The Processing of Adjective Agreement Morphology in Native, Heritage, and L2 Arabic

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Abstract

According to previous research, speakers of European languages parse regularly-inflected, morphologically-complex words into stems and grammatical affixes during word recognition. In contrast, some studies suggest that late second language (L2) learners do not. We ask how these types of words are processed in Arabic, a language whose primary morphological process is infixation, which exists alongside prefix- and suffixation. Specifically, we ask how natives, heritage, and late L2 learners process regular gender and number agreement morphology on adjectives. Results of a masked priming experiment suggest that all three groups parse adjectives into stems and affixes depending on agreement type, suggesting that learners store and process morphologically-complex words like native speakers, even when the first and second language have very different morphological systems.

Keywords: *Arabic morphology, heritage learners, lexical processing, L2 learners*

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Introduction

A consistent finding in the literature on second language (L2) acquisition is that post-puberty, or *late*, L2 learners do not always produce inflectional morphology accurately and consistently, even at advanced proficiency levels. The cause of these morphological difficulties has been hotly debated. According to one view, as the result of a critical period for language acquisition, late L2 learners lack nativelike knowledge of the second language, which leads to morphological errors (e.g., Clahsen, 1990; Hawkins & Chan, 1997; McCarthy, 2008). In opposition to this view is the claim that late L2 learners may not differ from native speakers in their knowledge of the L2; however, they may not be able to access their L2 knowledge consistently and accurately, possibly due to factors such as time pressure, working memory constraints, slowed lexical access, or interference from the native language (e.g., Ellis & Sagarra, 2010; Hopp, 2013; McDonald, 2006; Prévost & White, 2000). Recent research has taken the debate about L2 morphology to the lexical level, asking how L2 learners process words that are morphologically-complex due to inflectional processes, with the idea that one possible cause of morphological difficulties could be that these types of words are not represented or processed in the same manner by learners as they are by native speakers. This possibility has led to a significant body of research that has been devoted to the question of how and why L2 learners may differ from native speakers in the manner in which they process morphologically-complex words. According to several studies on English and other languages, native speakers seem to decompose words that consist of more than one morpheme into their component parts during lexical processing. To give an example, if an English native speaker is exposed to the morphologically-complex word *pushed*, he or she automatically and unconsciously segments the word into its stem, *push*, and the inflectional morpheme, *-ed* (Marslen-Wilson & Tyler, 1997). In contrast, several studies that have examined lexical processing in late L2 learners seem to show that learners do not segment morphologically-complex words into their component morphemes, but rather process them as non-decomposable wholes (Silva & Clahsen, 2008). Based on this finding, Clahsen et al (2010) hypothesize that late L2 learners do not have as detailed a representation of morphologically-complex words as native speakers do, and hypothesize that this could be because of an increased dependence on declarative instead of procedural memory in post-puberty L2 acquisition, as proposed by Ullman's (2005) declarative/procedural model for L2. According to this model, there are two different memory systems that are used for language: the declarative memory system is used for form-based, memorized knowledge, while the procedural memory system is used for rule-based, grammatical processing. With increased age, the procedural memory system becomes less available for use, forcing older language learners to depend more on the memorization of discrete forms instead of rule-based processing. At the lexical level, this means that learners may not process morphologically-complex words via decomposition as native speakers do, since decomposition relies on the application of the rules of morphological structure. Instead, late L2 learners may rely on memorizing and storing complex words as whole word forms, and processing these forms on a word by word basis.

In contradiction to this proposal, however, some studies indicate that late L2 learners are in fact sensitive to morphological structure, showing evidence of decomposition during lexical processing (e.g., Foote, 2017; Lehtonen & Laine, 2003; Portin, Lehtonen, & Laine, 2007). Based on some of these studies, learners and native speakers do not store and process morphologically-complex words differently. According to others, learners may even rely more heavily on decomposition than native speakers; natives have been found in some studies to process high-frequency complex forms as undecomposed wholes while reserving decomposition for mid- or lower-frequency forms. Since L2 learners do not have as much experience with L2 words, they do not develop undecomposed whole word forms until higher levels of proficiency, but instead rely on decomposition for almost all word forms once they have acquired the morphological rules of the language.

