Native and Non-Native Processing of Morphologically Complex English Words: Testing the Influence of Derivational Prefixes

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1. Introduction

1.1. Background

Understanding knowledge of morphology in second language acquisition (SLA) has been important since Bailey, Madden & Krashen's (1974) morpheme order studies. More recently, debate has centered on the interpretation of persistent errors in morphological accuracy, focusing on the reasons for the order in which morphemes are most accurately marked (Goldschneider &Dekeyser, 2001), whether L1 influence is evident in this domain (Luk & Shirai, 2010) and whether a lack of morphological accuracy indicates that the underlying syntactic component is permanently impaired (Hawkins & Liska, 2003; Prévost & White, 2000). In this context, a recent set of papers by Clahsen and colleagues have suggested that the computational component of morphological processing is impaired in both competence and processing (Clahsen et al. 2010, Neubauer & Clahsen, 2009; Silva & Clahsen, 2008). Instead of computational processing, second language learners rely on declarative memory to list forms in the lexicon rather than create them with stems and affixes as native speakers. This claim is based on a series of psycholinguistic experiments using the masked priming paradigm.

In this paper, we report a modified replication of Silva & Clahsen (2008), which analyzed knowledge of English suffixes, specifically, the inflectional past tense, *-ed*, and the derivational suffixes, *-ity* and *-ness.* An additional aim of this study was to test the critical items used in Silva & Clahsen (2008) on an additional group of L2 speakers to determine any potential L1 transfer effects. We also extended the experiment by testing the potential influence of the prefixes, *re-* and *un-* on L2 morphological processing.

1.2. Brief literature review

Although morphology has long been of interest in SLA, in the past ten years techniques in mainstream psycholinguistics have been introduced as research tools (Jiang, 1999). Specifically, priming and masked priming paradigms have been used extensively in second language acquisition studies to investigate links between form and meaning, as well as the role of the first language in the development of the second language lexicon (see Kroll & de Groot, 1997; Kroll & Sunderman, 2003; and Kroll & Tokowicz, 2001, and Juffs (2009) for recent overviews and discussion). Although Jiang (2002), for example, has investigated the role of semantics in the L1 and L2 as well as some lack of sensitivity to morphology in processing (Jiang, 2004), as Feldman et al. (2010) note, the forward masked priming technique has not been widely applied to the study of inflectional or derivational morphology. In both L1 and L2 inflectional processing in English and German (Clahsen, 1995),

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research questions have involved the proposed distinction between lexically stored items, especially irregular forms (e.g. ‘saw’ and ‘teeth’, versus those claimed to be formed by rules, especially regularly inflected forms (e.g. ‘walked’ and ‘cats’).

Clahsen and colleagues’ recent work is based on Ullman’s (2001, 2005) model of native speaker morphological processing, which assumes a dual mechanism for morphological processing. Declarative memory systems are associated with listed lexical items, whereas procedural memory systems are associated with grammatical or rule processing. In this model, non-native speakers’ problems with morphology are attributed to reduced access to procedural memory and a corresponding overreliance on declarative memory.

Silva & Clahsen (2008) used a masked priming experimental method to explore this proposal. The masked priming technique involves three visual events presented on a computer screen:

Fixation: (##########)
Prime: (linked) → 60ms
Target: (LINK)

For each stimulus trial, there is first a fixation, then a 60 millisecond exposure to a prime, e.g. “linked,” and then a word in upper case, “LINK”—the target of a lexical decision (namely, whether or not the word is a possible word in English). If the prime is subconsciously recognized as being related to the target, then the decision should be made faster than if the prime is a word completely unrelated. The presentation of an affixed word before its bare stem target is expected to yield retrieval times that are similar to the baseline condition since processing is thought to happen at the earliest stages of word recognition, i.e., before explicit application of grammatical rules.

In Silva & Clahsen (2008), advanced Chinese-speaking and German-speaking learners of English as a second language showed no priming effects for inflectional morphology and only limited priming effects for derivational morphology. Moreover, Neubauer & Clahsen (2009) investigated Polish-speaking learners’ knowledge of German inflectional morphology and found no priming effects. Clahsen et al. (2010) provide an overview and interpretation of a series of experiments in which non-native speakers show greater effects for frequency in both regular and irregular inflection, whereas native speakers show asymmetric frequency effects with regulars being less affected by frequency. In addition, in priming experiments they note “attenuated” sensitivity in priming effects for both inflectional and derivational morphology, and reduced ability to process morpho-syntax in subject-verb agreement and noun-adjective agreement. Importantly, they note a “surprising” lack of effect of the first language: rich morphological marking in the L1 did not put learners in the experiments discussed by Clahsen et al. (2010) at an advantage. Clahsen et al. (2010) point out that, where lexical storage is concerned, L1 and L2 processing seems remarkably similar; whereas, when computing or decomposing items is required, L2 processing appears quite different. It is this difference that leads them to suggest Ullman’s model as one appropriate for accounting for the L1-L2 processing differences.

Given the limited number of studies using the masked priming technique and given the surprising lack of L1 influence, a replication of Silva and Clahsen (2008) is appropriate. We describe our modified experiment in sections 2 and 3. Key differences from the Silva and Clahsen (2008)’s experiment are the inclusion of a Spanish-speaking group of learners and the testing of prefixes. Section 4 provides discussion. We maintained a Chinese-speaking group to include speakers of a language that has little inflectional morphology and limited bound derivational morphology.

