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Online Processing of English Wh-Dependencies by Iranian EFL Learners

L. Samavarchi *
M.A., TEFL
Yazd University
email: laila_samavarchi@yahoo.com

M. J. Rezai
Assistant Professor, TEFL
Yazd University
email: mjrezai@yahoo.com

Abstract

To be able to reach the level of ultimate attainment in an L2, learners need to acquire not only the grammar of the L2 but also the language processing mechanisms involved in the comprehension of sentences in real time. Contrary to its importance, very little is known yet about online L2 processing. This study examines whether advanced Iranian learners of English reactivate dislocated indirect objects at gap positions in accordance to the "trace reactivation hypothesis" (TRH) and also whether their individual working memory capacities play any role in antecedent priming in such processing. To this end, 44 participants were randomly selected for the study after being given the Oxford Placement Test. The participants were then given the reading-span test to check their working memory (WM) and were divided into 2 groups (low and high-span groups). A cross-modal priming task was conducted using the software package E-Prime Professional to record their reaction times (RTs). The data were analyzed quantitatively and the results of 3 paired samples *t*-tests showed that the learners differed from native speakers as they did not reactivate the antecedents at the gap position, indicating that foreign language learners resort to shallow parsing during L2 comprehension. Furthermore, a mixed ANOVA showed that the participants' performance was not influenced by their individual working memory differences unlike high-span native speakers.

Keywords: processing, wh-dependency, filler-gap, trace reactivation hypothesis

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* Corresponding author

1. Introduction

One of the principal differences between first language (L1) and second language (L2) acquisition is the level of ultimate attainment (Marinis, 2003). Children, unlike adult L2 learners, are able to acquire their native language fully within a relatively short period of time when they are exposed to it. According to Marinis (2003), adult L2 learners cannot attain full acquisition of the L2 grammar, irrespective of the amount of L2 exposure.

Most L2 research has focused on the acquisition of grammar using offline techniques such as grammaticality judgment, elicitation, and comprehension tasks (Johnson & Newport, 1991; Martohardjono & Gair, 1993; Schachter, 1989). On the other hand, when it comes to how learners process an L2 online, relatively very little is known (Clahsen & Felser, 2006; Felser & Roberts, 2009; Marinis, Roberts, Felser & Clahsen, 2005). Research has been conducted to investigate how native speakers (adults and children) process sentences online by using various online techniques such as moving window, cross-modal priming, eye-tracking, and neurophysiological techniques (Clahsen & Featherstone, 1999; Marinis et al., 2005; Nakano, Felser & Clahsen, 2002; Nicol, 1993). Research conducted in several typologically related and unrelated languages has made it apparent that mature readers and listeners do not employ the same processing strategies across languages. Therefore, language variation does not involve just the grammatical system of language, but also the language processing mechanism.

Given the above points, this has led to a conclusion that L2 learners have to acquire both the grammar of the L2 and the processing strategies involved in the comprehension of sentences in the L2 if they want to reach the level of ultimate attainment (Marinis, 2003). L2 learners must also discover the processing strategies of the L2 which may differ from the ones of their native language. Hence, it can be said that second language learners fail to achieve success due to their failure to acquire the processing strategies of the target language and not due to their inability to acquire its grammar per se.

One of the processing mechanisms which might be language-specific concerns the grammatical processing of sentences containing filler-gap or wh-dependencies. In generative-transformational theories of grammar (Chomsky, 1981, 1995), syntactically dislocated constituents are assumed to be linked to their original structural position through a movement chain, with the highest member of the chain (i.e., the dislocated constituent) being the head of the movement chain, and the lowest trace being the foot of the chain. The original position of the displaced constituent hosts a phonetically unrealized trace of the moved constituent. Based on this view, the mental

underlying representation of an interrogative sentence such as (1a) below includes a trace (t_i) of the displaced constituent *which book* in direct object position, as shown in (1b).

(1) a. Which book did Mary say John had read?
b. [*Which book*]$_i$ did Mary say [John had read t_i]?

Sentences containing wh-dependencies pose a challenge for the sentence comprehension mechanism due to the reason that the "displaced constituent must be retained in short-term memory until it can be linked to its subcategorizing head or other licenser, which often does not appear until much later on" (Felser & Roberts, 2007, p.10). In native sentence processing, when a dislocated constituent (filler) such as wh-phrase *which book* in (1b) above is encountered, it triggers the prediction of a lexical head to license it, or of a corresponding syntactic gap (Frazier & Clifton, 1989; Gibson, 1998).