One type of language user that has not been extensively studied in this area is the heritage speaker. In this paper, we define a heritage speaker as someone who is exposed to a minority language at home as a native or first language, while also being exposed to the majority language, either simultaneously with the home language, or later during childhood (Montrul 2010). Although heritage speakers vary widely in their proficiency in the home language as they reach adulthood, it is common for them to become dominant in the majority language, and to be less proficient in the minority language than native speakers who grew up in an environment where the home language was the majority language. Focusing specifically on morphology, research in the field of heritage language acquisition has provided empirical evidence that, as a group, heritage speakers do not show the same levels of accuracy in their production of inflectional morphology as monolingually-raised native speakers (e.g., Albirini, Benmamoun, & Chakrani, 2013; Montrul, Foote, & Perpiñán, 2008), although they still tend to outperform L2 learners in this area, depending on task type and proficiency level (e.g., Albirini & Benmamoun 2015; Montrul et al., 2008). This finding suggests that they may also differ from monolingually-raised native speakers in terms of their processing of morphologically-complex words. The few existing studies that examine morphological processing in heritage speakers do seem to point to possible differences in the processing of these words in the two populations, emphasizing the need for more research on this group (Gor & Cook, 2010; Jacob & Kirkici, 2016). However, the proposal that late L2 learners do not decompose morphologically-complex words, or that they show decreased sensitivity to morphological structure at the lexical level due to a heavier reliance on declarative memory in late language acquisition should not apply to heritage speakers, as they learned the heritage language from birth as a native language.

An important question to ask, given the conflicting results in existing studies on morphological processing, is what factors may affect whether a particular speaker or speaker group decomposes morphologically-complex words or not. Some possibilities include language proficiency (Feldman et al., 2010), frequency of the word forms (Portin et al., 2007), the native language of the speaker in the case of L2 learners (Basnight-Brown, Chen, Hua, Kostić, & Feldman,2007), task type (Clahsen et al., 2010), and the particular language investigated. Focusing on this last possibility, it is the case that a large portion of previous research that has suggested that late L2 learners do not decompose morphologically-complex words has examined decomposition in Germanic languages such as English or German. Studies on languages that are richer in morphology, such as Russian and Finnish, tend to provide evidence that learners do decompose complex words into their component parts (Gor & Jackson, 2013; Lehtonen & Laine 2003), although there is at least one exception with a study that looks at Turkish (Kirkici & Clahsen, 2012). The aim of the present study is to expand the research on morphological decomposition by examining a language that consists almost exclusively of morphologically-complex words, namely Arabic. Arabic is an understudied Semitic language with comparatively few empirical studies on native speakers, and very limited data on heritage speakers and L2 learners. However, it has become a language that is frequently studied as a heritage and second language, with enrollments increasing dramatically in the last decade. Moreover, theoretically speaking, it is of interest because of its complex morphological system.

Morphologically-Complex Words in Arabic

Arabic has a number of characteristics that distinguish it from other languages in which morphological decomposition has been investigated. Arabic requires subjects and verbs to agree in person, number, and gender, and nouns and adjectives to agree in number, gender, case, and definiteness. Existing studies on morphological decomposition, and more broadly, the processing and production of inflectional morphology, have examined languages with concatenative morphology, in which agreement morphology appears in inflectional suffixes that are concatenated onto a noun, verb, or adjective root. In contrast, in Arabic, agreement morphology can also be found on prefixes and infixes. In Arabic, words are composed of a minimum of two abstract, bound morphemes, known as the _root_ and the _word pattern_. The root provides the central meaning of the word, and the word pattern establishes the syntactic category of the word and its phonological form (Marslen-Wilson, 2001). These two morphemes combine non-concatenatively to form a word. For example, the root _k-t-b_ "~write" combines with the word pattern _ma--a-a_ "~location" to form the word _ma**kt**a**b**a_ "library". The same root can be combined with different word patterns to form derivationally-related words, or in the case of the Arabic broken plural, inflectionally-related words. For example, the root _k-t-b_ is used with different word patterns to form derivationally-related words like _**k**a**t**a**b**a_ "he wrote", _**k**i**t**aa**b**_ "book", _ma**kt**a**b**_ "office" and _**k**u**t**ayyi**b**_ "booklet". However, it can also be used with a different word pattern in order to form the plural of, for example, _ma**kt**a**b**_ "office": _ma**k**aa**t**i**b**_ "offices" or _**k**i**t**aa**b**_ "book": _**k**u**t**u**b**_ "books". In sum, Arabic agreement morphology can be found on prefixes, suffixes, and infixes, which may make learning and using the agreement system in Arabic a daunting task for the L2 learner and possibly the heritage speaker as well.

