Semantic Priming Effect on Relative Clause Attachment Ambiguity Resolution in L2

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Abstract
This study examined whether processing ambiguous sentences containing relative clauses (RCs) following a complex determiner phrase (DP) by Persian-speaking learners of L2 English with different proficiency and working memory capacities (WMCs) is affected by semantic priming. The semantic relationship studied was one between the subject/verb of the main clause and one of the DPs in the complex DP to see if, as predicted by Spreading Activation Model, priming one of the DPs affects the L2 learners' preference. The results of a task using Rapid Serial Visual Processing showed that semantic priming does not affect the choice of the antecedent; rather, the L2 learners' processing is guided by syntactic information. A negative correlation was found between WMC and RC attachment preferences. The findings support the predictions of the chunking hypothesis for L2 learners.
Key words: Attachment preference, Proficiency, Relative clause ambiguity, Semantic priming, Working memory capacity

Introduction

Numerous studies have focused on the processing of structurally ambiguous sentences in order to shed light on the nature of the human sentence processing mechanism. Several studies have shown that there are cross-linguistic differences in the resolution of ambiguous relative clauses (RCs) like *Someone shot [the servant]$_{DP1}$ of [the actress]$_{DP2}$ [who was on the balcony]$_{RC}$*, where the RC can modify either DP1or DP2 in the preceding complex DP. A high (DP1) attachment preference has been reported in Dutch (Brysbaert & Mitchell, 1996; Desmet, Brysbaert & De Baecke, 2002), French (Baccino, De Vincenzi & Job, 2000; Colonna, Pynte, & Mitchell, 2000; Quinn, Abdelghany & Fodor, 2000, Zagar, Pynte, & Rativeau, 1997), German (Hemforth, Konieczny, Scheepers & Strube, 1998; Hemforth, Konieczny & Scheepers, 2000), Persian (Arabmofrad & Marefat, 2008), and Spanish (Cuetos & Mitchell, 1988), whereas a low attachment (DP2) preference has been found in Brazilian Portuguese (Finger & Zimmer, 2000; Miyamoto, 1998), English (Cuetos & Mitchell, 1988; Frazier & Clifton, 1996;

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Deevy, 2000), Norwegian, Swedish, and Romanian (Ehrlich, Fernandez, Fodor, Stenshoel & Vinereanu, 1999). A number of attempts have been made to account for these cross-linguistic differences.

The dominant account in the literature for RC attachment preferences has been based upon Recency (Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996), Late Closure principle (Frazier & Fodor, 1978), or Right Association (Kimball,1973), which assume that all human languages are processed in the same way. Frazier (1978) defined Late Closure as "When possible, attach incoming material into the clause or phrase currently being parsed" (p. 49). This is similar to Kimball's (1973) Right Association principle "Terminal symbol is optimally associated to the lowest nonterminal node" (p. 24). According to Recency principle, constituents such as RC modifiers are attached to the most recently processed (or closest) phrase, regardless of the language being processed (Fernandez, 2003). The principle of Late Closure has been found to apply in a number of languages, with a wide variety of constructions.

Cuetos and Mitchell (1988) were among the first to challenge the 'universalist' view; they showed that parsing does not proceed in the same way in all languages. In their experiment, they gave constructions comparable to *Someone shot [the servant]$_{DP1}$ of [the actress]$_{DP2}$ [who was on the balcony]$_{RC}$* to English and Spanish native speakers. They found that English subjects tended to attach RCs to DP2. On the other hand, speakers of Spanish showed an overall high attachment (DP1) preference. This led them to conclude that certain parsing strategies may not be universal, and that there exists cross-linguistic variation. Following Cuetos and Mitchell, further studies were conducted in order to examine RC attachment preferences in other languages. The results have provided additional support for the view that the Late Closure principle might not be generalized cross-linguistically, and there exist strategies that are more likely to be operative in other languages.

The data obtained from Gibson et al. (1996) experiment on sentences with three potential antecedents for the ambiguous RCs in English and Spanish provided evidence for developing the Predicate Proximity principle, as another factor that competes with the universal Recency principle. According to Predicate Proximity, incoming constituents are favorably attached to a verb argument. Gibson and Pearlmutter (1998) argued that in certain languages like German, Russian and Spanish, Predicate Proximity outranks the Recency principle and leads to a high (DP1) attachment preference. By contrast, in configurational languages such as English, Norwegian, and Swedish, ambiguous modifiers attach to the most recent phrase in harmony with the locality principle of Recency (Felser, Roberts, Marinis & Gross, 2003), leading to low-attachment instead.

Ambiguous RCs in Persian

According to Karimi (2001, p. 31), "Persian is a null-subject verb final language with SOV word order in declarative sentences and subordinate clauses". Similar to English, Persian RCs are post-nominal, and since there is no relative pronoun in Persian, RCs are always introduced by complementizer *ke* in Persian (Taleghani, 2008, p. 84).