2. Method

2.1. Participants

Three different groups participated in these experiments with native language (L1) acting as the independent variable. The English L1 control group consisted of 25 native English speakers (mean age: 21.48, range: 18-29, 7 males). These participants were recruited from the University of Pittsburgh’s student population.

The L2 groups consisted of “advanced/proficient” L1 Spanish or Mandarin Chinese speakers. These two L2 groups were chosen based on the different morphological structures of the two L1s. Like English, Spanish is a multimorphemic language and contains verbal prefixes similar to those tested in these experiments. Furthermore, Spanish and English use the same prefix, *re-*, to represent the meaning: “to do again.” Unlike English or Spanish, Mandarin Chinese is monomorphemic. Although there is a way to express *re-* in Mandarin, there is no equivalent to the English *un-*.

Table 1

Summary of participant data

L1	*n*-size	Age	Age of onset	MTELP score	Cloze score
English	25	21.48 (sd: 3.6)			
Spanish	24	33.04 (sd: 9.11)	11.0 (sd: 4.31)	89.67 (sd: 6.91)	31.08 (sd: 6.36)
Mandarin Chinese	26	27.23 (sd: 5.32)	11.46 (sd: 1.50)	86.73 (sd: 4.64)	28.12 (sd: 4.91)

Participants in Groups 2 and 3 were recruited from the greater metropolitan area of Pittsburgh. A summary of group *n*-sizes is shown in Table 2. The Spanish L2 group consisted of 24 members (mean age: 33.04, range: 19-61, 7 males). There were 26 qualified participants in the Mandarin Chinese L2 group (mean age: 27.23, range: 21-42, 8 males).

Data from participants exposed to English in an ESL setting before the age of 10 were not submitted to analysis. The mean age for age of onset for the Spanish L2 group was 11.0 (range: 3-18) and the Mandarin Chinese L2 group was 11.46 (range: 9-14). The length of time that participants lived in the United States prior to testing varied extensively. All qualified participants reported that they had been exposed to English in a non-native classroom setting, and no participant reported a need to use English outside of the classroom before the age of 18.

All participants performed the five lexical decision tests, except for 2 participants in the Mandarin Chinese L2 group: one participant only took the lexical decision tests for Experiments 2, 3, and 4. Additionally, data from another participant is missing for Experiment 4.

L2 participants were administered the Michigan Test of English Language Proficiency (MTELP), Form R, to determine “advanced/proficient” level for the purpose of these experiments. The MTELP is a paper-based multiple-choice proficiency test which sections related to grammar, vocabulary, and reading. Only data from candidates with scores above 80 (out of a maximum score of 100) were included in our analyses. There was no significant difference between Spanish L2 and Mandarin Chinese L2 groups for this proficiency measure ($F(48) = 6.39$, $p = 0.082$). The average scores for both of this study’s L2 groups fall within the “advanced” range of the Oxford Placement Test, which was used as a proficiency measure in Silva & Clahsen (2008).

A paper-based cloze test was piloted as an additional proficiency measure to the L2 candidates at the end of the testing section. An “appropriate word” instead of an “exact word” method of scoring (Brown, 2004: 202) was used to evaluate each participant’s score on this proficiency measure.

Out of a potential 40, the Spanish L2 group averaged a 31.08 (sd: 6.36) and the Mandarin Chinese L2 group averaged 28.12 (sd: 4.91). A independent mean *t*-test showed no significant difference for the cloze test scores for these two L2 groups ($t(46) = 1.45$, $p = 0.076$).

Upon completion of the experiments, the L2 participants received a payment of $20 cash. All participants had normal or corrected-to-normal vision and were told that these experiments would look at how quickly non-native speakers recognized English words. They were, therefore, unaware that the primes were in position during the lexical decision tasks.

2.2. Materials

This study was designed based on Silva & Clahsen (2008). Table 2 shows a summary of the experiments and affixes tested in Silva & Clahsen (2008), including prime exposure times and the group information for the native and non-native English speaking participants tested.

E-Prime software, Version 1.1 was used to run the lexical decision tests in these experiments. Each experiment contained three combinations of prime-target pairs. By comparing the reaction times (RTs) between the different prime-target pairs (Condition), the effect of priming could be measured.

Table 2

Summary of experiments in Silva & Clahsen (2008)

Experiment 1, 3, 4:	tested 3 groups (English L1, German L2, Chinese L2) used prime exposure time of 60 ms
Experiment 1 -	tested inflectional past tense suffix *-ed*
Experiment 3 -	tested derivational deadjectival suffix *-ness*
Experiment 4 -	tested derivational deadjectival suffix *-ity*
Experiment 2:	tested 2 groups (English L1, Japanese L2) used prime exposure time of 30 ms
Experiment 2 -	tested inflectional past tense suffix *-ed*

Table 3

Definitions for the different priming types

Type of priming	Definition
Full priming	RTs in Condition 1 & 2 are similar to each other and different than RTs in Condition 3
Partial priming	RTs for Condition 1 are faster than Condition 2 and faster in Condition 2 than in Condition 3
Repetition priming	RTs are shorter for Condition 1 than in Condition 3
No priming	RTs in Conditions 2 & 3 are not different

