behaved like the native English speakers. Although high proficiency learners were asked to evaluate the sentences for grammaticality when parsing them, they processed native-like (Jackson & Dussias, 2009). This might not be the case in reading study in which the participants are only asked to parse the sentences for comprehension (Jackson & Bobb, 2009). Unlike the native speakers, the L2 learners however often have difficulty integrating syntactic and lexical-semantic information to parse L2 sentences, specifically in a grammaticality judgment task. It is thus likely that no reading time differences due to the influence of both proficiency or WM span be observed during L2 sentence processing. It was found that there are reliable correlations between WM span and L2 proficiency (Juffs & Harrington, 2011). The higher L2 proficiencythe L2 learner show, the less WM span is used when doing intended tasks (Service et al., 2002). Therefore, L2 parsing can lead to processing cost, in particular for individuals with low L2 proficiency than those with high L2 proficiency.

It is theoretically important whether or not L2 parsing strategies is modulated L2 factors such as cognitive span, general proficiency and age is of theoretical importance. Some argued that the difference between L2 learners' and native speakers' RC parsing cannot be caused by discrepancies in cognitive span, proficiency, and age. Whereas others assume that L2 parsing differences are influenced by such factors. However, it remains still unclear whether and how L2 sentence parsing might be affected by such individual factors.

Under specific situations, when L2 learners are involved in paying their attention to the manipulation and interpreting the input simultaneously individual differences in L2 factors such as low L2 proficiency and/or low WM span can influence L2 learners' processing online. Under such conditions, L2 learners for example with a high WM span or high proficiency are more able to interpret the input native-like. Otherwise, learners appear to show a shallow processing of the input, regardless of individual differences. The results of Hopp's study (2010) revealed that individual variability in processing speed can affect participants' online interpretation, when engaging in the grammatical information of the input. In contrast, some researcher believe that slower processing speed does not qualitatively impact L2 learners' performance, especially when performing the task involving sentence comprehension (e.g., Roberts & Felser, 2011). Reading for interpretation entailing more implicit processes is more viable than individual variabilities in cognitive capabilities (Robinson, 2005). This suggests that when L2 sentence comprehension itself can be influenced by tasks design and materials, it is less likely that high-spans and L2 learners with low proficiency parse the input differently from those with low WM span or proficiency.

Few studies have been done to examine the impact of differences in WM capacity, proficiency and age, specifically when the participants are required to process L2 ambiguous sentences with manipulated conditions, such as length of RC (short/long) and position of RC (extraposed/non-extraposed). This is the first that aims to test whether L2 RC processing can be affected by the individual factors when reading experimental stimuli manipulated with structural variables.

METHODOLOGY

Carrying out the current study, the influence of independent variables (WM, proficiency, AoA) on outcome variables (RTs of RC processing and attachment choices) when reading ambiguous sentences was tested. The research questions are concerned with examining the effect of individual factors on RC parsing. Hence, the study tried to answer the following questions and test the null hypotheses:

1. Is participants' online RC processing significantly affected by individual factors?
2. Is participants' offline RC attachment significantly influenced by individual factors?
3. Is there any statistically significant difference between the Persian learners' and native speakers' mean RTs of RC processing and comprehension questions?

This study employed different tasks in order to measure participants' individual differences in L2 factors and compare the control and experimental groups' performance in RC processing.

Participants

Thirty-three participants participated in this study after filling out the consent form (Appendix A). They were recruited through releasing research details on Facebook and Instagram with the help of friends and classmates. Finally, they were given gift cards (the SF-Anytime cards, each 49 SEK) as compensation for their participation after completing the experiment.

The L1 group sample included fifteen English native speakers (13 females, 2 males) who took part in the experiments (mean age = 30.67; SD = 4.67). Although some of them were not attending in their home countries at the time of conducting the experiment, English was still dominant language in their daily conversations. For them, no eyesight problem, mental disorder or physical inability were reported.

The L2 group comprised 18 Persian L2 learners (6 females, 12 males). They were university graduates or students who had been exposed to English from 7th grade until their 12th year of high school during English courses while Persian was the main medium of instruction mean age = 31.44; SD = 5.49). In addition to English, 13 participants had knowledge of another language, whereas five of them had no knowledge of other languages. They were all residing in their homeland during the experiment. No impaired vision, mental or physical illnesses were reported for L2 group participants.

Materials

LHQ3

The language history questionnaire (LHQ3), as an online version tool designed by Li et al. (2020), was employed to gather information about individuals' linguistic and educational background. This questionnaire provides data about age, education, and also gives details about L2 aptitude in reading, writing, speaking, knowledge of other languages, and duration of staying overseas (Appendix B).