Previous studies have shown that Persian native speakers have a high attachment

preference (Arabmofrad & Marefat, 2008; Marefat & Meraji, 2005; Moghadassian, 2008). Forty five Persian-speaking monolinguals participated in an on-line study conducted by Arabmofrad and Marefat (2008). Fifteen sets of items were developed and normed; each set contained sentences in three conditions: 1) RC was semantically related to DP1 and could be attached only to it and not to DP2 (sentence 1 below); 2) RC could be attached only to DP2, based on a semantic relationship (sentence 2 below); 3) an ambiguous condition in which RC could be attached to both DP1 and DP2 (sentence 3 below).

(1) *an mærd pæræstar-e nozad [ke dašt ghædæm mizæd] ra did*
'That man saw the nurse of the infant [who was walking].'

(2) *an mærd nozad-e pæræstar [ke dašt ghædæm mizæd] ra did*
'That man saw the infant of the nurse [who was walking].'

(3) *an mærd dokhtær-e pæræstar ke dašt ghædæm mizæd ra did*
'That man saw the daughter of the nurse [who was walking].'

The rationale behind the study was that if the participants prefer DP1 attachment, then the reaction time for sentences in which the RC is, contrary to their expectation, semantically related only to DP2 would be slower than that for sentences in which the RC is semantically related to DP1. And, conversely, if they have a tendency to attach RC to DP2, then, reaction time for sentences in which the RC could only be attached to DP1 would take longer. The participants, tested individually, were required to make grammaticality judgments about the sentences that were presented in a non-cumulative way. Decisions as well as decision times were automatically recorded. The results for accuracy responses showed no difference between the three conditions which implies that after reading the sentences, participants accurately made grammaticality judgments about the sentences. However, analysis of the reaction times for grammaticality judgment of the sentences in the three conditions showed that the participants took shorter reaction times for sentences in which due to a semantic cue, RC had to be attached to DP1, but longer reaction times to sentences in which the RC had to be attached to DP2. Moreover, there was no difference between ambiguous sentences and those in which RC referred to DP1. These results show a high attachment preference by Persian native speakers.

Factors Affecting Attachment Preferences within a Language

There are a number of individual-level factors, such as proficiency and WMC, which can cause intra-lingual differences in attachment preferences.

As for proficiency, Miyao and Omaki (2006) used an off-line and an on-line self-paced reading task to examine RC attachment preferences of intermediate to advanced Korean L2 learners of Japanese and Japanese native speakers. Results from the off-line sentence interpretation task showed that both Korean L2 learners and Japanese natives preferred high attachment. However, results from the on-line self-paced reading task showed that Japanese natives preferred high attachment but Korean L2 learners preferred low attachment. To account for these results, Miyao and Omaki stated that there may be three different stages in development of L2 processing: L1 transfer phase, intermediate phase, and target-like phase. They defined the L1

transfer phase as the stage in which low-proficiency L2 learners transfer their L1 grammar, including their L1 parsing preference. In the intermediate phase, medium-level L2 learners' grammar and parsing preferences are still developing and not yet efficient, i.e., their grammar is non-target like and includes traces of their L1. In the target-like phase, high-proficiency L2 learners have target-like parsing preferences. They stated that participants in their study were in the intermediate phase, and as a result they resorted to a parsing strategy that minimized their processing burden (i.e., locality principle), which resulted in low attachment.

Although some L2 studies on RC attachment preferences have found no effect of WMC, numerous studies have shown that individuals with high WMC process syntactically ambiguous sentences differently from those with low WMC (Kim & Christianson, 2013; Mendelsohn & Pearlmutter, 1999; Swets, Desmet, Hambrick, & Ferreira, 2007; Vos, Gunter, Schriefers, & Friederici, 2001). Swets et al. (2007) examined the role of WMC in RC attachment preferences of English and Dutch native speakers. Test sentences were ambiguous structures such as: *[The maid]$_{DP1}$ of [the princess]$_{DP2}$ [who scratched herself in public]$_{RC}$ was terribly embarrassed.* They reported a negative correlation between WMC and RC attachment preference. To account for these findings, they proposed the 'chunking' hypothesis: low span readers do not have enough resources to parse a sentence without stopping at intermediate places, which causes them to pause before the RC. This pause in processing makes them chunk DP1 and DP2 into a single unit, leading them to attach the following RC to the head of the complex DP, i.e., DP1 (*the maid*).