Lexical Organization and Processing in Arabic

Although there is not as much research on Arabic as there is on European languages, there are some empirical studies that examine how words are represented and processed in native speakers of Arabic as well as Hebrew, another Semitic language that is similar in terms of its morphological structure and complexity. Most of these studies employ priming methodologies in order to investigate lexical processing. These methodologies are based on the conceptualization of the mental lexicon as a network of connected nodes, or morphemes, with the connections based on relationships between the nodes. In priming tasks, a participant is typically presented with a word form (the prime), which is followed by another word form (the target). If the prime and target are related or connected in some way, or if they share some element in common (for example, form or meaning), then prime's presentation will affect the response to the target. Specifically, access to the target can be facilitated (be faster or more accurate) or inhibited (be slower or less accurate) in comparison to when the target is preceded by a completely unrelated prime. In some studies, the response time to the target when preceded by a particular type of prime is also compared to the response time when the target is preceded by an identity prime (the target word itself). If the prime in question leads to the same magnitude of priming as an identity prime in terms of response time facilitation, then *full priming* is said to have occurred, so that the effect of the prime in question does not differ from the effect of seeing the same word as both prime and target (see, e.g., Silva & Clahsen, 2008).

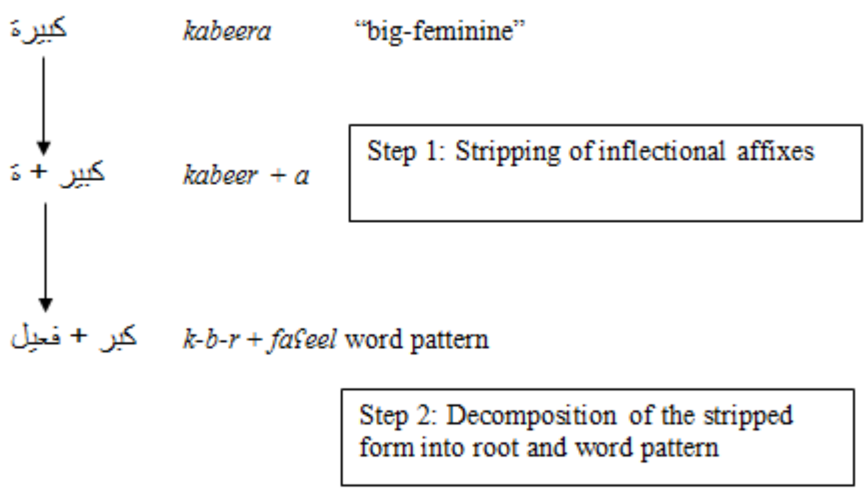
There is a variety of types of priming methodologies; the one employed in this study is masked priming. In masked priming, the prime is presented for a very brief period of time (usually less than 60 milliseconds), and is masked by some type of pattern, such as hash marks. Once the target appears, the participant is asked to make a response to it; for example, to push a button to specify whether the target is a real word in a particular language, or to read the target word aloud. Masked priming is generally used to investigate the unconscious, early processes of lexical access, as the prime is usually not consciously perceived by experimental participants given its brief presentation time. Responses in this type of task are believed to be automatic, uncontrolled by conscious thought or response strategies, and not usually subject to the effects of episodic memory (Forster, Mohan, & Hector, 2003). This is desirable in order to try to isolate automatic processes of lexical access from other types of more controlled, conscious processes. In terms of the types of lexical relationships that this task targets, masked priming seems to only be sensitive to orthographic and morphological relationships between primes and targets. Semantic relationships do not usually come into play during these earlier stages of lexical processing, although some recent research indicates that meaning can, in fact, affect processing even with such a brief presentation of the prime (Feldman, Milin, Cho, Moscoso del Prado Martín, & O'Connor, 2015).