LexTALE

In order to measure L2 learners' proficiency level, LexTALE test as a reliable predictor of English vocabulary knowledge was used. LexTALE, usually employed by L2 researchers, can be also regarded as measure of general English proficiency. In this task, a line of letters is showed up on the screen and participants are required to decide if the line is a real English word by pressing yes or no buttons. LexTALE is run online and downloadable from www.lextale.com.

Reading span task

The current study measures working memory capacity by a reading span test taken from Klaus & Schriefers' research conducted in 2016. The test includes two components including processing components in which participants are asked to decide if the sentence makes sense (e.g. *In summer they should buy a cooler to reduce the temperature*) and storage component in which a set of recalled nouns are appeared (e.g. *orange, leg and lamp*) and participants are required to recall them later. Trials are constituted from combining a sentence and a noun. Such trials containing two to six set sizes of sentences construct single columns of blocks, which appeared in random for participants to decide about the semantic correctness of the stimuli and remember as many words as they can following each sentence[1].

Backward digit span task

To satisfy the objective of the current study targeting participants' memory capacity and WM function, the digit span task taken from Luthra & Todd (2019), initially designed to estimate forward digit span, was redesigned to measure backward digit span (Stimuli 1 2 3 4, response 4 3 2 1). The motive behind this change was that the backward digit span is in compliance with the RC attachment processing in which the L2 learner first needs to encode and store antecedents from back, and then recall them later to parse sentences through incorporating data. Some Javascript coding (*return selection* into *return selection.reverse()*, changing *minSetSize*) was manipulated to redesign the task. Additionally, in order to properly implement the task and defining instructions and to recall the items in a reverse order, some instructions was redefined. (Appendix C). Cognition.run was the server on which the test was coded, run and data was accessible there to get.

Self-Paced Reading (SPR)

A total of Sixty-four sentences, 32 experimental sentences and 32 fillers, were designed for this experiment. The stimuli for online measuring of RC attachment were initially adopted from prior L2 studies, Felser et al. (2003), Hopp (2014), and Rah (2009). However, some changes were added to stimuli to fit them in terms of the length of stimuli, naturalness, and task conditions. After piloting the stimuli, some sentences were reconstructed to adjust them to the same length, form/tense of verbs, structural pattern, and elements order. The reason for these adjustments was that for the reading time experiment, it is necessary that the sentences should be not only designed for general length but also for the same chunk length (Appendix D). To lessen the possible effect of processing difficulty for all the L2 learners, more frequent words were used in the sentences. Both the British National Corpus (BNC) and the Corpus of Contemporary American English (COCA) were employed to check the frequency of words.

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[1] The scripts to run the task are available here: https://github.com/janakl4us/workingmemory.

Eight lists of experimental sentences were organized, each consisting of four items from each condition. The stimuli were designed, including the variables such as definite/indefinite nouns, short/long length of RC, extraposed/ non-extraposed RCs, following a 2*2*2 factorial design (see Appendix D). Psychopy builder was the software on which the SPR task was designed using added codes. Then, the Pavlovia.org server was employed for conducting the the SPR task online and getting data.

Offline questionnaire

Apart from SPR as an online experiment, the offline questionnaire taken from Rah (2009) was also employed to test participants' offline preference of RC attachment (Appendix E). It consisted of eight questions with three choices to evaluate the judgement for RC attachment, as one example is shown below (3).

(3) The photographer ignored the daughter of the manager who was impolite and arrogant.

- o the photographer was arrogant.
- o the daughter was arrogant.
- o the manager was arrogant.

Procedure

All tasks were performed online. The links of the tasks were sent to participants via email. Participants were asked to complete the tasks in order they received them and informed the researcher.

According to the objective of the present study, the LHQ items were customized. Participants were asked to enter the questionnaire using their password after clicking on the following link, and fill out it.

(lhq3.herokuapp.com/student/student_signin/?questionnaire_ID=vvz27qcx).

To do the LexTale test, participants were required to enter the task by clicking on the link below and start the task by clicking on Start LexTale after selecting English. *www.lextale.com*

In the reading span task, participants were asked to read the sentences which were presented at the center of the screen for 10 seconds. If the sentences did not make sense, participants were required to press the right arrow button corresponding to the response "no". If they made sense, participants were required to press the left arrow button corresponded to the response "yes". The word displayed for 1,200 ms after a blank screen of 500 ms, and participants were guided to read and recall this word. After appearing two to six combinations of sentences or words, six blank spaces were showed up on the left side of the screen. Then the participant was asked to remember all words they could for each blank space, regardless of the word order in which they were shown up. Lasty, the participant went for next attempt by clicking on the continue button.

In the backward digit span, a list of words was shown on the screen and presented to participants to remember them in backward order. The test began with groups of numbers that had 3-digit sets up to 13-digits sets which were shown randomly after 1 second. The feedback for each response was presented each time (https://1plpk9wavy.cognition.run).