Fodor (2002) proposed the Implicit Prosody Hypothesis (IPH) to justify the intra-lingual variation in attachment preferences. According to IPH, different prosodic groupings of a sentence can result in different interpretations. In case of ambiguous RCs, a prosodic grouping of (DP1) (DP2 RC) reflects a low attachment; while a prosodic grouping of (DP1 DP2) (RC) demonstrates a high attachment interpretation. Thus, for sentence (4a), where the prosodic grouping is (DP1) (DP2 RC) and prosodic boundary is put after DP1 (i.e., servant), the parser is likely to attach the ambiguous RC to DP2 (i.e., *the actress*), while, in sentence (4b) where the prosodic grouping is (DP1 DP2) (RC) and prosodic boundary comes after DP2 (i.e., *the actress*), the parser interprets the RC as modifying DP1 (i.e., *the servant*).

(4) a. *Someone shot the servant #of the actress who was on the balcony.*

b. *Someone shot the servant of the actress #who was on the balcony.*

More support for IPH has been provided by Jun (2003) who examined native speakers of English, French, Greek, Farsi (Persian), French, Japanese, Korean, and showed that in each language there is a correlation between attachment preferences and the default prosody assigned upon reading ambiguous sentences containing RCs.

The Present Study

This study undertakes to see if the different findings across and within languages with regard to the resolution of ambiguous RCs can be accounted for by the role of semantics. Previous research has shown that the effect of semantics is "strong enough to over-ride any phrase structure based locality principle that

might otherwise favor NP1 attachment" (Felser, et al., 2003, P. 457). But the type semantics Felser et al. refer to is limited to the distinction between thematic preposition *with* and the case assigner preposition *of*. Since the former preposition constructs a local thematic domain, the ambiguous RC is associated with the DP inside this domain. Thus, semantics was limited to the lexical semantic features of prepositions and the results from many studies (Felser et al., 2003; Papadopoulou & Clahsen, 2003) have shown that L2 learners are sensitive to the bias provided by the preposition *with*. But in this study, semantics has a broader domain. In the two experiments reported in this study, the sentence contexts are varied to establish a semantic relationship between the subject of the main clause and one of the DPs in a complex DP (*Experiment 1*) and the verb of the main clause and one of the DPs in the complex DP (*Experiment 2*). In sentence (5) below, the subject of the matrix sentence is related to DP1, and in sentence (6) it is related to DP2.

(5) *The doctor saw [the nurse]$_{DP1}$ of [the pupil]$_{DP2}$ [who was in the yard]$_{RC}$.*

(6) *The teacher saw [the nurse]$_{DP1}$ of [the pupil]$_{DP2}$ [who was in the yard]$_{RC}$.*

When the parser starts reading a sentence, the first piece of information s/he encounters is most often the subject of the sentence. When the first DP, *the doctor*, in the case of sentence (5), is activated, based on the Spreading Activation Model (Collins & Loftus 1975; Dell, 1986), other words that are semantically related to it also become activated, and when the parser gets to DP1 *the nurse*, the two semantically associated words reinforce the activation of each other and remain more accessible in comparison to DP2 *the pupil*. Encountering the RC, *who was in the yard*, the parser is expected to attach it to the more accessible DP which is *the nurse*. Moreover, being the subject of the sentence, *the doctor* occupies a syntactically prominent position and thus its accessibility is enhanced (Bock & Warren, 1985; Brennan, 1995; Brennan, Friedman, & Pollard, 1987; Prat-Sala & Branigan, 2000) and this makes its semantically related item in the sentence (i.e., the nurse) more accessible as well.

Another kind of semantic relationship that may affect RC attachment preference is when the verb of the main clause is semantically related to one of the DPs in the complex DP preceding RC. Altmann and Kamide (1999) reported an eye-tracking study in which participants listened to sentences such as *The boy will eat the cake* and *The boy will move the cake* while they viewed a scene containing a boy who was sitting on the floor surrounded by various items such as a toy train set, a ball, a toy car, a balloon, and a birthday cake. When participants heard the verb *eat*, they tended to look at *the cake* more often compared to when they heard the verb *move*. This happened because the selectional restrictions of the verb *eat* prescribed that only one object in the visual scene could be relevant (i.e., *the cake*), but the verb *move* could refer to all of the movable objects in the scene (i.e., *the toy train*, *the ball*, *the toy car*, *the balloon*, and *the cake*). This finding shows that by using the selectional restrictions of the verb, comprehenders are able to predict an upcoming direct object of the verb. In sentence (7) below, encountering the verb *inject*, the parser "not only analyses [it] . . . but also predicts upcoming unseen elements" (Arai & Keller, 2013, p. 525). Thus, when the parser sees *the nurse* (DP1), a strong association is developed between the verb and this DP which is expected to make it more accessible in comparison to *the*

lawyer DP2, when the parser is at the stage of attaching the RC to a preceding DP. In sentence (8), on the other hand, there is a strong semantic relationship between the verb *defend* and DP2 *the lawyer* compared to DP1 *the nurse*, and is thus more accessible, and if priming plays a role, the RC is expected to attach to DP2.