Reaction times were recorded by measuring the length of time between the exposure of the target word (or non-word) on the computer screen and the amount of time required for participants to perform the lexical decision. By comparing the different RTs among the three conditions, the extent of priming can be determined. As set forth in Silva & Clahsen (2008) and shown in Table 3, “full priming” occurs when the RTs for the Identity and Test conditions are similar and both shorter than the Unrelated condition. “Full priming” is thought to indicate morphological decomposition. A morphologically-complex prime (Test) accesses the lexical entry as quickly as the bare stem prime

(Identity), allowing for quicker RTs. "Partial priming," is when participants take more time to respond to the Test condition than the Identity condition and, also, longer for the Unrelated condition than the Test condition. "Repetition priming" occurs when the Identity and Unrelated conditions are significantly different, and "no priming" occurs when there is no difference between the mean reaction times in the Test and Unrelated conditions.

Each of the five experiments contained an equal amount of prime-target types for each of the three prime-target pair conditions. Every experiment contained a total of 21 prime-target pairs — 7 in each condition. To ensure that each prime-target pair was tested in all 3 conditions and that each participant would only see each target word one time, the 21 prime-target pairs were distributed among three different versions of tests.

This study used the same primes as those used in Silva & Clahsen (2008) for Experiments 1, 2, and 3. For the new prefix stimuli tested in Experiments 4 & 5, both prime and target words were checked for frequency in the CELEX database (Baayen, Piepenbrock & van Rijn, 1993). The morphologically-complex primes for Experiments 4 and 5 have lower frequencies than the bare stem forms, which could contribute to any potential lack of priming.

Table 4

Description of the prime-target pairs tested in Experiments 1-5

Experiment	Condition	Prime target type	Example	
			Prime	Target
1	1	Identity	wrap	WRAP
	2	Test		
		Inflectional Morpheme *-ed*	wrapped	WRAP
	3	Unrelated	greet	WRAP
2	1	Identity	dumb	DUMB
	2	Test		
		Derivational Morpheme *-ness*	dumbness	DUMB
	3	Unrelated	short	DUMB
3	1	Identity	valid	VALID
	2	Test		
		Derivational Morpheme *-ity*	validity	VALID
	3	Unrelated	rough	VALID
4	1	Identity	hook	HOOK
	2	Test		
		Derivational Morpheme *un-*	unhook	HOOK
	3	Unrelated	search	HOOK
5	1	Identity	build	BUILD
	2	Test		
		Derivational Morpheme *re-*	rebuild	BUILD
	3	Unrelated	hope	BUILD

Each experiment contained a total of 324 words—21 critical items and 303 "filler" words and non-words. Additional primes were created in which we manipulated either the semantic and orthographic characteristics of the target word in an effort to prevent participants from deriving patterns of distribution of the test items. Each experiment also included a total of 162 non-words as targets in order to counterbalance positive and negative answers to the lexical decision task, which required participants to judge whether the target was a possible English word or not.

Additional word/non-word combinations for the filler stimuli were chosen and/or modified from the first 2,000 words in the General Service List (GSL) (http://www.nottingham.ac.uk /~alzsh3/acvocab/wordlists.htm). The manipulated stimuli were evenly distributed per experiment in 9 different prime/target combinations that were set forth in Silva & Clahsen (2008). The stimuli were presented in a randomized order, selected by the E-Prime software package.

2.3. Procedure

We collected reaction time data for this study by using the masked priming paradigm (Forster & Davis, 1984). The masked priming technique was developed so that "any observed priming effects cannot be a result of any conscious appreciation of the relationship between the prime and the target stimulus" (Forster 2003).

A series of ten hash marks (font: Verdana, size: 18) appeared on a 21" monitor for 500ms before the target word (or non-word) appeared in black font on a white background. The number of hash marks corresponds to the number of characters of the longest stimuli used. While participants were focusing their gaze on the hash marks, the prime word, in all lowercase letters, "to minimize the visual overlap between primes and targets" (Silva & Clahsen, 2008, p. 250), appeared for 60 ms. Finally, the target word, presented in all uppercase letters, appeared, forcing the software to start calculating the RT.

We chose 60 ms for the prime exposure time because participants should not see and consciously process the prime within this length of time. Although Lavric, Clapp and Rastle (2007) found that some semantic information is available at 60 ms, we chose to use this length of prime exposure time because of the report in Forster (1999) that 60 ms is the approximate amount of time required in order for the brain to open a lexical entry (pg. 10). Since "priming is seen as a savings effect" (Forster, 1999, p. 10), the amount of exposure time should be equal to the priming effect. Additionally, the 60 ms exposure time was chosen as it was the length of time used in Silva & Clahsen (2008)'s Experiments 1, 3, and 4—the three experiments that are the basis for this study's Experiments 1-3.

In effect, the flash of the prime word, however brief, allows lexical access to occur at a quicker rate. For all of these experiments, we were working under the assumption that masked priming leads to quicker lexical access, and, therefore, results in faster RTs.