The studies that have examined Arabic and Hebrew using priming tasks have found that native speakers of these languages show facilitatory priming when primes and targets share a root (e.g., *kataba* "he wrote" and *maktaba* "library"), and also when they share the same word pattern (e.g., *kataba* "he wrote" and *darasa* "he studied"), depending on the amount of time the prime is presented, the word pattern's productivity, and whether the pattern represents the same morpheme in the prime and the target (Boudelaa & Marslen-Wilson 2005, 2015; Deutsch, Frost, & Forster, 1998; Frost, Deutsch, & Forster, 2000; Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2005). However, there is no priming in native speakers when the prime and target differ in just one root letter (without a shared word pattern), while morphological root priming is robust even when there is little orthographic overlap, and even when the meaning relationship between same-root primes and targets is not transparent (e.g., *suʔaal* "question" and *masʔuuliyya* "responsibility"; Boudelaa & Marslen-Wilson 2015; Frost et al., 2000; Frost et al., 2005). Together, these findings imply that morphological priming in these languages cannot be attributed simply to form and/or meaning relationships, but rather are due to shared morphemic units that regulate lexical access (Frost et al., 2000). In other words, the Arabic lexicon seems to be organized and accessed according to morphological similarity. According to this view, when a native speaker of Arabic encounters a word that is composed of a root and word pattern, he or she automatically and unconsciously decomposes the word into its component parts, the root and the word pattern, as a part of lexical access.

One question that previous research on Semitic languages has not addressed, to our knowledge, is how regularly-inflected (prefixed and/or suffixed) words are processed. Arabic scholars do generally make a clear distinction between affixation and the root and word pattern morphological mechanisms, which exist alongside each other in the language (e.g., McCarthy & Prince, 1990; Ryding, 2005). Prefix- and suffixation in Arabic are considered to be linear processes, while the root and word pattern mechanism "involves the nonlinear superimposition of templatic consonant-vowel patterns onto triradical roots" as Saiegh-Hadded, Hadieh, and Ravid (2012, p. 1084) state in their description of how these two mechanisms apply to noun plural formation. In terms of the processing of prefixed and/or suffixed words, combining the research on Arabic with research on other languages, we hypothesize that the decomposition of these words in Arabic occurs as a two-step process. Taking the example of a feminine, singular adjective in Arabic, Figure 1 illustrates this process. The first step is the stripping of inflectional affixes. In the example given, there is one inflectional affix, a suffix that indicates feminine gender (the *taa' marbuuTa*). After inflectional affixes have been stripped, the remaining stem form is then decomposed into the root, which provides the central word meaning, and the word pattern. In the example in Figure 1, the root *k-b-r* gives a meaning of "~large", while the word pattern *faʕeel* in its citation form, is a pattern that is used in adjectival forms.

Figure 1.

Morphological decomposition in Arabic.



If this hypothesis about how morphological decomposition functions in regularly-inflected words in Arabic is correct, then priming experiments with native speakers should show the same types of priming patterns for regularly-inflected adjectives in Arabic as have been found for regularly-inflected words in European languages, such that one inflected form of an adjective primes another inflected form of the same adjective, given that once the affixes are stripped from the inflected forms, the same root and word pattern combination is accessed for further decomposition. Whether the same processes of decomposition occur during lexical processing in late L2 learners or heritage speakers of Arabic is an open question, as there are no published studies that investigate morphological decomposition of regularly-inflected words in these populations to our knowledge. Studies with late L2 learners of other languages have produced conflicting results, with some indicating a lack of morphological decomposition in late learners and others showing the opposite. One difference between the present study and most previous research with L2 learners is that our focus is on adjectives rather than on verbs. Adjectives are morphologically simpler than verbs in Arabic, as in other languages, since they only mark gender and number. Verbs, on the other hand, can mark tense, aspect, mood, person, gender, and number. Because adjectives are simpler than verbs morphologically, we hypothesize that late learners may be more likely to decompose them, although some recent research shows no difference in decomposition based on word class (Foote, 2017). This leads us to the goal and research questions of this study.