The non-canonical ordering of constituents in filler-gap dependencies may create an added burden on the L2 processing system, causing L2 processing to be slower than native processing, even among highly proficient speakers (Skehan, 1998). Current research suggests that L2 speakers do actively posit gaps as they process filler-gap dependencies in real time, but that they may not be influenced by lexical and syntactic information in the same manner as L1 speakers.

1.1 Purpose of the study

The present study aimed to test whether advanced Persian learners of English are able to process sentences involving dislocated and fronted wh-dependencies in a way that is similar to the native speakers' processing of such sentences in accordance to the trace reactivation hypothesis (TRH). TRH is structure-based hypothesis proposed to study how filler integration dependencies are processed. According to the TRH, filler integration is mediated by empty syntactic categories (traces) during online comprehension of sentences containing wh-dependencies (Love & Swinney, 1996; Nicol & Swinney, 1989). On identification of the potential gap, the filler is retrieved from WM and integrated into the sentence representation irrespective of the position of its lexical sub-categorizer (Felser & Roberts, 2007). Temporarily storing the filler in WM requires higher processing depending on the distance between the filler and its associated gaps (Gibson, 1998; King & Just, 1991). Hence, the parser will attempt to integrate a dislocated constituent at the earliest grammatically possible point during sentence parsing. The parser's preference for keeping the filler-gap dependencies as short as possible is known as the "active filler hypothesis"

(Clifton & Frazier, 1989). Primary evidence for this comes from studies that have demonstrated that parsing can be disrupted if the expected gap in a wh-question is filled with an object NP (Crain & Fodor, 1985; Stowe, 1986).

Taking into account the abovementioned TRH, the study investigated whether or not Persian advanced learners of English are able to identify the gap in sentences involving wh-dependencies as in sentence (2) below and whether or not they are able to retrieve the antecedent *the peacock* from their WM on identification of the gap (marked t_i).

(2) John saw *the peacock* $_i$ to which the small penguin gave a nice birthday present t_i in the garden last weekend.

During ongoing sentence comprehension, the filler has to be retrieved from WM when the syntactic gap is identified which requires the storage of the filler in WM which incurs a processing cost that has been found to increase with distance (Gibson, 1998). In L1 processing, it has been found that the high span participants were able to retrieve the filler from their WM faster than the low span participants (Nakano et al., 2002). Hence, because WM is said to influence the antecedent reactivation in native processing, this study also aimed to investigate whether individual WM differences influence the L2 processing of sentences involving filler-gap dependencies.

2. Literature Review

Having knowledge of the combinatorial rules and linguistic constraints applicable in the language being processed would not lead to successful grammar learning unless appropriate mechanisms for processing the linguistic input are available (Chaudron, 1985; Fodor, 1999). Moreover, the existing knowledge of language learners' grammatical development needs to be supplemented by a detailed and systematic investigation of their grammatical processing routines, which could prove to be problematic for theories of language acquistion (Felser & Clahsen, 2009). With regards to the processing of wh-dependencies, a number of studies have investigated the online processing of these dependencies by adult native speakers, monolingual children and adult language learners (Felser & Roberts, 2007; Love & Swinney, 1996; Nakano et al., 2002; Nicol & Swinney, 1989).

2.1 Adult L1 processing of wh-dependencies

Several studies have been carried out to investigate whether antecedent priming is mediated by structurally defined gaps or not in L1 sentence processing. Love and Swinney (1996), by using a cross-modal priming experiment, found that adult native speakers of English reactivate the antecedent once a structural gap is identified during online processing in

English object-relative constructions in sentences such as (3) in which the direct object *(the new pen*) has been dislocated and fronted to the left of the verb.

(3) Jimmy used *the new pen* [*1] that his mother-in-law recently [*2] purchased *[3].

The findings of this study were consistent with the trace reactivation hypothesis, according to which the parser reactivates the grammatical and semantic features of the antecedent at a potential gap site by creating a silent syntactic copy of the antecedent. Alternatively, their results could also be explained in terms of the "direct association hypothesis" (Pickering & Barry, 1991), according to which as soon as the sub-categorizer is processed, a displaced argument will be linked to it directly. According to this hypothesis, reactivation effects for dislocated objects (e.g., *the new pen* in the sentence above) are the result of lexically processing the sub-categorization frame of a transitive verb such as *purchase* and do not require the postulation of movement traces or syntactic gaps.