After exposure to the stimuli, participants were forced to make a lexical decision by pressing a *Yes* or a *No* key. Participants were instructed to keep one finger on the *Yes* key and one of the *No*, at all times throughout the experiment so reactions times were not compromised.

Although all of the lexical decision experiments performed in this study were self-paced, each took approximately 8-10 minutes to complete, with all five experiments lasting less than one hour. After completion of each experiment, participants were offered the opportunity to take a break before they began the next experiment. All testing took place in the same office, lit appropriately according to the time of day when testing took place.

Participants were given written and oral instructions of the design of the experiments. As the participants were aware that RTs were under investigation, they were instructed to make their decisions as quickly and as accurately as possible. One participant said that he was able to see the prime words, so this participant's data was not included in the statistical analyses. Three participants from the Mandarin Chinese L2 group reported difficulty reading the targets because the letters were all uppercase.

2.3.1. Statistical measures

The distribution for the three groups was positively skewed so we transformed the group means in an effort to normalize the distribution for these groups. Both the error data and the reaction times for the 21 critical items for each experiment were analyzed using a mixed-design omnibus analysis of variance (ANOVA) with two variables: Group (English L1, Spanish L2, Mandarin Chinese L2) and

Condition (Identity, Test, Unrelated). Since the L2 groups had more variability, the error data for each experiment underwent the Friedman non-parametric test to reliably determine goodness of fit. If any significance was shown, then we ran a Wilcoxon Signed Ranks Test to establish which Group or Condition was causing more erroneous answers than normal.

The transformed log data were used in the reaction time analysis. We used a repeated-measure ANOVA to determine any priming effects for the RT data with Group and Condition as variables and Group held constant. We performed post-hoc paired t-tests if the ANOVAs yielded significant *p* values, with significance at or below 0.05. The post-hoc tests will compare the three prime-target conditions for each of the three groups to determine if the experiment yielded repetition, full, partial, or no priming effects for each group.

For the by-items analysis, we submitted the error data to a Kruskal-Wallis test to determine which Group provided more erroneous answers for a given experiment and/or which items in a particular Condition received more incorrect responses. We then submitted the log reaction time data to an additional ANOVA in which both Group and Condition were treated as repeated factors to determine if the items in any experiment were problematic for our participants.

To test if L1 is a factor contributing to differences within these two groups, the RT results for Groups 2 and 3 were submitted to an additional repeated measures ANOVA test to determine if there was interaction of Group and Condition. If the results from this additional ANOVA test yield a significant *p* value, then L1 must be considered as an influence on L2 processing. These data would contrast with claims made in Silva & Clahsen (2008).

3. Data Analysis

3.1. Experiment 1- Inflectional suffix -ed

This experiment tested for priming effects of inflectional affixes on the recognition of the base form, specifically: the *-ed* suffix used to form the simple past tense for regular verbs. The target words tested for Experiment 1 were the same 21 verbs in Silva & Clahsen (2008)'s Experiments 1 and 2.

Table 5

Mean reaction times (in milliseconds) and percent error for Experiment 1

	Condition	Mean	Standard Deviation	Percent Error
English L1				
(n = 25)	Identity	561	(113)	4.0%
	Test	538	(96)	1.7%
	Unrelated	600	(100)	4.0%
Spanish L2				
(n = 24)	Identity	692	(279)	1.8%
	Test	671	(253)	3.0%
	Unrelated	738	(211)	7.1%
Mandarin Chinese L2				
(n = 25)	Identity	645	(191)	3.4%
	Test	720	(295)	4.6%
	Unrelated	765	(237)	2.9%

The non-parametric test for the error data only revealed an effect of Condition for the Spanish L2 group, with significance between the Test and Identity conditions for the Spanish L2 group. Table 5 shows the percentage error data for each group in each condition in this experiment. The Spanish L2 participants gave erroneous answers for 7.1% of the targets primed by the Unrelated condition. Compared with the other two groups, this high percentage rate might have contributed to the significant interaction of Group and Condition. For the by-items analysis of the error data, we found no effect of condition for Experiment 1.

Erroneous responses accounted for 4% of the total critical items in this study's Experiment 1, and the RTs of these items were excluded from the reaction time analyses.

The ANOVA for the reaction time data revealed an effect of Group ($F1(2, 71) = 4.27$, $p = 0.018$) and Condition ($F1(2, 142) = 14.34$, $p < 0.001$), but no significant interaction of Group and Condition ($F1(4, 142) = 1.65$, $p = .166$).

The mean RT for the English L1 group in this study's Experiment 1 was actually slower in the Identity condition than in the Test condition, but post-hoc tests revealed that the difference between these two conditions was not significant. For the native English speakers in this study, the RTs were the slowest for the Unrelated condition.

The RT data for the native Spanish speakers suggest a repetition priming effect as well as a full priming effect of the inflectional simple past tense morpheme. For the Mandarin Chinese L2 group, the RT times for the Test condition were faster than the Unrelated one; furthermore, the Mandarin Chinese L2 speakers showed a repetition priming effect, with the Identity condition being significantly longer than the Unrelated condition.