In the SPR task, a fixation point (+) was initially displayed in the middle of the screen, then the sentences were shown phrase by phrase in the middle of the screen. Every time participant pressed the button, the old part of the phrase went away and the new phrase of the sentence was shown up instead. As an alarm for presentation of new sentence, each new sentence appeared with an asterisk (*). A comprehension question appeared immediately after some of sentences for participants to answer by pressing one of two buttons (y=yes) and (n=no). The reason for adding these questions was to decrease the possibility of continuous motor behaviour by participants.

In addition to SPR as an online experiment, participants were given an offline questionnaire and they were required to show their RC attachment preferences by choosing one of the three potential alternative choices they found most plausible and correct.

Participants were allowed to complete the tasks in their free time without monitoring and ask any questions about the issues they might face when performing the tasks via email.

RESULTS

LHQ3

Table 1 presents the descriptive information of L2 proficiency and exposure measured from the LHQ3 since L2 proficiency and exposure were found to be two of the most important factors influencing participants' online processing by L2 researchers.

Table 1. Persian learners' Self-rated proficiency and exposure

LHQ3 metrics	Mean	SD
L2 Proficiency	0.71	0.14
L2 Exposure (year)	20.44	6.67
Range (10-35)		

In order to test whether Persian participants' L2 proficiency and exposure can predict or affect their L2 online processing, correlation tests were performed after eliciting data of online processing from the SPR experiments.

LexTALE

Participants' LexTALE scores were calculated based on their proportion of correct responses. Not surprisingly, descriptive information, as presented in table 2, showed that native English speakers' LexTALE scores (M = 91.40) was higher than the Persian learners' scores (M = 74.09).

Table 2. LexTALE scores for L2 learners and native English speakers

Group	N	Mean	SD

Native speaker	15	91.40	7.76
Persian learners	18	74.09	15.83

To present a comprehensive illustration of L2 Persians' proficiency scores measured by both LHQ3 and LexTALE tasks, a Pearson correlation test was run, as measured in Table 3. This was to test whether there is a relation between them and if they can influence participants' online processing. Additionally, a linear regression model was performed for more clarification, as illustrated in figure 1.

Table 3. Correlations of Proficiency measures for Persian learners

		Proficiency	LexTALE
Proficiency	Pearson Correlation	1	.503*
	Sig. (2-tailed)		.033
	N	18	18
LexTALE	Pearson Correlation	.503*	1
	Sig. (2-tailed)	.033	
	N	18	18

*. Correlation is significant at the 0.05 level (2-tailed).

The Pearson's test results revealed a significant correlation between the proficiency measures (r (18) = 0.503, p = 0.033). Similarly, the regression model showed that the correlation coefficient was positive since y goes up as x increases, showing an upward trend.

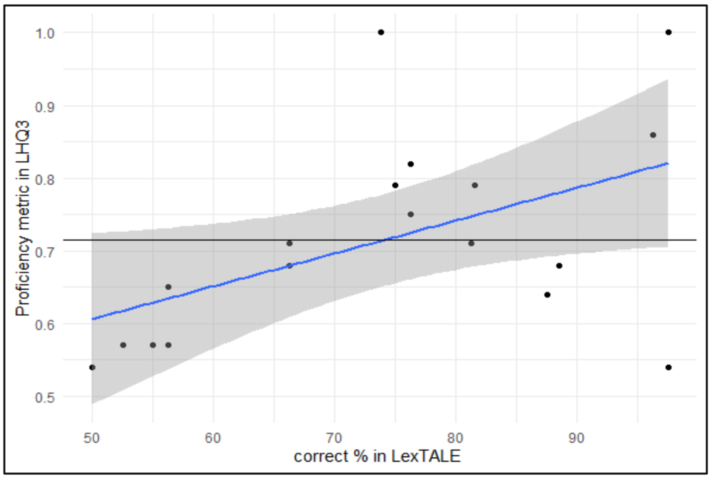

Figure 1. Scatterplot and regression line of lexTALE and self-rating proficiency scores for Persian learners

Backward digit span

As shown in Table 4, both groups' total number of correct answers on the backward digit span task were calculated and their descriptive information was provided.

Table 4. Descriptive statistics for both participants' performance on the BDS

	Persian learners		Native speakers	
	ML	DS	ML	DS
Mean	9.39	8.17	8.33	7.53
SD	1.75	1.58	2.22	1.95
C.V	18.63%	19.33%	26.65%	25.8 %

ML = Maximum length over all trials, DS = Digit Span over all trials and C.V = Coefficient of Variance

Although the mean of ML over trials the Persian learners could remember was higher than that of native speakers (9.39 digits vs 8.33 digits, respectively), non-significant difference was found between the groups on the BDS task, showing both groups performed similarly on the task.