Decisive evidence could be reached to by studying antecedent priming in head-final languages such as Japanese and German by Nakano et al. (2002), and Clahsen and Featherston (1999) respectively. The results of these two studies were consistent with the TRH because filler-reactivation effects were found before the subcategorizing verb had been encountered.

Marinis et al. (2005) modeled the study of Gibson and Warren (1999) who had studied the processing of long wh-dependencies by adult native speakers of English by using a self-paced reading task. The experiment focused on sentences in the two Extraction conditions (VP, NP) and two Non-Extraction conditions (VP, NP). The VP sentences postulate an intermediate gap, whereas the NP ones postulate no intermediate gap. The sentences were divided into 6 segments such as in (4a) which are in the Extraction-VP condition with intermediate gap (after the verb *argued)*, whereas there is no intermediate gap in sentences such as (4b) which are in the Extraction-NP condition.

(4) a. The nurse who / the doctor argued _ / that / the rude patient / had angered / is refusing to work late.

b. The nurse who / the doctor's argument / about / the rude patient / had angered / is refusing to work late .

The results from these native speakers also replicate Gibson and Warren's (1999) results. Elevated reading times at the intervening clause boundary and shorter RTs to the segment containing the filler's sub-categorizer for the Extraction-VP condition were reported which provide

evidence for the fact that native speakers of English postulate intermediate gaps during the processing of long wh-dependencies, which facilitates the filler's integration with its sub-categorizer ("intermediate gap effect").

In order to be able to come to a conclusion in head-initial languages such as English as to whether antecedent priming is trace-based or due to direct association, Roberts, Marinis, Felser and Clahsen (2007) conducted a study on the processing of filler-gap dependencies in which the indirect object is dislocated and fronted to a preverbal position by adult English natives. Using a cross-modal picture priming task, they were able to investigate antecedent priming in sentences such as (2) above.

RTs to identical targets at the gap position by high span adults were faster when compared to unrelated targets at that position, whereas at an earlier control position, there was no such advantage for identical targets. On the other hand, there was no such facilitation for identical targets at either the gap position or the control position for low-span participants. In short, it suggests that high-span adults prime antecedent at indirect object gap site, providing evidence that in L1 sentence processing, individual WM differences influence antecedent reactivation at gap sites.

Based on the above findings, it can be said that native speakers of a language tend to rely more on structural information during grammatical processing. L1 speakers possess the knowledge of deep, abstract hierarchical representations of structures such as movement traces that are absent in the surface forms, due to which they can reactivate the antecedent in sentences with wh-dependencies which is, in turn, influenced by the individual WM difference of the adult native speakers.

2.2 Adult L2 processing of wh-dependencies

As far as antecedent priming in second language acquisition (SLA) research is concerned, comparatively fewer studies have been conducted so far using online techniques. Juffs and Harrington (1995) carried out a reading-time study to investigate whether Chinese learners whose L1 does not show successive-cyclic wh-movement encounter difficulties with certain filler-gap dependencies such as wh-dependencies due to processing difficulties or a competence deficit. Using online grammaticality judgment experiments, Juffs and Harrington studied these learners' speaking accuracy and reading times for sentences (grammatical and ungrammatical) which involved either subject or object extractions such as in sentences (5a) involving subject extraction and (5b) involving object extraction.

(5) a. *Who*¡ did Ann say *e*¡ likes her friend?

b. *Which man*¡ did Jane say her friends like *e*¡?

It was found that the learners encountered much more difficulties with sentences involving subject extractions than object extractions. The authors claim that this was not due to competence problems but rather processing difficulties caused due to reanalysis by the learners on encountering the verb *likes* in (5a) because the gap is first analyzed as the object gap rather than as the subject of the verb *likes*. But the result does not point to the learners' use of empty categories due to the reason that in the sentences used in the experiment, the trace position was adjacent to the subcategorizing verb which points to the possibility that antecedent priming could be compatible with the DAH, i.e., it may be lexically or verb-driven and not trace-based.

However, the results from Juffs and Harrington's (1995) study were problematic in nature because they did not directly answer the question of whether or not L2 learners postulate empty syntactic categories during L2 processing. The filled-gap effect observed on the post-verbal noun in L2 participants could have been purely thematic, rather than thematic and syntactic, reanalysis processes (Marinis et al., 2005).