Table 6

Results from the post-hoc tests for Experiment 1

	English L1	Spanish L2	Mandarin Chinese L2
Test – Identity	t = 0.89	t = 0.54	t = -2.15*
Test – Unrelated	t = -2.68*	t = -2.74*	t = -1.96
Identity – Unrelated	t = -1.79	t = -2.19*	t = -4.11*

An additional ANOVA revealed that there was no difference between the two L2 groups for the interaction of Group and Condition, implying there was no L1 effect for the decomposition of inflectional morphology.

3.2. Experiment 2 – Derivational suffix -ness

This experiment tested the possible priming effects of the deadjectival suffix *–ness* on the bare stem of the target items. The 21 critical items used in this experiment were the same targets used in Silva & Clahsen (2008)'s Experiment 3.

The non-parametric test for the error data for these items showed no effect of Condition for any of the three tested groups. Similarly, the by-items analysis yielded no significant effect of condition. Table 8 reports the mean percent errors for each condition. Erroneous answers were found for 6% of the total responses, and these responses were excluded for the RT ANOVA analyses.

The by-subject analysis of the reaction time ANOVA showed a significant effect of Group ($F1(2, 72) = 9.83$, $p< 0.001$) and Condition ($F1(2, 144) = 3.92$, $p = 0.022$) but no significance of the interaction of Group and Condition ($F1(4, 142) = 1.74$, $p = 0.144$). The large amount of variability within the Spanish L2 and the Mandarin Chinese L2 groups might have contributed to the lack of significance for the interaction of Group and Condition.

The post-hoc tests for this experiment also showed a full priming effect for the native speaker participants, as is shown in Table 8. The mean RTs for the English L1 group were almost identical across all conditions in this study's Experiment 2.

Table 7

Mean reaction times (in milliseconds) and percent error for Experiment 2

	Condition	Mean	Standard Deviation	Percent Error
English L1				
(n = 25)	Identity	555	(105)	2.9%
	Test	554	(76)	2.3%
	Unrelated	624	(143)	5.1%
Spanish L2				
(n = 24)	Identity	699	(209)	7.1%
	Test	682	(192)	6.0%
	Unrelated	687	(213)	5.4%
Mandarin Chinese L2				
(n = 26)	Identity	768	(297)	7.7%
	Test	823	(324)	8.2%
	Unrelated	833	(223)	5.0%

According to the post-hoc tests, no priming effects were recorded for the Spanish L2 group in this study, not even a repetition priming effect. The RTs for The Spanish L2 group in this study were only a few milliseconds apart across all conditions, and the longest mean RT was actually found for the targets primed by the Identity condition. The Mandarin Chinese L2 group in this study, though, showed a repetition priming effect, as participant RTs yielded faster results for Identity primes than Unrelated ones. The additional ANOVA that we performed for the two L2 groups showed that there was no significant difference between the two groups in this study. Like the Spanish L2 group, The Mandarin Chinese L2 group also showed no priming effect for the derivational affix *–ness*.

Table 8

Results from the post-hoc tests for Experiment 2

	English L1	Spanish L2	Mandarin Chinese L2
Test – Identity	t = -0.5	t = 0.44	t = -1.86
Test – Unrelated	t = -2.63*	t = -0.16	t = -0.76
Identity – Unrelated	t = -2.68*	t = 0.27	t = -2.61*

3.3. Experiment 3 – Derivational suffix -ity

The same prime-target pairs in this experiment were used in Silva & Clahsen (2008)'s Experiment 4, with the deadjectival suffix, *-ity* under investigation.

The error data was submitted to a non-parametric test to check for goodness of fit, which showed an effect of Condition for the English L1 group. The mean percentage error rates in Table 9 show a significantly higher error rate for the Unrelated condition. All participants provided a larger percentage of errors for the Unrelated condition in this experiment; however, the English L1 group provided the only significant difference. The by-items analysis also revealed an effect of Condition for the native

English speakers, who made significantly more errors for items in the Unrelated condition (9.8%) than the Identity (4.3%) and Test (3.4%) conditions.

Experiment 3 yielded the highest error rate of all experiments, with a total error rate of 10%. The high rate of errors could be attributed to the lower frequency in some of the primes and targets used in this experiment. The targets, *arid, docile, profane, and sterile,* seemed to cause some difficulty for participants, regardless of Group. The erroneous answers from Experiment 3 were not included in the reaction time data analysis.

Table 9

Mean reaction times (in milliseconds) and percent error for Experiment 3

	Condition	Mean	Standard Deviation	Percent Error
English L1				
(n = 25)	Identity	612	(340)	4.6%
	Test	590	(99)	3.4%
	Unrelated	656	(108)	9.7%
Spanish L2				
(n = 24)	Identity	636	(142)	5.4%
	Test	661	(205)	6.0%
	Unrelated	717	(194)	8.6%
Mandarin Chinese L2				
(n = 26)	Identity	908	(304)	15.4%
	Test	1116	(428)	15.4%
	Unrelated	1027	(324)	19.2%

The reaction time ANOVA for this study's Experiment 3 revealed significance for Group (F1(2, 72) = 20.89, $p < .001$) and Condition (F1(2,144) = 6.87, p = 0.001) but no effect for the interaction of Group and Condition (F1(4, 144) = 1.69, p = 0.156). Compared with the English L1 and Spanish L2 groups, the Mandarin Chinese L2 participants provided much slower reaction times across all of the different prime conditions. The RTs for the Spanish L2 group pattern similarly to those for the English L1 group, but the Spanish L2 group provided the fastest RTs in the Identity condition, while the English L1 group had its fastest responses for targets primed by the Test condition. Both the English L1 group and 2 have the slowest RTs under the Unrelated condition. In contrast, the Mandarin Chinese L2 group is slowest in Condition 2.