The Present Study: Goal and Research Questions

As noted above, the aim of the present study is to extend the existing research on morphological decomposition to Arabic, with the objective of investigating how native speakers, heritage speakers, and late L2 learners process regularly-inflected, morphologically-complex words in Arabic, namely adjectival forms. With this goal in mind, we conducted a masked priming, lexical decision experiment in order to answer two specific research questions. First, do native speakers, heritage speakers, and late L2 learners of Arabic segment adjectives into their stems and agreement affixes during visual word recognition? There is a lack of research on how any of these populations process inflection in Arabic, so we formed our hypotheses about the answer to this question based on investigations carried out in other languages: native speakers of Arabic will show morphological decomposition. Heritage speakers and L2 learners may also do so, since Arabic is a morphologically-rich language and morphological decomposition has been noted in learner populations in most studies on languages with rich morphology. As noted above, the use of adjective rather than verb targets may also make it more likely that these populations will show decomposition in the present study. However, this may also depend on the general proficiency level of the heritage speakers and L2 learner participants. In addition, if age of acquisition plays a role in whether a speaker decomposes morphologically-complex words, as suggested by the declarative/procedural model, then heritage speakers of Arabic may show evidence of morphological decomposition, while late L2 learners may not.

The second research question is: does type of agreement morphology affect whether segmentation occurs? We investigated morphological decomposition in adjectives using primes that differed from targets on gender or on both gender and number. Based on the previous research outlined above, we hypothesized that priming would occur in both prime-target relationships tested, since the same process of decomposition should apply in both cases. However, an additional issue related to type of agreement morphology is the indication from previous research that both late L2 learners and heritage speakers tend to be less sensitive to and accurate with gender morphology than with other types of agreement morphology in Arabic and in other languages (e.g., Albirini et al., 2013; Montrul et al., 2008). We therefore hypothesized that these two populations may not show the same magnitude of priming with primes and targets that differ on gender as they do with primes and targets that differ on both gender and number.

Method

Participants

Twenty-six native speakers of Levantine and Egyptian Arabic participated in the experiment, along with 20 heritage speakers, also of Levantine and Egyptian Arabic, and

31 late L2 learners of Arabic. However, not all of the participants were included in data analyses; as we examined the response time results from the masked priming experiment, we found that some participants from each group did not show identity priming[2], suggesting that they were not processing the primes. We therefore eliminated these participants from our analyses, leaving us with 16 native speakers, 16 heritage speakers, and 16 late L2 learners. The dominant language of the heritage speakers and L2 learners included in analyses was English. Table 1 provides information about the participants, including age at the time of the experiment, age of acquisition of English and Arabic, self-ratings of proficiency in English and in Arabic (on a scale of 1 to 4, with 4 being nativelike), and percentage scores on a measure that we used as an estimate of proficiency in Arabic (heritage speakers and L2 learners only). This measure was a version of the Swadesh list with 100 common, basic words in English that participants were asked to translate into Arabic. One point was given for each correct answer.

Table 1

Participant information, means and standard deviations (in parentheses).

	Native speakers n=16	Heritage speakers n=16	L2 learners n=16
Age	34.0 (10.0)	21.0 (1.7)	22.0 (2.0)
Age of acquisition (English)	6.6 (4.1)	1.7 (2.5)	0.9 (1.9)
Age of acquisition (Arabic)	0.0 (0.0)	0.0 (0.0)	17.3 (5.7)
Self-rating (English)	3.1 (1.1)	4.0 (0.0)	3.9 (0.3)
Self-rating (Arabic)	3.9 (0.3)	3.1 (0.5)	2.8 (0.6)
Swadesh score	----------	89.9 (4.6)	62.3 (11.1)

[2] Identity priming is the facilitative priming of a target by a prime that is exactly the same as the target. Typically, the presentation of the same word as prime and target leads to the maximum amount of facilitation in comparison to the presentation of a prime that has no relationship to the target. In the case of some of the participants in this study, there was either no facilitation, such that they responded with the same speed to targets preceded by identity primes and those preceded by unrelated primes, or their response speed was faster to targets preceded by unrelated primes than to targets preceded by identity primes.