To dissociate verb-driven integration effects from syntactic gap-filling, Marinis et al. (2005) examined L2 learners' processing of successive-cyclic wh-movement structures. The adult L2 learners were from different backgrounds: wh-in situ backgrounds (Chinese and Japanese) and *wh*-movement backgrounds (German and Greek). It was found that none of the learners from the different backgrounds showed any intermediate gap effect for sentences like (4a) whether or not their L1 postulated intermediate gap. This finding apparently provided support to the hypothesis that L2 learners underuse syntactic information in L2 processing due to which they are not able to process L2 in a native-like fashion .

Felser and Roberts (2007) investigated the real-time processing of filler-gap dependencies by advanced Greek-speaking learners of English. Using the cross-modal priming technique and the materials from Roberts et al.'s (2007) study (such as sentences like 2), they came to a conclusion that Greek-speaking learners of English did not reactivate the antecedent structurally at gap positions but just maintain antecedent activation. Furthermore, antecedent priming by Greek learners of English was not influenced by individual WM capacity. They came to these conclusions based on the finding that these L2 learners (both low and high-span) showed shorter reaction times (RTs) to identical targets at both test positions (control and gap) which points to the fact that the learners retained the antecedent in WM but did not retrieve them from WM at the structural gap sites. L2 learners' failure to postulate movement traces during real-time processing was considered not to be due to a shortage of WM resources but rather due to the reason that they may compensate for their relatively shallower

grammatical analyses of the L2 input by making use of the available lexical, pragmatic, and nonstructural cues to interpret in contrast to the native speakers who mainly exploit the structural cues.

Based on the above findings and those of other studies examining L2 ambiguity resolution (Felser , Marinis & Clahsen, 2003), Clahsen and Felser (2006a, 2006b) proposed "shallow structure hypothesis" for L2 processing according to which late L2 learners differ from native speakers as they are predominantly restricted to shallow parsing. Shallow parsing involves identifying parts of speech, then segmenting the input string into meaningful chunks, and determining what relations the chunks have to the main verb (Hammerton, Osborne, Armstrong, & Daelemans, 2002, p. 552).

Summing up the studies on L2 learners' processing of filler-gap dependencies, it can be said that these nonnative speakers differ from native speakers as far as the grammatical processing is concerned and that L2 learners tend to rely more on lexical-semantic and other nonstructural information than on structural information during grammatical processing. The results of the abovementioned study support the shallow structure hypothesis, according to which "learners compute grammatical representations that lack complex hierarchical structure and abstract, configurationally determined elements such as movement traces, and that native-like grammatical processing is restricted to 'local' domains such as word segmentation or morpho-syntactic agreement between closely adjacent constituents" (Clahsen & Felser, 2006a, p. 9-10).

3. Methodology

3.1 Participants

Forty-four advanced Iranian learners of English (average age: 29.60, range: 21-44), all of whom had been formally educated in English in Iranian universities, were randomly selected for the study. All the participants were exposed to English education for a period ranging from 4 to 9 years and were graduates or postgraduates. None of the participants had ever traveled to or lived in an English-speaking country. The participants were ignorant of the purpose of the study.

In order to be able to assess their general English proficiency level at the time of the experiment, the participants completed the Oxford Quick Placement Test (OQPT) which is a standardized English proficiency test. The OQPT is a flexible test of English language proficiency developed by Oxford University Press and Cambridge ESOL and it has been pretested and validated by about 6,000 students in about 20 countries. The test includes items which have gone through Cambridge ESOL quality control procedures

(Geranpayeh, 2003). The participants' age and proficiency scores are summarized in Table 1 below.

Table 1. Participants' age and proficiency scores (N = 42)

	Minimum	Maximum	Mean	Std. Deviation
Age	22	44	29.60	6.255
OQPT	45	60	52.33	3.924

3.2 Materials

Three types of data collection instruments were used in this study: a general English proficiency test, a reading-span test, and a cross-modal priming task, each of which are discussed in the following sections.

3.2.1 Oxford quick placement test

Considering the fact that the experimental materials used in this study involved structurally complex sentences to assess whether Iranian EFL learners achieved native-like comprehension, only learners at or above advanced level (i.e., learners scoring 48/60 points or above) had to be included in the study. For this purpose, the paper and pencil version of the Oxford Quick Placement Test (Syndicate, 2001) was administered to 44 participants who were either M.A. students at Yazd University or language teachers.