Table 10

Results from the post-hoc tests in Experiment 3

	English L1	Spanish L2	Mandarin Chinese L2
Test – Identity	t = -0.34	t = -0.37	t = 2.89*
Test – Unrelated	t = -1.99	t = -1.61	t = 0.99
Identity – Unrelated	t = -2.32*	t = -1.99	t = -1.90

As shown in Table 10, the Test and the Identity conditions for both the English L1 and Spanish L2 groups are similar, though only the native English L1 group showed a repetition priming effect. While the English L1 respondents gave the fastest responses for the Test condition, the Spanish L2 group provided the shortest RTs in the Identity primed condition. The post-hoc test results for the non-native English speaking groups in this experiment showed no significant difference in RTs between any of the conditions.

The additional ANOVA for the two L2 groups, however, did show a significant difference for the two L2 groups. This significance suggests a possible L1 effect for this Test item that challenges the findings from Silva & Clahsen (2008). The suffix under investigation in this experiment has Latin origins. Although the by-subject data did not show a repetition priming effect or any difference between either the Test or the Identity conditions with the Unrelated condition, the significant difference between the L2 groups suggests that something in the item data is contributing to the lack of priming for the Spanish L2 group.

Since a similar suffix is found in the native language of participants in The Spanish L2 group (usually represented by the suffix *-idad* in words such as *fatalidad* – fatality or *tocicidad* – toxicity), the difference between the two L2 groups for Experiment 3 could suggest a L1 influence for the Spanish speakers for the derivational suffix *-ity*. If this is true, then the claim in Silva & Clahsen (2008) that L1 transfer is not a factor in non-native word processing should be reevaluated.

3.4. Experiment 4 – Derivational prefix un-

This experiment tested verbs that can also feature the prefix *un-* as the prime to bare stem targets. These stimuli are new to this experiment and were included to measure the influence of prefixes on non-native morphological processing.

Table 11

Mean reaction times (in milliseconds) and percent error for Experiment 4

	Condition	Mean	Standard Deviation	Percent Error
English L1				
(n = 25)	Identity	586	(176)	4.6%
	Test	566	(107)	3.4%
	Unrelated	705	(341)	6.9%
Spanish L2				
(n = 24)	Identity	751	(308)	13.1%
	Test	793	(325)	9.5%
	Unrelated	761	(252)	15.5%
Mandarin Chinese L2				
(n = 25)	Identity	780	(350)	5.1%
	Test	806	(258)	10.9%
	Unrelated	757	(180)	11.4%

We submitted the error data for this experiment to a non-parametric test, which yielded no significant effect of Condition for any of the participant Groups. Table 11 shows the mean percent errors across Groups and Conditions, with native speakers providing the fewest errors for all conditions.

Participants gave erroneous responses to 9% of all critical items in Experiment 4. These erroneous answers were not included in the reaction time analysis.

The reaction time ANOVA for Experiment 4 revealed an effect of Group (F1(2,71) = 5.91, p = 0.004) but no significance for Condition (F1 (2,142) = 2.50, p = 0.069). The interaction of Group and Condition, however, was significant (F1 (4, 142) = 2.74, p = 0.031). The effect of both Group and the interaction of Group and Condition are probably caused by the lower mean RTs for the native speaker control group for this Experiment. The Spanish L2 group logged higher mean percentage rates in Experiment 4 than any of the other experiments in this study.

As shown in Table 11, the L1 English group logged faster reaction times in the Test condition than in the Identity or Unrelated conditions. The difference between the Identity and Test conditions, however, was not significantly different for the native English speakers. The post-hoc tests showed that both the Test and Identity conditions were significantly different than the Unrelated condition, which is indicative of a full priming effect. In contrast to the native English speakers, neither of the L2 groups provided a repetition priming effect or any other priming effect for *un-*.

The RT data, likewise, showed no significant difference between conditions for either L2 group. The additional RT ANOVA that was performed on the non-native participant groups also failed to reach significance.

Table 12

Results from the post-hoc tests in Experiment 4

	English L1	Spanish L2	Mandarin Chinese L2
Test – Identity	t = -0.32	t = 1.16	t = 1.00
Test – Unrelated	t = -3.01*	t = -0.67	t = -0.18
Identity – Unrelated	t = -3.33*	t = 0.49	t = 0.82

3.5. Experiment 5 – Derivational prefix re-

With this Experiment, we tested the priming effects of the prefix *re-*. Like the stimuli in Experiment 4, the critical items in this Experiment were introduced in this study.