(7) *Someone injected [the nurse]$_{DP1}$ of [the lawyer]$_{DP2}$ [who was on the balcony]$_{RC}$.*

(8) *Someone defended [the nurse]$_{DP1}$ of [the lawyer]$_{DP2}$ [who was on the balcony]$_{RC}$.*

Thus, in line with previous studies (Schafer, Carter, Clifton, & Frazier, 1996), we predicted that the primed word would become more salient and therefore would attract the ambiguous RC. The present study builds on the above findings and aims to delve into the role of priming in RC attachment preferences of Persian L2 learners of English. In particular, this study aims to provide answers to the following question:

Does priming one of the DPs in the complex DP through associating it with the subject/verb of the sentence influence the RC attachment preferences of Persian L2 learners of English with different proficiencies and WMCs?

Experiment 1

The aim of this experiment was to explore the impact of semantic priming created by the association between the subject of the matrix sentence and one of the DPs preceding RC on participants' preferences with different proficiency and WMCs.

Method

Participants

33 Persian-speaking learners of English (mean age 20, range18-22, 11 females) majoring in English Language and Literature at two universities participated in this experiment as a course requirement. They were B.A. students and had not received advanced linguistic instruction and had no idea about the aim of the study. Persian was the L1 of all participants and they had all started learning English at high school. Two participants were excluded because they had not completed the proficiency test and 2 more ones were excluded because they could not meet the criterion of 90% comprehension accuracy of fillers (see below for details). In this way, data from 29 participants were used for data analysis.

Instruments

The Operation Span Task (OST)

The vast majority of previous studies have used the reading span task as the sole index of WMC while there exist many different assessments, which tap different working memory mechanisms (Conway, Kane, Bunting, Hambrick, Wilhelm & Engle, 2005). The reading span task assesses the ability to sustain and process information through reading sentences while participants' attention is split. In this study, OST was used rather than the reading span task. In OST, instead of sentences, mathematical operations are used. Both tasks (i.e. reading span task and operation task) have been shown to predict sentence comprehension performance (Turner & Engle, 1989) but O'Rourke (2013) stated that only operation span predicts accuracy for syntactically complex sentences.

The OST was administered using Microsoft PowerPoint 2010. Participants were presented with sets of simple equations ranging from two to five equations per set. There were three trials for each set size, resulting in a total of

forty-two (3 × (2 + 3 + 4 + 5) = 42) equations for the entire test. A sample set including three items is presented below:
a. 5 + (8 × 2) = 21, ?, Z
b. (2 + 9) – 4 = 5, ?, Y
c. 5 × (7 – 2) = 45, ?, B
???
Before starting the task, a 15-item warm-up activity was administered. Then the 42-item OST was presented in a fixed order for all participants. Each item appeared on the screen and remained there for 5 seconds. The length of this interval was based on the findings of a pilot study. Then a question mark ('?') appeared on the screen, at this point participants were instructed to judge the accuracy of the equations by saying 'true' or 'false'. After the equation judgment, participants were instructed to press the space bar. Then a capital letter appeared on the screen to be read aloud. After 3 seconds this letter disappeared and the participants proceeded to the next item. When the participant reached the last item in a set, three question marks ('???') appeared. The participants were instructed to stop at this point and recall the letters in the order in which they had appeared in the set. The experimenter recorded the responses on an answer sheet.
Two scores were reported based on this test: one for the true/false answers to the equations (judgment accuracy) and one for the number of letters recalled accurately. The correlation coefficient between these two scores was .80 (p = .000). Since there was the possibility that the participants focus on the letters they were to recall (which was a measure of their WMC) and take the truth value of the equations not seriously, their performance on equations was considered as a criterion for selection.
In order to be qualified to participate in the study participants were required to correctly judge at least 38 equations out of 42 (i.e. 90 percent).
As for the OST, one point was given for every letter correctly recalled in the correct order. The scores ranged between 25 and 42; and the mean and standard deviation were 32 and 5.31, respectively. Reliability of this test, based on the KR-21 formula, turned out to be .63.

Proficiency Test
Prior to the main test, the participants' proficiency in English was assessed through the Oxford Placement Test (OPT, Allan, 2000). The scores ranged between 22 and 54 (out of a maximum possible score of 60); and the mean and standard deviation were 39.59 and 7.25, respectively. KR-21 reliability of this test turned out to be .76.
Descriptive statistics for the OST as a measure of WMC and OPT as a measure of proficiency are documented in Table 1 below.