3.2.2 Reading-span test

Because WM capacity was found to be a predictor for native speakers' online processing in several studies, the participants underwent a reading span test (Harrington & Sawyer, 1992). Harrington and Sawyer (1992) found that L2 reading span scores showed significantly high correlations with performance on the grammar (r = 0.57, p < 0.01) and the reading (r = 0.54, p < 0.01) sections of the TOEFL exam. The reading span test comprised 42 sentences (Appendix A). The sentences were active and 11-13 words in length. The sentences were presented on the computer screen in sets of increasing size, starting with two sentences per set and extending up to five sentences per set. The first set included three subsets of two sentences each, the second set included three subsets of three sentences each, the third set included three subsets of four sentences each, and the fourth set included three subsets of five sentences each.

3.2.3 Cross-modal priming task materials

The materials for the cross-modal priming task comprised 20 experimental sentences (adopted from Felser & Roberts, 2007; Roberts et al., 2007) containing indirect-object relatives as in (6) in addition to 40 filler sentences similar in length to the experimental ones (Appendix B).

(6) John saw *the peacock* $_{i}$ to which the small penguin gave a nice birthday present t_i in the garden last weekend.

The experimental sentences included indirect-object relatives as the hypothesized gap t_i in such sentences is not directly adjacent to the subcategorizing verb *gave*. If the hypothesized gap were directly adjacent to the subcategorizing verb, it wouldn't be clear as to whether the antecedent priming is due to the gap (TRH) or due to the directly being associated with the subcategorizing verb (DAH). To empirically dissociate between the two hypotheses, experimental sentences with indirect-objects were adopted as only the TRH predicts antecedent priming effects at the position of indirect object gap.

The sentences were read by a female native speaker of English which were recorded on a digital tape recorder to be used as the auditory stimuli in the cross-modal task. The visual targets were equal numbers of pictures of animals and inanimate objects. For each experimental sentence, two visual targets were selected: an identical picture target showing the referent (antecedent) of the indirect object picture (e.g., a picture of peacock for (6)) and an unrelated target showing an unrelated picture (e.g., a picture of carrot for (6)). The identical targets were pictures of animals; in contrast, the unrelated targets were pictures of inanimate objects. The identical and unrelated objects were matched for syllable length and lemma frequency (Francis & Kucera, 1982). The pictures were presented at one of two test points:

- at the offset of the direct object NP (gap/trace position) (e.g., after *present* in (6); and
- at a pregap position 500 ms earlier (control position).

This 2 × 2 design led to four experimental conditions, as shown in (7a) – (7d).

(7) John saw the peacock to which the small penguin gave …

a) Identical, gap position:
… a nice birthday present [PEACOCK] in the garden last weekend.

b) Identical, control position:
… a nice [PEACOCK] birthday present in the garden last weekend.

c) Unrelated, gap position:
… a nice birthday present [CARROT] in the garden last weekend.

d) Unrelated, control position:
… a nice [CARROT] birthday present in the garden last weekend.

Hence, each experimental sentence was presented four times with different conditions. All the experimental sentences and targets are provided

in Appendix B. The experimental sentences were randomized and mixed with the filler sentences.

3.3 Procedure

3.3.1 Reading-span test

The reading-span test was conducted individually with each participant. The participants were given the following instructions on the procedure. They were seated in front of the computer as the test had been prepared using Microsoft PowerPoint. Each sentence was presented in the center of a slide. The participants were asked to read aloud each sentence only once. After the participants read a set, they would encounter a slide with RECALL on it. This required the participants to recall and write down the last word of every sentence in the set on the response sheet in the correct order of the sentences.

On the whole, the participants could write down maximally 42 words. Hence, the maximum score that one could obtain was 42. The participants were instructed to write the words in the correct order and if a word could not be recalled, they had to leave an empty space where they would write down the word. Each correct word was given one score and an incorrectly written word or a blank was given no scoring.

3.3.2 Cross-modal priming task (CMPT) procedure

This task was created using the software E-Prime 2.0 Professional (Schneider, Eschman & Zuccolotto, 2002). The participants were asked to come for the experiment individually to Yazd University, where a quiet room was designated by the English department for this purpose. They were seated in front of a 17" monitor and were given instructions on the procedure of the task. They were instructed to listen carefully to the prerecorded sentences over headphones. During the presentation of the sentences, pictures appeared on the screen, and the participants had to decide quickly whether or not the animal/object in the picture was identical or unrelated to the sentences they were listening to by pressing either *1* for identical pictures and *0* for unrelated ones.