Table 5. Correlation results between participants' age and digit span

		Estimate	Std. Error	t value	Pr(>|t|)
Native speakers	Intercept	2.2437	3.2875	0.682	0.507
	Age	0.1725	0.1061	1.626	0.128
Persian learners	Intercept	11.80746	2.10249	5.616	3.87e-05 ***
	Age	-0.11578	0.06592	-1.756	0.0981

In order to explore the correlation between participants' age and their digit span, a simple regression model was also run. Table 5 presented the intercepts values of the outcome variable (2.2437, 11.80746), slopes values (0.1725, -0.11578) and *p* values (0.507, 3.87e-05) for native speaker and Persian learners, respectively. The results from the model revealed that age and DS scores were not correlated among the native speakers, but a significant correlation between age and performance in the BDS task for the Persian learners, showing the younger learners did better than older ones.

Regarding the impact of age reflected in the line slope, the correlation is different for both groups of participants. While for Persian learners it is negative, it is positive for native speakers. It means that for Persian learners, the age increase leads to the digit span decrease, while it was a reverse trend for native speakers. This odd result among native speakers might be aligned with Winter's argument (2020:72), stating that "regression models might sometimes produce strange findings when predicting values beyond the known data range, called 'extrapolating'". It can be therefore concluded that the age increase might not always lead to weaker action when performing tasks demanding high memory span.

Reading span

Table 6 and Table 8 indicates the WM component scores and participants' processing performance in the reading span task respectively. As shown in Table 6, native speakers's WM scores were higher than those for Persian learners (M = 54.33 vs. 48.72). However, Persian learners' error rate is somewhat lower than that for native speaker. Moreover, to measure the internal consistency for each of the 15 single blocks, a Cronbach's α (Table 7) was measured. This measurement calculated the scores as the proportion of the corresponding set. The task had a high level of consistency, meaning that all parts of the task contributed equally to the individual scores. The consistency was measured to be 0.97.

Table 6. Measures of Participants' WM capacity in the reading span task

	Mean	SD	Recalled (range)	Skew	kurtosis	Error rate
Native speakers	54.33	9.34	40-65	-0.545	-1.352	4.84
Persian learners	48.72	9.20	28-66	-0.223	0.780	4.23

Table 7. Reliability test

Cronbach's Alpha	No of Items
0.97	15

Table 8 presents the descriptive information of both groups' mean RTs and error rates. The native English speakers showed shorter RTs *(M* = 2.295 vs. 5.643), meaning that they outperformed Persian learners. Standard deviations for Persian learners (*SD* = 2.18) were higher than those for native speakers (*SD* = 1.69), reflecting individual differences. It can, however, be proposed that native speakers' lower error rate may be correlated with higher WM scores. The overall results from this task indicated that while native speakers attempted to perform equally well on both components of the task, recalling and processing, Persian speakers seemed to concentrate more on the recalling, sacrificing the processing accuracy. *Table 8.*

Table 8. Descriptive summary of participants' performance in WM processing component in reading span task

	Mean	SD	RT (range)	Skew	kurtosis	Error rate
Native speakers	2.295	1,698	1.031-6750	2.267	.536	7.85
Persian learners	5.643	2,182	1.087-9877	-.412	.686	11.05

Offline task (Questionnaire)

Participants' offline attachment preference was examined through the offline judgement task and its descriptive analysis was shown in Table 9. The results from the participants' off-line behaviour revealed that the two groups did not perform similarly. Whereas the native English speakers showed a relatively consistent low attachment preference (i.e. 60

%), their percentage of high attachment preference was also remarkable (i.e. 40 %). Persian learners, in contrast, showed a dominant high attachment (i.e. 83.3%), and a lower tendency to prefer low attachment (i.e. 16.7 %). Similar to prior L2 studies on Persian speakers, the results of this study revealed the Persian learners' much tendency to show high attachment preference, whereas the native English speakers' behaviour were more different. Proficiency was also shown not to be a reliable indicator to predict low attachment choices by the Persian learners (see Table 10).

Table 9. Descriptive statistics of both groups' RC attachment preferences

Group	Response	Frequency	Percent	Mean	SD
Native speakers	High	6	40	4.27	1.33
	Low	9	60	4.00	1.73
Persian learners	High	6	83.3	6.61	1.65
	Low	9	16.7	1.33	1.53

Table 10. Relationship between Proficiency and Low attachment

		Proficiency	Low attachment
Proficiency	Pearson Correlation	1	.089
	Sig. (2-tailed)		.725
	N	18	18
Low attachment	Pearson Correlation	.089	1
	Sig. (2-tailed)	.725	
	N	18	18

After examining RC attachment preference offline in both groups, an one-way ANOVA and an independent samples t-test was also performed to know whether there is any significant difference between groups in high or low attachment preference.