Table 1: Descriptive Statistics for WMC and Proficiency (Experiment 1)

	Min.	Max.	Mean	SD
WMC	25	42	32	5.31
Proficiency	22	54	39.59	7.25

The Main Test
The main test consisted of 70 sentences including 10 practice items (three of which also served as warm-ups across four versions of the main test), 20 test sentences, and 40 fillers

Test Sentences
The test sentences were all structurally ambiguous sentences containing a main clause and an RC, which could refer to either of two preceding DPs that were linked together by genitive *of* and functioned as the object of the sentence. The RC, in all sentences, was introduced by the relative pronoun *who*. The subjects

of the sentences were animate and represented different occupations such as *teacher*, *lawyer*, *doctor*, etc.

Based on the relationship between the subject of the main clause and either of the two DPs in a complex DP, test sentences were categorized into three types: DP1-biased subject in which the subject of the main clause and DP1 were semantically related; DP2-biased subject in which the subject of the main clause and DP2 were related; Unbiased subject with no specific relationship between the subject of the main clause and either of DPs. Examples for each category are provided below:

DP1-biased subject
(9) *The doctor saw the nurse of the pupil who was in the yard.*

DP2-biased subject
(10) *The teacher saw the nurse of the pupil who was in the yard.*

Unbiased subject
(11) *The lawyer saw the nurse of the pupil who was in the yard.*

Sentences (9), (10) and (11) were regarded as a set of test sentences.

To assess the relationship set by the researchers between the subject and either of the DPs, a norming study was conducted. Seven applied linguists and 25 participants from the same pool as in the main study, none of whom participated in the main experiment, took part in the norming study. They were asked to decide whether there was an occupational semantic relationship between the underlined words. All the items were likert-scaled, ranging from 0 to 4, where 0 meant there was not any semantic relationship between the words and 4 meant they were strongly related. Based on the results of the norming, 10 sets (those for which 90% of the subjects had rated the semantic relationship as 4) were selected. Each set had 3 test sentences, so we had a total of 30 sentences to be used in the main test.

These 30 test sentences were divided into two versions to make the test shorter and to discourage the participants from developing any strategies. Each version included 10 subject-biased sentences (five DP1 and five DP2 subject-biased sentences). For each DP biased item, there was an unbiased item. So there were 10 unbiased-subject sentences in each version. If the DP1-biased-subject item of a set appeared in *Version 1*, it was replaced with DP2-biased-subject item in *Version 2*. The unbiased-subject item of each set was common in both versions.

Filler Sentences and Comprehension Questions

Forty filler sentences were developed. Like test sentences, all the fillers included RCs which were introduced with a relative pronoun. Thirty-five out of 40 filler sentences were not ambiguous. The remaining 5 filler sentences were ambiguous and looked exactly like test sentences, but it was the unambiguous part that was questioned.

The filler items were used to ensure that the participants attended to the content of the sentences they read on the monitor. So participants whose score on filler sentences was less than 90% were excluded.

All the sentences were followed by a fill-in-the-blank comprehension question; (1) to find out which DP was recognized by participants as the host of the RC; (2) to check whether participants paid attention to the content of the test. With regard to fillers, the questions only served the second purpose because their answers

could be checked for accuracy. The answers to the ambiguous experimental items simply indicated a participant's preference and could not be checked for their truth value. A sample item of a test sentence followed by the corresponding comprehension question is provided below.

(12) *The doctor saw the nurse of the student who was in the yard.*
……was in the yard.

To ensure that ordering had no effect, the item presentation order in the two versions of the main experiment was reversed. So there were four versions including 63 items: 3 warm-up sentences, 20 test sentences, and 40 fillers. Warm-up and filler sentences were the same across the four versions.

Procedure

The OST and the main test were administered in two different sessions with a one week interval. The Rapid Serial Visual Processing paradigm (in which parts of a sentence are presented in a time-controlled manner, this short period of time between the presentations of different parts of the sentence prohibit development of any strategy by the participants) was adopted and each stimulus was presented on the screen for nine seconds in black letters on a white background. This interval was decided upon based on the findings of a pilot study. After that a fill-in-the-blank comprehension question appeared on the screen and participants were required to provide an answer to the question by typing in the specified space. Participants' answers were automatically recorded.

Scoring System

We identified whether the participants referred to DP1 or DP2 in each item. In case a participant completed the sentence with the whole phrase "DP1 of DP2", this would count as a DP1 choice because it is the head the whole phrase. Out of the 580 answers (29 participants × 20 items) provided, 378 were DP1 and 178 were DP2 and 24 (4.14%) were not included in the analysis because they referred neither to DP1 nor to DP2.

In this study, WMC and proficiency scores were not used to classify participants into groups because such classification leads to "loss of statistical power" (1983, p. 260). Moreover, as Conway et al. (2005) put it "information and power are lost, because less variability is captured by categories than a continuum" (p. 782).