RTs were measured from the point at which the visual target appeared on the screen to the participants' pressing of the response button. The presentation of the auditory and visual stimuli as well as the recording of RTs were controlled using the E-Prime software package. To ensure that the participants were paying attention to the experiment at hand, they were asked to respond to 30 prerecorded auditory comprehension questions interspersed randomly. For instance, for the experimental sentence (8), they had to answer the question (9) by pressing *y* for yes and *n* for no.

(8) Sue saw the hippo to which the small penguin gave the sweet tasty orange in the jungle yesterday afternoon.

(9) Did Sue see the hippo?

4. Data Analysis

4.1 Reading-span test

The scores from the reading-span test indicated the maximum number of words that were correctly recalled out of a possible 42. The scores from the test were entered onto the Statistical Package for the Social Science (SPSS) software (version 11.5) for the purpose of data analysis. These scores were then categorized into two groups: high span and low span. The participants scored an average of 31.58 (range: 20-42, *SD*: 5.129) in this task. Participants with a score above the average were placed in the high span group (*N* = 21) and those below the average were placed in the low span group (*N* = 19), shown in Table 2 below.

Table 2. The span groups' mean scores

	N	Minimum	Maximum	Mean	Std. Deviation
Low-span participants	19	20	31	27.37	3.515
High-span participants	21	32	42	35.38	2.854

4.2 Cross-modal priming task

All the data obtained from the cross-modal priming task using E-prime were also entered onto SPSS 11.5 for the purpose of analysis.

4.2.1 Accuracy

One measure used to indicate that the participants were able to perform the cross-modal priming task with accuracy was the relatedness decision task, requiring the participants to correctly identify the picture targets as either *identical* or *unrelated* to the auditory stimulus. The participants correctly identified 92.4% of the picture targets as either *identical* or *unrelated* with a mean of 73.95 out of 80 (range: 68-80, *SD*: 3.26), indicating that attention was being paid to the task.

Another accuracy measure indicating that attention was being paid during the experiment was the percentage of correctly answered comprehension questions. The participants scored 86.4% correct on the comprehension questions with a mean of 25.925 (range: 23-29, *SD*: 1.817).

4.2.2 Reaction times

To analyze the RTs, only those trials that were responded to correctly be included, removing trials for which the identical/unrelated decision was

incorrect. The mean RTs of the low-span and high-span groups are presented in Table 3.

Table 3. Mean RTs of the span groups

	Low span group *N* = 19	High span group *N* = 21
Identical picture at gap position	705.70	690.46
Identical picture at pregap position	783.55	720.78
Unrelated picture at gap position	690.60	687.99
Unrelated picture at pregap position	785.31	784.91

To assess the normality of the distribution of the mean RTs and recognize any outliers, further descriptive statistics were carried out. The results indicated non-significant values for the mean RTs, indicating normality of the distribution of the RTs. Also, the results indicated that none of the participants were to be considered as outliers.

One of the aims of this study was to determine whether or not individual WM differences play any role during online processing of wh-dependencies by nonnative speakers. To this end, a mixed ANOVA with the within-participants factors, Position (gap vs. pregap) and Target Type (identical vs. unrelated), and Memory Span as a continuous variable was carried out on the data. The first multivariate analysis for the within-participants factor revealed no significant main effect for Target, Wilks' Lambda = .987, F (1, 38) = .497, p = .485. This indicated that as far as the target type was concerned, on the whole, there was no significant difference between the target types (identical vs. unrelated pictures). In other words, RTs to identical pictures were not significantly different from the RTs to unrelated pictures.

With regards to the factor Position, the multivariate analysis revealed a significant main effect for Position, Wilks' Lambda = .454, F (1, 38) = 45.719, p = .000, partial eta squared = .563, indicating a very large effect size. This indicates that as far as Position is concerned, there was a significant difference in RTs between the two positions: pregap vs. gap. RTs were significantly shorter at the gap (M = 698.08) position than the pregap position (M = 752.17) for both the target types on the whole. A further multivariate analysis reveals significant interaction within-subjects effects with the two experimental factors (Target Type × Position); Wilks' Lambda = .787, F (2, 40) = 10.28, p = .003, partial eta squared = .213, suggesting a large effect size.