Table 11. Mean RTs of participants' RC attachment preference

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Offline task	Equal variances assumed	8.264	.007	-2.794	31	.009	-.433	.155	-.750	-.117
	Equal variances not assumed			-2.724	25.714	.011	-.433	.159	-.761	-.106

One-way ANOVA showed a significant difference between groups in high attachment (F (1, 31) = 1.346, p < 0.001). As illustrated in Table 9, the Persian learners preferred high attachment more clearly than low attachment preferred by native speakers in the offline task. This being clearer is evidenced by the significant difference of attachment preferences in both groups. Similarly, T-test yielded significant difference between groups in attachment preference (p = 0.007). Furthermore, interval confidence measured by the values of the lower and upper bounds revealed higher means of attachment preference for the Persian learners and also greater mean difference for high attachment compared to low attachment, as measured in Table 11.

Self-Paced Reading (Online)

In SPR task, two measures were first calculated and analyzed: critical regions' RTs means across the experimental conditions, (b) group and condition effects. finally, correlation tests and regression models were run to explore whether individual factors can affect online L2 RC processing.

RC processing

The two groups' mean RTs were presented across regions 2, 4 (non-*extraposed RC and extraposed RC*) in four pairwise comparisons across conditions with the noun types (*definite/ indefinite)* and RC length *(short/long)*. The focus of this study is to only analyze the critical regions 2 and 4 where the RCs occurred.

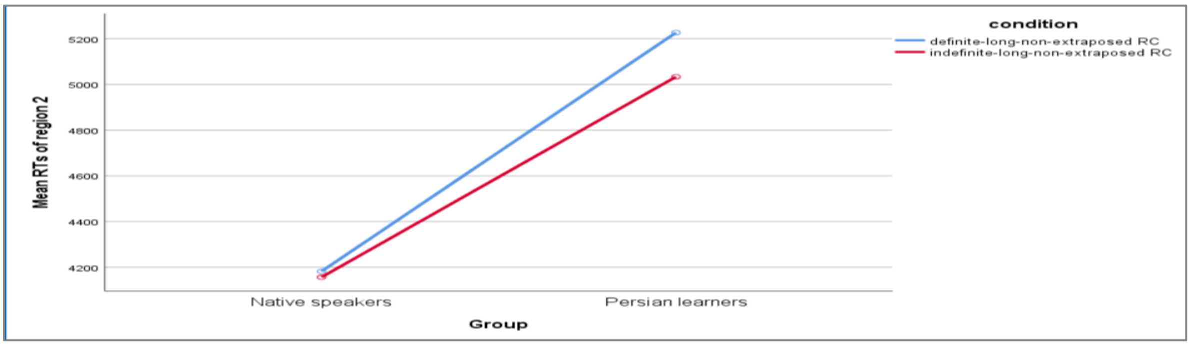

Figure 2. RTs mean of conditions (1) (2) (definite vs. indefinite-long-non-extraposed RCs) in both groups

The mean RTs for the Persian learners are overall longer than those of native speakers, as shown in Figure 2. However, for both groups, the mean RTs in the condition 1 (blue color) are overall higher than in condition 2 (red color). Testing for effects of group in region 2 a significant main effect was found (F (1, 31) = 13.337, p = 0.001), showing a difference in RTs between the two groups of participants, but no interaction effect (F (1, 31) = 1.719, p = 0.195).

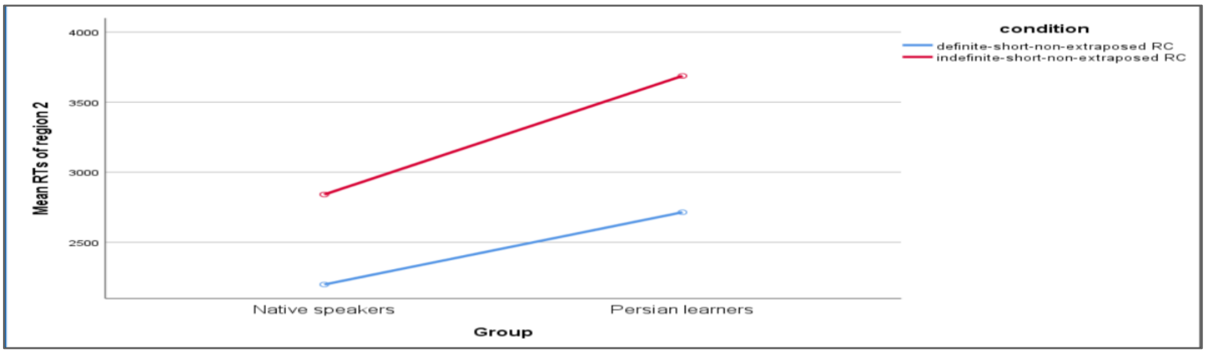

Figure 3. RTs mean of conditions (3) (4) (definite vs. indefinite short-non-extraposed RCs) in both groups

The mean RTs of conditions 3 (blue color) and 4 (red color) are illustrated in Figure 3. Unlike RTs in figure 2, here in figure3, the mean RTs in condition (4) are overall higher than in condition (3). At region 2, ANOVA results showed no significant effect for group (F (1, 31) = 3.308, p = 0.074) also no significant interaction effect (F (1, 31) = 0.025, p = 0.874). The mean RTs analysis for condition (3) and (4) at region 2 revealed identical results as for conditions (1) and (2).