Results

Before analyzing the data, answers to the comprehension questions following the fillers were checked to ensure the participants had read the sentences attentively. Those with accuracy scores lower than 90% (2 participants) were excluded from analysis.

Table 2 shows the frequency and percentage of DP1 and DP2 choices across the three conditions. In the DP1 biased condition, 67.4% of the responses referred to DP1 while only 32.6% of the responses referred to DP2. Similarly, in the DP2 biased condition, a large percentage of replies, i.e., 72.5% referred to DP1, but just 27.5% of the replies referred to DP2. In the unbiased condition, too, DP1 responses were twice as many as DP2 replies (66.1% vs. 33.9%, respectively). As can be seen, irrespective of the semantic manipulation, the participants rarely selected DP2 as the antecedent of the RC.

Table 2: Frequency (Percentage) of DP1 and DP2 Choices across the Three Conditions in Experiment 1

Condition	Antecedent	
	DP1	DP2
DP1-biased subject	95 (67.4%)	46 (32.6%)
DP2-biased subject	100 (72.5%)	38 (27.5%)
Unbiased subject	183 (66.1%)	94 (33.9%)

The following table presents the correlation coefficient between WMC and proficiency and DP1 attachment preferences across different conditions.

Table 3: Correlation coefficient between WMC and Proficiency and DP1 Attachment Preferences across Different Conditions in Experiment 1

	DP1 biased condition	DP2 biased condition	Unbiased condition	Total DP1 choices
WMC	-.424 p = .022	-.506 p = .005	-.383 P = .040	-.442 p= .016
Profi-ciency	-.222 p = .246	-.288 p = .130	-.165 p = .398	-.225 p = .251

As the table displays, WMC correlates with DP1 choices negatively and significantly in all conditions, meaning that as WMC increases, preference for DP1 decreases. As for proficiency, the correlations are negative in all cases but do not reach significance.

The Pearson correlation between total DP1 choices (the total of DP1 choices in the three conditions) and WMC indicates that the effect size of the correlation was medium ($r = -.442$, $N = 29$, $R^2 = .195$). On the other hand, the Pearson correlation between total DP1 choices and proficiency was not statistical and the effect size turned out to be small ($r = -.225$, $N = 29$, $R^2 = .051$).

The following figure shows the scatter plot for the correlation between WMC and total DP1 choices. The loess curve, having smoothed the data, shows that preference for DP1 across different conditions decreases as WMC increases. As is evinced in the figure, there is a sharp slope indicating that when WMC increases, preference for DP1 severely drops, while those with lower WMCs prefer DP1.

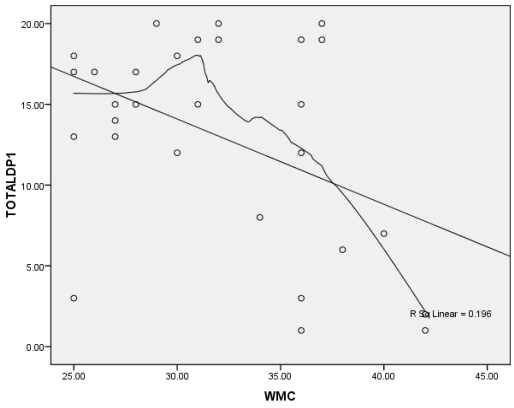


Figure 1. Scatter plot for the correlations between WMC and total DP1 choices in Experiment 1

We used a Mixed Effect Model to evaluate the relation between different variables with preference. All statistical analysis were carried out using R (*R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL).* Among the 9 models including the simplest model with only one variable to the most complicated one with all interactions, we chose the model with the best AIC. The inclusion of interactions did not improve the model, so they were not included in the final model. This model includes the cross random coefficient of condition and random intercept defined in the levels of subject and item and with main effects of condition, standardized proficiency and WMC. The results are demonstrated in Table 4. These results revealed no

significant effect for condition and proficiency (ps > .05), but WMC had a significant effect (P < .05), indicating that those who selected DP1 had a significantly lower WMC. In this way, semantic manipulation was found to play no role in the participants' preferences.

Table 4: Simultaneous Effect of Variables with Cross Random Coefficient of Condition and Random Intercept Defined in the Levels of Subject and Item in Experiment 1

Parameter	Estimate	SE	Z value	P value
(Intercept)	3.68	2.03	1.82	0.069
DP1-biased subject	0.31	0.43	0.72	0.472
DP2-biased subject	1.32	0.67	1.95	0.091
Standardized Proficiency	0.72	0.48	1.49	0.135
Standardized WMC	-1.13	0.56	-2.02	0.043*

Experiment 2

This experiment explored whether Persian-speaking EFL learners' RC attachment preference is affected by the semantic relationship between the verb of the main clause and one of the DPs in a complex DP across different proficiency and WMCs.