As displayed in Table 1, the native speakers of Arabic rated themselves as having higher proficiency in Arabic than in English, although many had learned English in school growing up, and all were currently residing in the U.S. Heritage speakers and L2 learners rated themselves as having higher proficiency in English than in Arabic, illustrating their English dominance. Age of acquisition of Arabic and English was similar for the heritage speakers, although on average, English was learned later than Arabic. Age of acquisition of Arabic for the L2 learners was post-puberty, with a mean of around 17 years of age.

Materials

The masked priming task consisted of a total of 160 target items, half real words in Arabic, and half nonwords. Of the real word targets, 30 were critical items and 50 were fillers. Both critical items and fillers were adjectival forms. The nonwords were adjective-like, and did not violate the phonotactic rules of Arabic words. All filler and nonword targets were paired with one real word prime each (adjectives). Critical items were originally paired with prime words in five different conditions: (1) identity (identical to the target), (2) morphologically-related (differing from the target only in gender or in both gender and number – 15 items in each category), (3) orthographically-related (differing from the target in only one root letter), (4) semantically-related (related in meaning to the target), and (5) unrelated (not related in form or meaning to the target). However, it was discovered after completing data collection that this classification of primes did not take into account whether primes and targets shared word patterns. As mentioned above, priming in native speakers of Arabic can occur when primes and targets share not just roots, but also word patterns (e.g., Boudelaa & Marslen-Wilson 2005, 2015; Deutsch et al., 1998; Frost et al., 2000; Frost et al., 2005). All of the primes in the orthographically-related condition, as well as many in the semantically-related condition and some in the unrelated condition shared a word pattern with our targets, so we reclassified our primes into the following four conditions, some of which overlap with the original conditions: (1) identity (identical to the target), (2) morphologically-related-root (differing from the target only in gender or in both gender and number and sharing both a root and a word pattern with the target), (3) morphologically-related-pattern (differing from the target in only one root letter, but sharing a word pattern), and (4) unrelated (not sharing either a root or a word pattern with the target). Because many of the semantically-related primes shared a pattern with the target, we removed this condition entirely, and did not analyze semantic priming data. We also had to remove one item set (target and primes) from the gender category and two item sets from the gender and number category because there was no prime in these item sets that was not related to the target. This left us with 14 item sets in the gender category and 13 item sets in the gender and number category.

In the morphologically-related-root/gender category, target adjectives were masculine forms, and primes were feminine forms. In the morphologically-related-root/gender and number category, targets were also masculine forms, while primes were feminine plural forms. Within each category of morphological relatedness, the primes were matched across conditions on word form frequency and length in letters as much as possible, with Arabic word frequencies retrieved from the Aralex database (Boudelaa & Marslen-Wilson, 2010). Table 2 displays an example of one target and associated primes in each category of morphological relatedness.

Table 2

Example sets of targets and primes in each category of morphological relatedness.

	Target	Identity	Morph-Root	Morph-Pattern	Unrelated
Gender	واسع waasiʕ “spacious” (masc, sing)	واسع waasiʕ “spacious” (masc, sing)	واسعة waasiʕa “spacious” (fem, sing)	تاسع taasiʕ “ninth” (masc, sing)	لطيف latˤiif “nice” (masc, sing)

Gender & Number	نظيف naðˤiif "clean" (masc, sing)	نظيف naðˤiif "clean" (masc, sing)	نظيفات naðˤiifaat "clean" (fem, pl)	نحيف naħiif "thin" (masc, sing)	تعبان taʕbaan "tired" (masc, sing)

Counterbalanced experimental lists were created. Targets, fillers, and nonwords appeared only once per list. Fillers and nonwords appeared with the same prime in each list; targets were preceded by one of the possible primes in each list, so that each prime appeared with its target only once across the lists.