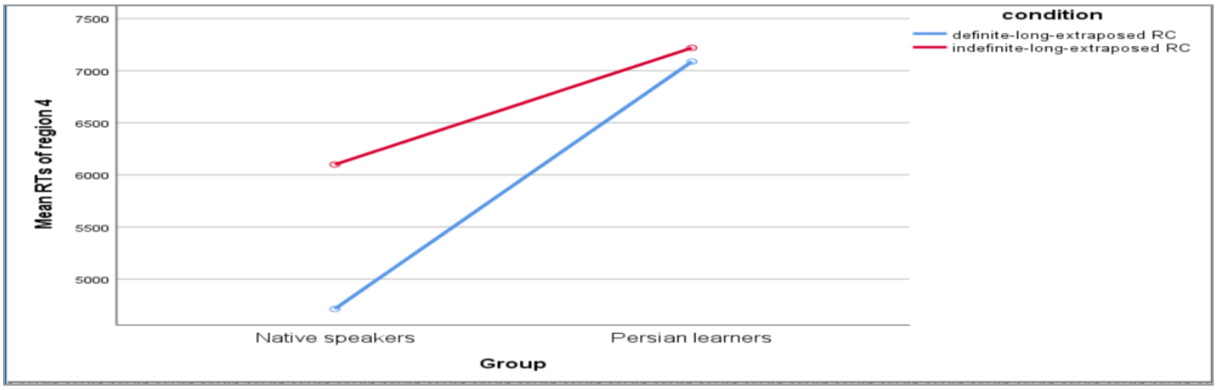

Figure 4. RTs mean of conditions (3) (4) (definite vs. indefinite short-extraposed RCs) in both groups

In figure 4, while the mean RTs of conditions 5 (blue color) and 6 (red color) for native speakers are not close to each other, those are relatively equal for Persian learners in two conditions. However, the mean RTs for native speakers are overall higher than those of Persian learners. The results yielded a significant main effect of group (F (1, 31) = 13.337, p = 0.001), meaning that a difference in the mean RTs was observed between the two groups of participants.

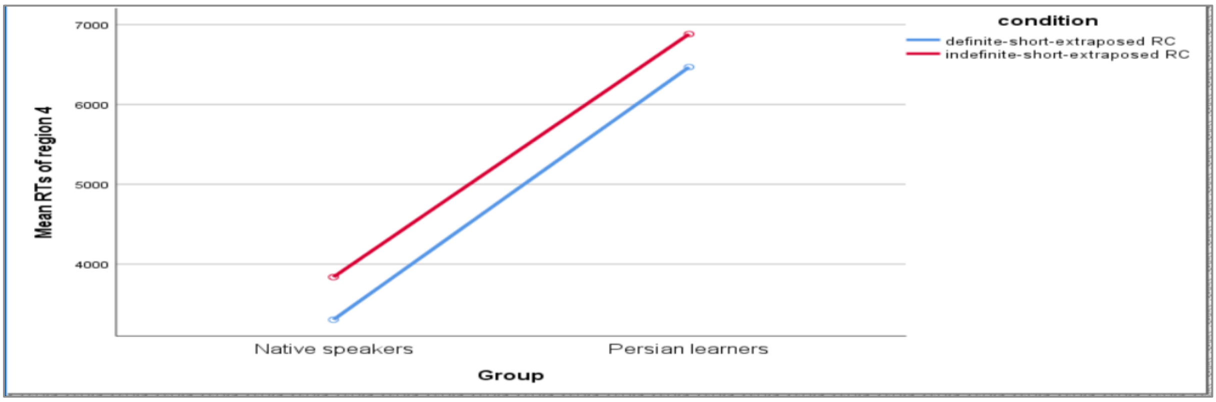

Figure 5. RTs mean of conditions (7) (8) (definite vs. indefinite short-extraposed RCs) in both groups

Figure 5 presents longer mean RTs for conditions 8 (red color) among the Persian learners in comparison with native speakers than for 7 (blue color). A two-way ANOVA was performed for region 4. The results showed that the condition had a noticeable effect ($F(1, 31) = 4.368$, $p = 0.041$), but the group did not show a significant effect ($F(1, 31) = 3.102$, $p = 0.083$). In addition, native speakers had a faster reading with overall higher RTs.