Method

Participants

A total number of 33 participants (14 females) were selected from the same pool as those in *Experiment 1*. None of them had participated in *Experiment 1*. Their ages ranged between 18-22 years. Two participants were excluded because they did not show up for the main test. And 2 more were excluded since they did not satisfy the requirement on the fillers (90% accuracy).

Descriptive statistics for WMC and Proficiency are documented in Table 5.

Table 5: Descriptive Statistics for WMC and Proficiency (Experiment 2)

	Min.	Max.	Mean	SD
WMC	25	42	31.65	4.72
Proficiency	29	53	38.79	5.73

Martials

The OST, OPT, and the practice test, warm-up sentences, filler sentences, and fill-in-the-blank comprehension questions were similar to those used in *Experiment 1* in terms of structure and number. Test sentences that were different are elaborated below.

Test Sentences

The structure of experimental sentences was similar to that used in *Experiment 1*, but in *Experiment 2* a semantic relationship was established between the verb of the main clause and one of the DPs in the complex DP. Each pair of words, i.e., the DP and the verb, was chosen on the basis of their semantic relationship. The following website was consulted to determine the semantic relationships, http://semantic-link.com.

Based on the relationship between the verb of the main clause and either of the two DPs in the complex DP, test sentences were categorized into three types: DP1-biased verb with an occupational semantic relationship between the verb of the main clause and DP1; DP2-biased verb with a relationship between the verb of the main clause and DP2; and Unbiased verb with no specific relationship between the verb of the main clause and either of the DPs. Examples for each category are provided below:

DP1-biased verb

(13) *Someone cured the doctor of the teacher who was preparing to go home.*

DP2-biased verb
(14) *Someone scored the doctor of the teacher who was preparing to go home.*

Unbiased verb
(15) *Someone saw the doctor of the teacher who was preparing to go home.*

Sentences (13), (14), and (15) are regarded as a set of experimental sentences. Similar to *Experiment 1*, a norming study was conducted to establish the semantic relatedness of the verbs and DPs.
A sample experimental item and a sample filler item followed by their corresponding comprehension questions are provided below.

(16) *Someone cured the doctor of the teacher who was preparing to go home.*
……was preparing to go home.

(17) *Someone knew the police officer to whom I gave my passport.*
I gave him my…… .

As in *Experiment 1*, there were four versions of the main test and each version included 63 items: 3 warm-up sentences, 20 test sentences, and 40 fillers.

Procedure
Procedure was identical to that of *Experiment 1*.

Scoring System
The scoring system was the same as that of *Experiment 1*.

Results
Table 6 presents the frequency and percentage of DP1 and DP2 choices across the three semantically manipulated conditions. As in the previous experiment, the participants' preference for DP1 was stronger for DP1 than DP2 irrespective of the condition. In each of the three conditions, preference for DP1 was twice more than that for DP2. This finding is comparable to that in *Experiment 1*.

Table 6. Frequency (Percentage) of DP1 and DP2 Choices across the Three Conditions in Experiment 2

Condition	Antecedent	
	DP1	DP2
DP1-Biased verb	91 (64.5%)	50 (35.5%)
DP2-Biased verb	98 (68.5%)	45 (31.5%)
Unbiased verb	180 (62.3%)	109 (37%)

Table 7 displays the correlation coefficient between WMC and proficiency with DP1 attachment preferences across the three conditions. In the same vein as in *Experiment 1*, WMC correlated significantly negatively with DP1 choices in all conditions and with the total DP1 choices. Proficiency, too, had a negative correlation with DP1 preferences but failed to reach significance.

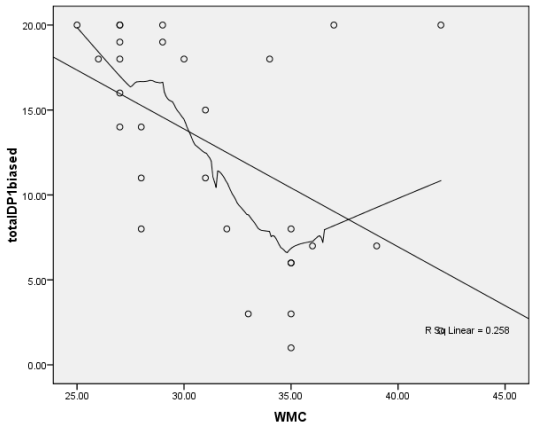
Table 7: Correlation Coefficient between WMC and Proficiency and DP1 Attachment Preferences across Different Conditions in Experiment 2

	DP1 biased condition	DP2 biased condition	Unbiased condition	Total DP1 choices
WMC	-.421 p = .021	-.501 p = .005	-.509 p = .005	-.508 p = .005
Profi-ciency	-.195 p = .310	-.323 p = .087	-.225 p = .241	-.252 p = .188

The Pearson correlation between total DP1 choices and WMC was -.508 and the effect size was medium (R^2 = .258). On the other hand, the Pearson correlation between total DP1 choices and proficiency was not statistical and the

effect size was small (r = -.252, N = 29, R^2 = .063).