To determine whether or not WM span had any influence on antecedent priming, the results obtained from the test of between-subjects effect was

observed showing no statistically significant difference between the low and high-span groups, F (1,38) = .010, p = .921.

The results indicate that WM does not influence the processing of sentences involving wh-dependencies by advanced Persian EFL learners. On the other hand, it was observed in Robert et al.'s (2007) study that high-span native adult participants' RTs to identical targets were shorter than those to unrelated targets at the gap position, whereas there was no such difference observed at the pre-gap control position. Low-span native participants had shown no advantage for identical targets at all at either the gap or control position.

In Roberts et al.'s (2007) study, the high-span native speakers' (both adults and children) RTs to identical pictures were significantly shorter than RTs to unrelated pictures at the gap position, whereas the low-span native speakers (adults and children) took longer to respond to the identical targets than to unrelated targets at the gap position, especially the low-span children. To compare the Iranian learners' RTs to identical with unrelated pictures at the gap position, a paired-samples *t*-test of RTs to identical and unrelated pictures at the gap position was conducted. The results revealed no statistically significant difference between the means of RTs of identical pictures and unrelated pictures, t (39) = .760, p = .452. Iranian EFL learners responded to identical (M = 698) and unrelated pictures (M = 689) at the gap position in a similar fashion, showing no facilitation effect for the identical pictures.

Furthermore, Roberts et al. (2007) found that the high-span native speakers (both adults and children) responded faster to identical targets at the gap position than at the control position which indicated reactivation of the indirect object at the gap position, whereas as the low-span natives performed in a different fashion, taking longer to respond to identical targets at the gap position. To investigate whether or not advanced Persian EFL learners performed similarly to the native speakers in this respect, another paired-samples *t*-test of RTs to identical pictures at the gap and control position was conducted. The results showed that there was a statistically significant difference between the RTs for identical pictures at gap position and control position, t (39) = .-3.734, p = .001. This indicates that the Iranian EFL learners, like the high-span native speakers, responded faster to identical pictures at the gap position (M = 698) than at the control position (M = 752).

Concerning the mean RTs to identical targets and unrelated targets at the control position, Roberts et al. (2007) found that the high and low span children (but not adults) responded to identical targets slower than to unrelated targets, i.e., children's RTs were longer to identical than to

unrelated pictures at the control position. In this respect, the high-span adults performed differently from the high-span children, as for high-span adults there wasn't a statistically significant difference between the mean RTs to different visual targets at the control position, with a difference of just 2ms.

To determine the performance of the Iranian learners in this respect, a third paired-samples *t*-test of RTs to identical and unrelated pictures at the control position was performed. The results indicated that with regards to the control position, there was a statistically significant difference between the mean RTs to identical pictures and unrelated pictures, t (39) = .-2.669, p = .011, suggesting Iranian learners responded faster to identical pictures (M = 752) than to unrelated ones (M = 785) at the control position. This performance of the Iranian EFL learners was similar to that of the low span adults.

In sum, the results indicated that advanced Iranian EFL learners process wh-dependencies differently from the English natives as the learners could not reactivate the antecedent at the gap position, rejecting the hypothesis that they reactivate antecedents in accordance to the TRH. Moreover, the results suggested that individual WM differences do not influence L2 sentence processing.

5. Discussion and Conclusion

The Persian learners' nonnative-like performance in online sentence processing may be due to the following reasons (Clahsen & Felser, 2006c; Felser & Roberts, 2007):

5.1 Lack of L2 knowledge

With regards the first reason of L2 knowledge deficit, this possibility can be ruled out considering the participants' high level of English proficiency and their high accuracy scores on the comprehension questions. The absence of any gap-specific priming effects in L2 may reflect something more than just a mere knowledge deficit (Felser & Roberts, 2007).

5.2 L1 influence

Few online studies have examined the potential influence of abstract syntactically complex structures such as sentences involving nonlocal syntactic dependencies. Current evidence suggests that these have no effect on L2 processing (Felser & Roberts, 2007, Marinis, et al. 2005, Williams, et al. 2001). Abstract syntactic properties such as the availability of wh-fronting in the L1 are argued not to influence the processing of wh-dependencies in the L2. Furthermore, even though indirect object wh-dependencies are not formed exactly similarly in English and Persian, wh-

movement takes placing fronting the wh-constituent. Hence, the participants' online performance cannot be accounted for by considering L1 influence.