Working memory

To test whether online processing is influenced by WM, a Pearson test was performed to examine whether WM span is correlated with RTs of comprehension questions. Therefore, the scores from BDS and reading span tasks were elicited to perform the test.

Table 12. Relationship between participants' digit span and their comprehension question RTs

		Digit span	RT
Digit span	Pearson Correlation	1	-.418*
	Sig. (2-tailed)		.015
	N	33	33
Comprehension Qs RTs	Pearson Correlation	-.418*	1
	Sig. (2-tailed)	.015	
	N	33	33

*. Correlation is significant at the 0.05 level (2-tailed)

The test results revealed that there is a significant correlation ($p = 0.01$) between digit span and RTs of comprehension questions (-.418), indicating that the participants with high digit span outperformed in reading the comprehension questions than those with low digit span. In contrast, correlation tests showed no significant correlation ($p = 0.623$) between digit span and high/low attachments RTs, as seen in Tables 13 and 14.

Table 13. *Correlation between participants' digit span and RTs of high attachment*

		Digit span	RT
Digit span	Pearson Correlation	1	.089
	Sig. (2-tailed)		.623
	N	33	33
High attachment	Pearson Correlation	.089	1
	Sig. (2-tailed)	.623	
	N	33	33

*. Correlation is significant at the 0.05 level (2-tailed).

Table 14. Correlation between both groups' digit span and RTs of low attachment

		Digit span	RT
Digit span	Pearson Correlation	1	.193
	Sig. (2-tailed)		.283
	N	33	33
Low attachment	Pearson Correlation	.193	1
	Sig. (2-tailed)	.283	
	N	33	33

*. Correlation is significant at the 0.05 level (2-tailed).

In addition to correlation tests, a multiple regression model was run to probe whether individual factors, such as memory digit span, age, and proficiency can predict participants' L2 RC processing when reading ambiguous sentences. Since adding more variables into a regression model might lead to overfitting, the most potential variables based on research literature were selected to account for variation in the dependent variable. Additionally, the independent variables are not occasionally associated with the predicted variable but might be correlated with each other, leading to multicollinearity (winter 2020). To reduce the possible effect of overfitting and the multicollinearity, memory digit span, age, and proficiency were, therefore, included as variables to test whether they can affect participants' RC parsing.

The regression model revealed that as proficiency values decline, the RTs go up by -0.003, suggesting that RTs variation cannot be explained by the proficiency. However, RTs can be expected to increase or decrease by 0.104 for every change in span. Multiple R-squared is 0.3887 and adjusted R-squared is 0.3014, which is not a steep decline from the adjusted R-squared. The model fit revealed good results. However, none of the predictors were found to be statistically significant, which is assumed to be due to the correlation between variables or the number of participants. Although the results were not significant, the overall regression measures including *p*-value (0.006) and *F*-statistic (4.452) showed that the model as a whole is statistically significant, suggesting that there is a relation between the L2 factors and the RT, however, non-significant.

Table 15. Regression model of L2 individual factors in predicting online sentence processing

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1.589349	1.124759	1.413	0.16866
Proficiency	-0.00345	0.009579	-0.361	0.72098
Digit pan	0.104822	0.076246	1.375	0.18010
Age	0.042423	0.029411	1.442	0.16028

Table 16. Statistics summary for overall model fit

Regression statistics	
Residual standard error	0.7552
Multiple R-squared	0.3887
Adjusted R-squared	0.3014
F-statistic	4.452
p-value	0.006

DISCUSSION

The current study examined the effect of L2 individual factors on the processing of RC attachment. Linear regressions and correlation tests were run in order to explore whether the L2 factors would affect the online SPR and offline results with sentential stimuli. Three L2 factors were taken into consideration and their influence on RC processing will be separately discussed.

Working memory

A significant correlation was found between digit span and the RTs of comprehension questions, meaning that the higher digit span the participants show, the lower reading time it takes for them to interpret comprehension questions. This suggests that Persian learner's performance in processing comprehension questions, specifically questions containing short length and non-extraposed RCs, can be modulated by individual differences in WM span. The result is aligned with the statement proposed by Caplan's (2016), stating that comprehension question interpretation entails WM in real-time processing. WM is thus evidenced not only to affect the overall comprehension but also to influence the participants' performance in incorporating syntactic-semantic dependencies in online sentence processing.