Table 13

Mean reaction times (in milliseconds) and percent error for Experiment 5

		Mean	Standard Deviation	Percent Error
English L1				
(n = 25)	Identity	521	(80)	1.1%
	Test	569	(79)	1.7%
	Unrelated	586	(105)	2.9%
Spanish L2				
(n = 24)	Identity	643	(190)	7.9%
	Test	685	(215)	3.0%
	Unrelated	686	(215)	7.1%
Mandarin Chinese L2				
(n = 25)	Identity	625	(168)	2.8%
	Test	684	(176)	5.0%
	Unrelated	692	(180)	2.8%

The non-parametric test for the error data revealed no significance of condition for any group tested. The mean error rates, which are shown in Table 13, show that the native speakers tested in this experiment logged more accurate answers for the lexical decision tests in this experiment.

A total 3% of participant answers were erroneous, and the critical items that were answered incorrectly were not included in the ANOVAs for the reaction time data.

The reaction time ANOVA revealed an effect of Group ($F1(2, 70) = 4.66$, $p = 0.013$) and Condition ($F1(2, 142) = 11.67$, $p < 0.001$) but no effect of the interaction of Group and Condition ($F1(4, 140) = 0.28$, $p = 0.891$). The Group effect could be attributed to the overall faster RTs for the native English speakers and the Condition effect might be the result of the faster reaction times for the Identity primes for all three groups, which can be seen in Table 13.

The post-hoc tests for Experiment 5, the results of which can be seen in Table 14, revealed a repetition priming effect for the English L1 and Mandarin Chinese L2 groups, since both groups showed a significant difference between the Identity and Unrelated conditions. Apart from the repetition priming effects, there was no priming effect shown for any of the Groups in this experiment. The additional ANOVA on the non-native speakers showed no significant difference between the two groups.

Table 14

Results from the post-hoc tests for Experiment 5

	English L1	Spanish L2	Mandarin Chinese L2
Test – Identity	t = -2.53*	t = -1.62	t = -2.66*
Test – Unrelated	t = -0.68	t = -0.16	t = -0.30
Identity – Unrelated	t = -3.21*	t = -1.78	t = -2.96*

4. Discussion

4.1. Summary of results

The results from our study differ from Silva & Clahsen (2008) in terms of the inflectional suffix *-ed* and derivational suffix *-ity*. Silva & Clahsen (2008) showed no priming effects for the inflectional suffix *-ed*. Table 16, however, shows a full priming effect for the Spanish L2 group in this study for the past tense inflectional affix for regularly inflected verbs. The English L1 control group in this study did not exhibit any priming effects for *-ed*. As can be seen in Table 6, the mean reaction times for both the English L1 and Spanish L2 groups are faster for the Test condition that the Identity condition. The fact that the native English speakers gave faster reaction times for the Test condition than the Identity condition may have contributed to the lack of priming for the native English speakers in Experiment 1, especially since the Test and Identity RTs are similar and the English L1 post-hoc data also show a significant difference between the Test and Unrelated conditions.

Unlike the full priming effect witnessed for the inflectional suffix *-ity*, the L2 participants did not yield any priming effects for the derivational affixes tested. The English L1 group showed priming effects for the derivational suffix *-ness*, and the derivational prefix *un-*. The lack of full priming effects for the derivational suffix *-ness*, however, may have been caused by the high error rate found for items in the Unrelated condition. The English L1 group provided reaction times for the Test condition that were faster than the Identity condition. Since erroneous answers are not included in the RT analyses, the greater amount of RTs missing from the Unrelated condition in Experiment 3 may have also influenced the lack of full priming for *-ity*.

4.2. Implications to SLA processing theory

Our primary intention for replicating Silva & Clahsen (2008) was to test their claims that native speakers have access to Ullman (2001, 2004)'s declarative/procedural model, whereas L2 speakers rely on declarative memory alone to process morphologically complex words. The participants in Silva & Clahsen (2008) yielded priming patterns that suggested that morphologically complex words with inflectional morphemes have whole word representations in the mental lexicon and ones that contain derivational suffixes may be processed within the mental grammar. It is implied that these results might account for differences in the rate of native and non-native language processing.

Table 15

Summary of priming effects for Experiments 1-5

	English L1	Spanish L2	Mandarin Chinese L2
Experiment 1 – Inflectional suffix *-ed*	no priming	full priming	repetition priming
Experiment 2 – Inflectional suffix *-ness*	full priming	no priming	repetition priming
Experiment 3 – Inflectional suffix *-ity*	repetition priming	no priming*	no priming
Experiment 4 – Derivational prefix *un-*	full priming	no priming	no priming
Experiment 5 Derivational prefix *re-*	repetition priming	no priming	repetition priming

**Note: 2nd ANOVA between 2 L2 groups yielded significance, suggesting L1 transfer.*

The priming results provided by the Mandarin Chinese L2 group in these experiments are, more or less, similar to the results provided by the Mandarin Chinese L2 participants in Silva & Clahsen (2008), although we did not find partial priming effects for derivational suffixes. Overall, this group of L2 speakers provided slower RTs and higher error rates than the other non-native English speakers tested in both studies. The mean scores for both L2 groups on both proficiency measures used in this study were not significant, suggesting that both L2 groups in this study would be able to perform at the same level. The priming effects that we recorded in this study for the Mandarin Chinese L2 group could show that native speakers of Mandarin Chinese have a greater difficulty processing morphologically complex words than native Spanish speakers.