Whereas L1 is said to influence phonological and lexical properties, nonlocal dependencies do not seem to be susceptible to transfer effects in L2 processing. According to Clahsen and Felser (2006c), the absence of transfer effects in this domain could be due to a mapping incompatibility between learners' L1 and L2 representations, i.e., if the L2 representations are shallow.

5.3 Delayed or slowed processing

If the nonnative-like performance on the cross-modal priming task had been due to delayed or slowed processing, the participants' RTs for identical targets should have been larger at the gap position than at the pre-gap control position. On the other hand, the participants' RTs to identical targets were shorter at the gap position than at the pre-gap position. Moreover, the participants' RTs to identical targets were shorter than unrelated ones at the control position and their RTs were not significantly different at the gap position, indicating that recognition of the identical targets was facilitated at the control position in comparison to the unrelated ones. This indicates that the participants did not merely require more time to process the indirect object gap.

5.4 Reduced availability of the procedural memory system

Some of the findings of the studies conducted on L2 processing can be explained by taking into account the dual memory system (procedural vs. declarative) (Ullman, 2001; 2005 & Paradis, 1997; 2004). Nonnative readers or listeners apparently have no difficulty accessing and evaluating lexical-semantic or plausibility information during sentence processing, whereas they are said to underuse syntactic information when resolving temporarily ambiguous sentences or while interpreting sentences with filler-gap dependencies. By considering Ullman and Paradis' account, the former finding indicates the availability of an intact declarative memory system; however, the latter is indicative of the reduced availability of the procedural memory system. With respect to ultimate attainment, this model suggests that native like processing can emerge as a result of prolonged exposure and high proficiency in the L2 that leads to augmented efficiency and automaticity in the procedural system. However, even though the subjects were highly proficient in the L2 and were exposed to the L2 for a considerable period of time, it can be said that they did not show automaticity when processing the complex structure due to their nonnative-like processing. Moreover, this model claims that the learners' procedural

memory system may be reduced to the extent that they are unable to exploit their procedural system to the fullest extent. But what it fails to account is how reduced the Persian learners' procedural memory system is, i.e., whether the procedural system as a whole is reduced or whether there are some subcomponents of the procedural system which are unavailable during L2 processing.

5.5 Unavailability of certain processing routines in the L2

The results from the Iranian participants indicate that nonnative speakers are unable to apply some of the parsing routines used during native comprehension. Hence, Persian L2 learners of English differ from native speakers as the latter reconstruct the antecedent at structurally defined gap positions, in accordance to the TRH. The results from this study corroborate those from previous studies carried out by Marinis et al. (2005) and Felser and Roberts (2007) for investigating trace-based gap filling in nonnative sentence processing. Iranian proficient learners of English do not postulate traces when processing long-distance wh-dependencies in English even though interpretation of such sentences containing wh-dependencies would not be problematic. Evidence points to the conclusion that L2 learners rely less on phrase structure based parsing routines also for L2 ambiguity resolution (Papadopoulou & Clahsen, 2003; Malakooti & Rezai, 2010).

Clahsen and Felser (2006a, 2006c) provide a unified account of these findings by proposing the concept of shallow parsing. According to the shallow structure hypothesis, L2 learners typically perform partial or shallow parses by constructing syntactic representations that lack deep hierarchical structure, and abstract elements of phrase structure such as movement traces. In a similar vein, Hammerton et al. (2002, p. 552) states that shallow parsing refers to "the task of recovering only a limited amount of syntactic structure from natural language sentences."

L2 learners of English resort to shallow processing because of their insufficient WM resources needed to carry out full syntactic analyses of the input (Felser & Roberts, 2007). The results from this study fit with Felser and Roberts' (2007) observation that L2 reading span did not affect the participants' processing in the cross-modal priming task. The participants' shorter RTs to identical targets at the control position and no significant difference between the reactions time to identical and unrelated ones at the gap position suggest that they were able to keep the antecedent active in short-term memory but were unable to reactivate it at the gap site.

In conclusion, Iranian advanced learners of English showed evidence of maintained activation but not of antecedent reactivation as was observed in Felser and Roberts' (2007) study on Greek learners. Moreover, the learners

failed to postulate movement traces independent of their individual working memory resources. It is, finally, assumed that EFL learners may compensate for their relatively shallower structural analyses of the L2 by making use of lexical, pragmatic and other nonstructural cues.

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