Procedure

Participants were tested individually. They first completed a questionnaire about their experience with languages, and rated their proficiency in Arabic and English. Then, the heritage speakers and L2 learners completed the Swadesh list vocabulary task, described above. Finally, all participants completed the masked priming, lexical decision task. Each trial in the masked priming task proceeded as follows: first, a mask consisting of a series of hash marks appeared in the center of the computer screen for 500 milliseconds (ms). Then, the mask disappeared and the prime appeared in the same location for 50 ms. Immediately following the prime, the target appeared on the screen until a timeout of 5 seconds, or until the participant made a lexical decision to it by pressing a *yes* or *no* button on the keyboard, whichever came first. Experimental items were preceded by ten practice items, and were presented in a different random order for each participant. The E-Prime software package was used to present the stimuli and to record response accuracy and response time (RT). Response times were recorded from the onset of the target.

Results

All responses to experimental items were included in accuracy analyses; however, none of these analyses indicated any priming effects in any condition or in any participant group, so accuracy results are omitted from this paper. Only correct responses to experimental items were included in RT analyses. Data points were also removed for RTs that were greater than 2500 ms (for the heritage speakers and L2 learners) or 1500 ms (for the native speakers), and for RTs that were less than 100 ms. Results are presented below by category of morphological relatedness, gender or both gender and number. Within each category, analyses were conducted in *R* (R Development Core Team, 2015) using mixed-effect linear models with the maximal random effect structure supported by the design (Barr, Levy, Scheepers, & Tily, 2013). The *lme4* library was used to run the mixed effect models (Bates, Maechler, Bolker, & Walker, 2015), with the native speaker group serving as the baseline for group comparisons, and the identity prime condition serving as the baseline for prime type comparisons. We used the *mixed* function from the *afex* library to obtain *p* values (Singmann, Bolker, & Westfall, 2015), and significant effects were further explored with pairwise comparisons conducted with the *pairs* function from the *lsmeans* library (Lenth, 2015).

Gender

The removal of incorrect responses for the RT analysis in this category affected 5.1% of the native speaker data, 18.0% of the heritage speaker data, and 42.5% of the L2 learner data. Removal of RTs that exceeded the upper limit or that fell below the lower limit affected an additional 6.8% of the native speaker data, 10.1% of the heritage speaker data, and 8.4% of the L2 learner data. Response times in milliseconds along with priming magnitudes are listed in Table 3. Priming magnitude was calculated by subtracting the RT in the condition in question from the RT in the unrelated condition.

Table 3

Response time and priming magnitude (in ms) by group and prime type – Gender items (standard deviations in parentheses). Facilitatory priming is marked with a "+" and inhibitory priming is marked with a "-".

		ID		Morph-Root		Morph-Pattern		Unrel	
NS	RT	790	(240)	813	(280)	897	(291)	921	(325)
	Prmg	+131		+108		+24			
HS	RT	1556	(509)	1407	(603)	1530	(633)	1732	(577)
	Prmg	+176		+325		+202			
L2	RT	1349	(555)	1493	(605)	1746	(600)	1621	(649)
	Prmg	+272		+128		-125			

The *F* and *p* values obtained for the mixed linear model for RTs are listed in Table 4. The analysis showed a significant effect of prime type, and a significant effect of group, with no interaction between the two. Pairwise comparisons of prime type with a Tukey adjustment for multiple comparisons revealed that targets preceded by identity primes were responded to significantly faster than targets preceded by morphologically-related-pattern primes (p=.05) and targets preceded by unrelated primes (p<.01). Targets preceded by morphologically-related-root primes were responded to significantly faster than targets preceded by unrelated primes (p<.01). There were no other differences in response times by prime type. This pattern of results indicates identity priming, and morphologically-related root priming, as targets preceded by both of these types of primes were responded to significantly faster than targets preceded by unrelated primes.

Similar comparisons of group showed that the native speaker group responded significantly faster overall than both the heritage speakers and the L2 learners (both p's<.001). The heritage speakers and the L2 learners did not differ from each other (p=.940)

Table 4

Summary of F and p values obtained for the mixed effects model for response times in the gender category.