The results from the Spanish L2 participants diverge from some of those found for non-native speakers in Silva & Clahsen (2008) and Neubauer & Clahsen (2009). First of all, the Spanish group showed a full priming effect for the inflectional suffix tested in Experiment 1. These results could be the result of L1 transfer, although not overtly so, as the past tense in Spanish is not formed through the same affixation process as in English. Participants in the Spanish L2 group had been exposed to English earlier than the Mandarin Chinese L2 participants, albeit in an EFL classroom setting. Perhaps the results from the Spanish L2 participants for Experiment 1 support the claim made by Ullman (2001) that a longer amount of practice with a second language can lead to a more automatic processing of grammatical structures.

We found a possible instance of L1 transfer in the Spanish L2 groups processing of the derivational suffix *-ity*. Although the Spanish L2 participants did not show priming effects in our Experiment 3, we did find a significant difference between the L2 groups. The native Spanish speakers also provided mean reaction times that patterned more like the native English speakers than the Mandarin Chinese L2 group for this experiment, which suggests that they were transferring morphological processing from their native language while processing the English words primed with *-ity*.

The results of experiments 4 and 5 suggest that non-native speakers have difficulty processing derivational *prefixes* using the procedural memory system. However, native speakers exhibited either full or no priming effects, depending on derivational prefix. L1 participants successfully decomposed complex words that are derived from the prefix *un-* into a bare stem and its morphological parts, which implies processing. The semantic meaning in *un-* is consistent when applied to the verbs tested in this study as well as other word categories, e.g., adjectives (unhappy) or adverbs (unfortunately), which might explain why native speakers yielded priming effects for this variable in Experiment 4. The non-native speaker results, however, support the theory that non-native speakers rely more on declarative memory when processing words in their second language. This finding is consistent with production data reported in Friedline & Juffs (submitted).

The results from this Experiment 4, which tests the derivational prefix *un-* suggest that native speakers store *un-* as a morphological unit when processing verbs that are formed with this prefix. Non-native speakers, however, did not exhibit any priming effects. The faster RTs in the Mandarin L2 group under the Unrelated condition, in particular, suggest that the non-native speakers are not benefitting from any kind of priming. The slower RTs for the condition might also be attributed to the lower frequency of the primes used in this condition especially in comparison with the frequency of the bare-stemmed verbs in the Identity condition.

The priming results for the derivational prefix *un-* differ from the results for the *re-*. Neither the native nor the non-native speaker group yielded priming effects for *re-*. The variable tested in our Experiment 5 yielded no priming effects, which suggests that even native speakers fail to process the words formed with the derivational prefix *re-*. The lack of morphological decomposition witnessed in this experiment could be the result of the orthographic representation of the tested prefix (Marslen-Wilson, Komisarjevsky, Waksler, & Older, 1994). In a sight recognition task, such as the lexical decision experiments in this study, the presentation of the prefix *re-* in a prime, like 'rebuild', might prevent participants from accessing the morphological structure of these primes. The reason for this is that the prefix *re-* contains the exact same orthographic structure and positioning at the beginning of the word as countless other words in the English lexicon that do not contain a prefix, e.g., 'reach'. The difference between a prefixed word, like 'rebuild', and words like 'remiss' or 'return', is that the "to do again" meaning of the prefix is only found in 'return'. Compare also English words that are prefixed with *re-* and have forms that have an entire form overlap with an entirely different English word, such as: *realign-real* or *reapply-reap*.

Similarly, we did not find priming effects for the Spanish L2 group in Experiment 5, even though Spanish uses the same derivational suffix as English to indicate the meaning "to do again." The results for the Spanish L2 participants are difficult to interpret because the observed lack of priming could be caused by not only the effect of orthography (that might also have inhibited processing in the English L1 participants), but also the fact that non-native speakers store prefixed English words in the mental lexicon.

The processing of the prefix might also be inhibited because of the nature of the task performed. The morphological structure of the prefix *re-* is not as readily available in visual tasks as auditory tasks, as the *re-* in rebuild is pronounced differently in remiss and return, and may have caused an inhibitory effect for the participants in this study. The orthographic structure of a morpheme might inhibit processing of the complex word by the procedural memory system. Rastle, Davis, and New (2004), also, found that a combination of letters that resembled morphological units did not provide priming results unless the primes had a "morpheme-like" relationship to the stem. This possible facilitative effect for the prefix *re-* would have to be tested in order to determine if the orthographic representation is inhibiting priming or whether all complex words prefixed with *re-* receive whole-word representations in the mental lexicon.

4.3. Suggestions for future research

Studies that focus on non-native processing of derivational morphology are not abundant in the psycholinguistic literature, so additional on-line studies that measure non-native morphological processing are needed in order for us to gain a better understanding how second language learners process their L2. Based on the results of the Spanish L2 participants in these experiments, the most obvious recommendation that can be made for future research would be to test for priming effects for derivational affixes in Spanish on English L2 learners. Also, studies that examine the nature of non-native word processing in non-Indo-European languages might provide additional insights. For example, Bantu languages are regularly prefixing languages that require learners to process prefixes as part of the inflectional system. They offer an interesting context to test theories of L2 acquisition of morphology (Spinner, 2011). Hence, before concluding the all L2 learners are unable to acquire procedural processing of morphology in adulthood, we need to investigate other contexts and languages.

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