The figure below shows the scatter plot for the correlations between WMC and



total DP1 choices. As WMC increases, preference for DP1 decreases.

Figure 2. Scatter plot for the correlations between WMC and total DP1 choices in Experiment 2

To analyze the data, we followed the same procedure as in *Experiment 1*, by evaluating different models including the simplest one with only one variable to the most complicated one, with all interactions, and ending up in a model with the lowest AIC. The best fitting model includes the crossed random coefficient of condition and random intercept defined in the levels of subject and item and with main effects of condition, standardized proficiency and standardized WMC. Table 8 reports a summary of all coefficients for the choice of DP. The main effect obtained belonged to WMC (p = .008), with more choices for DP1 by those having lower WMC. Proficiency and condition had no main effects (ps > .05).

Table 8: Simultaneous Effect of Variables, based on GLMM with Cross Random Coefficient of Condition and Random Intercept Defined in the Levels of Subject and Item in Experiment 2

Parameter	Estimate	SE	Z value	P value
(Intercept)	1.158	0.443	2.61	0.009
DP1-Biased verb	0.129	0.363	0.36	0.722
DP2-biased verb	0.860	0.509	1.69	0.092
Standardized Proficiency	0.633	0.549	1.15	0.249
Standardized WMC	-1.480	0.556	-2.66	0.008*

Discussion and Conclusion

This study investigated whether ambiguity resolution by Persian-speaking learners of English as an L2 is sensitive to priming one of the DPs in the complex DP by creating a semantic relationship between the subject/ verb of the main clause and one of the DPs. The impact of proficiency and WMC as individual properties of the participants was also examined.

The findings showed no priming effect. In DP1 related condition, as in *The doctor saw the nurse of the pupil who was in the yard*, the first DP, *the nurse* was expected to be more accessible, following the Spreading Activation Model (Collins & Loftus 1975; Dell, 1986), and hence selected as the host of the ambiguous RC, but the second DP *the pupil* was not. As far as L2 learners with low WMC and proficiency are concerned, this prediction was borne out, but this preference was not due to DP1's being primed through its association with the subject of the main clause, because even in the DP2 related condition, as in *The teacher saw the nurse of the pupil who was in the yard*, where DP2 *the pupil* was expected to be more accessible, DP1 *the nurse* was selected as

the antecedent of the RC. The same results were obtained in the unbiased condition as well. As for the verb related data, the findings were exactly the same. In the three semantically different conditions, the low WMC L2 learners' preference was determined by the Predicate Proximity principle, which favors attachment to DP1. Earlier results from different studies (Arabmofrad & Marefat, 2008; Marefat & Meraji, 2005) have shown that in Persian, the native language of the participants of this study, in which adjuncts can occur between the verbs and their complements, Predicate Proximity is operative rather than Late Closure. Thus, semantic manipulation doesn't seem to influence the L2 learners' preference for the antecedent of ambiguous RCs. The theoretical account for these findings may be viewed as consistent with theories in which a structural analysis of a newly encountered word is constructed (Frazier & Fodor, 1978; Frazier & Rayner, 1982). But L2 learners with higher WMCs favored DP2; their preference was like that of the English native speakers.

English RC attachment preferences of the L2 learners were not associated with their proficiency. This result is inconsistent with Miyao and Omaki's (2006) developmental stages of L2 processing.

The factor shown to play a role in RC attachment preferences of the L2 learners in this study was WMC. This finding provides evidence in support of the 'chunking' hypothesis, suggested by Swets et al. (2007). Based on this hypothesis, low span participants, not having adequate resources, pause at the boundary between the complex DP and the RC and, in this way, chunk DP1 and DP2 into a single unit, producing, as a result, a DP1 attachment. In this study, too, participants with high WMC may have taken in longer chunks, without any break at the boundary between the complex DP and the RC and thus have attached low. Since the material in this study was not presented chunk by chunk, participants had the opportunity to chunk it themselves; thus, participants with different WMCs could chunk the sentences differently leading to different attachment preferences.

This finding is also consistent with the predictions of the Implicit Prosody Hypothesis (Fodor, 2002) which predicts that the prosodic grouping of the complex DP and RC in a way that a pause is inserted after the second DP -which is proposed to be the case for participants with low WMC- leads to a DP1 attachment preference.

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