In contrast, based on correlation tests, no significant relation was found between digit span and high attachment mean RTs (r = 0.089, p = 0 .623) or low attachment RTs (r = 0.193, p = 0 .283). Regarding stimuli with extraposed RCs and definite antecedents, the findings revealed that Persian learners attach the first antecedent as high attachment to the RC. This might suggest that the high-span readers process RC attachment more easily, and the low-span readers are unable to store the first noun phrases for a long time in order to retrieve them at the point where the RC appears, as argued by Payne et al. (2014) and Lee and Federmeier (2012). In this regard, longer RTs for low attachment can be attributed to low WM span during the retrieval process. However, the recalled items with similar syntactic cues in reanalysis caused interference, leading to more processing cost (Caplan, 2016). These findings highlighted the significance of WM span RC attachment processing during which constituents are required to be stored and retrieved later to comprehend sentences, as noted by Jacob (2009).

The results from the multiple regression revealed that WM span was not statistically significant, more likely because of multicollinearity or small sample size. However, the overall model fit was assumed to be statistically significant, suggesting that a trace of impact of WM is still involving in processing the L2 RC attachment ambiguity.

Proficiency

Although there were overall significant effects in the Persian learners' RTs patterns, individual preferences were not found either for high attachment or low attachment. Despite these differences, proficiency was not evidenced to be a factor affecting significantly RC attachment processing. In this regard, the analysis of relationship between low attachment choices and proficiency scores showed that proficiency is not directly a reliable predictor in predicting RC attachment choices (Persian learners: r = 0.089, p = 0 .725). These results are incompatible with the findings from the earlier research providing evidence that adult learners with low proficiency can also exhibit native-like processing of L2 RC attachment (Baek, 2012, Jegerski et al., 2016, Uludag, 2020).

Age

The results obtained from for two groups' mean ML (Maximum Length) suggest that, in addition to participants' individual differences in backward digit span, low standard deviations can be attributed to participants' age. Moreover, the values of the BDS metrics revealed that variability of dataB distribution for native speakers was higher than that for Persian learners. This suggests the wide range of the mean data might also be due to differences in age. This dispersion appeared when there were data points that were very different from the mean, called outliers. The BDS measures also might show that high or low span can be attributed to WM performance as well as age, influencing online L2 processing.

General discussion

The two groups showed relatively similar RTs patterns in most conditions, but with overall faster reading time for native speakers in RC processing. This RCs pattern is in line with the argument that L2 learners have often slower pace at reading compared to native speakers, reflecting individual difference in processing efficiency (processing speed), as proposed by Fender (2001). However, some results revealed that having slow pace in processing does not seem to qualitatively influence L2 learners' processing performance, in particular during doing the task demanding reading to interpret (e.g., Roberts & Felser, 2011). Despite these similarities and differences, the findings revealed that the way people understand sentences by updating information as they go along is not influenced by how well they are proficient in a second language and WM performance, which goes against what Cole and Reitter (2019) believe. Furthermore, although the multiple regression model indicated a non-significant effect of individual factors, the overall model fit revealed an overall significant effect (p-value = 0.006), reflecting that some trace of WM impact seems to be observable in parsing sentences with RC attachment ambiguity.

CONCLUSION

The current study aimed at providing empirical evidence on the impact of the individual factors on L2 sentence parsing. This research is the first to investigate whether L2 real-time sentence processing is influenced by L2 factors, specifically where the sentences as experimental stimuli are appeared with structural variables manipulated to evaluate participants performance during online incremental processing of RC attachment. Involving a range of different variables can give us a better understanding of whether individual factors influence L2 online processing, hence filling the gap of a less studied area of RC attachment ambiguity employing the SPR task and offline study with the questionnaire.

The results of the experimental tests performed through the online SPR, offline studies and memory tasks revealed that L2 RC parsing is not reported with a considerable influence by WM span, proficiency and age. The key finding of L2 processing analysis is that L2 learners have slower pace at reading than native speakers in online interpretation of L2 ambiguous sentences. However, they show an equal comprehension accuracy offline.

Concerning individual differences between learners, less robust evidence was found to show that WM capacity, proficiency and age are predictive of success in adult L2 sentence processing and attachment preference. However, there were some correlations between individual factors and both online and offline measures of sentence processing. The findings indicated that WM span can be correlated to RTs, specifically comprehension questions RTs, demonstrating that SPR is an influential methodology for examining the impact of L2 factors in RC attachment processing.

This study has employed a group of individual factors and structural variables that might have an influential effect in interpreting L2 RCs. Therefore, it can be served as a start point for bigger research where a bigger sample size and a more developed data design may strengthen findings. The findings of this research will prompt more studies into the influences of individual differences on RC processing among L2 learners using eye-tracking technique. Monitoring eye movements can inform pedagogical approaches to second language acquisition. For example, by promoting educational strategies and cognitively demanding skills in classroom setting, specifically more appropriate processing strategies, L2 learners are more likely to behave native-like and gain automaticity in English RC comprehension.

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