Fixed Effect	*F*	Degrees of Freedom	*p*
Prime type	6.06	3, 357.82	.0005
Group	26.12	2, 44.69	<.0001
Prime type x group	1.72	6, 354.27	.12

Gender and Number

In the gender and number category, the removal of incorrect responses for the RT analysis affected 0.6% of the native speaker data, 10.4% of the heritage speaker data, and 14.9% of the L2 learner data. Removal of RTs that exceeded the upper limit or that fell below the lower limit affected an additional 4.3% of the native speaker data, 5.5% of the heritage speaker data, and 5.0% of the L2 learner data. Response times in milliseconds along with priming magnitudes are listed in Table 5. Priming magnitude was calculated in the same way as it was calculated for the gender category.

Table 5

Response time and priming magnitude (in ms) by group and prime type – Gender and number items (standard deviations in parentheses). Facilitatory priming is marked with a "+" and inhibitory priming is marked with a "-".

		ID		Morph-Root		Morph-Pattern		Unrel	
NS	RT	730	(259)	798	(263)	774	(256)	837	(272)
	Prmg	+107		+39		+63			
HS	RT	1239	(489)	1455	(542)	1246	(538)	1488	(608)
	Prmg	+249		+33		+242			
L2	RT	1462	(547)	1441	(481)	1494	(562)	1596	(543)
	Prmg	+134		+155		+102			

Table 6 lists the *F* and *p* values yielded by the mixed linear model for RTs in the gender and number category. As in the gender category, the analysis indicated an effect of prime type and an effect of group, with no interaction between the two. However, in this category, the pairwise comparisons of prime type showed that this effect was only due to responses to targets preceded by identity primes being marginally faster than responses to targets preceded by unrelated primes (p=.06), indicating identity priming only in this category of morphological relatedness. Pairwise comparisons of group showed the same pattern of results as for the gender items; native speakers responded to targets faster overall than both heritage speakers and L2 learners (both p's<.001). Heritage speakers and L2 learners did not differ from each other (p=.196).

Table 6

Summary of F and p values obtained for the mixed effects model for response times in the gender and number category.

Fixed Effect	*F*	Degrees of Freedom	*p*
Prime type	2.81	3, 40.52	.05
Group	23.12	2, 41.06	<.0001
Prime type x group	1.00	6, 51.65	.43

Discussion

The goal of this study was to investigate how native speakers, heritage speakers, and late L2 learners process regularly-inflected adjective forms in Arabic. Using a masked priming task, we examined morphological decomposition in these populations with two different types of agreement morphology. Specifically, we included prime-target pairs that were either identical to each other (the identity condition), pairs that shared a root and differed only on gender (masculine versus feminine), or on both gender and number (singular, masculine versus plural, feminine; the morphologically-related-root condition), pairs that differed by one root letter only while sharing a word pattern (the morphologically-related-pattern condition), along with prime-target pairs that were unrelated. To summarize the results, there were no priming effects in the accuracy data, which is often the case with masked priming experiments. In terms of response times, we found significant identity priming and morphologically-related-root priming, but no other type of priming for the gender category of morphological relatedness. In the gender and number category of morphological relatedness, we found significant identity priming only. There was no interaction between prime type and group in either category, suggesting no significant differences in how the three groups responded to targets based on prime type.

Returning to our research questions, first we asked whether these populations segment adjectives into their stems and affixes during visual word recognition as evidenced by priming in the morphologically-related-root condition, a condition in which primes and targets shared the same stem (root letters and word pattern), but differed only in their inflectional affixes. We predicted that native speakers would show morphological decomposition in their priming results, and hypothesized that heritage speakers and L2 learners might also decompose adjectives since Arabic is a morphologically-rich language, and since adjectives are morphologically simpler than verbs, which have been the main experimental focus in previous studies. However, we noted that decomposition in heritage and learner populations may depend on overall language proficiency, and that if it is true that late age of acquisition reduces the likelihood of morphological decomposition, then the late L2 learners may not show priming patterns consistent with decomposition.

Based on the overall pattern of results, it does seem that these three speaker groups do segment adjectives into their stems and agreement affixes, then accessing roots and word patterns (following our hypothesized model of morphological decomposition in Arabic presented in Figure 1); we found morphologically-related-root priming in the gender category of morphological relatedness. However, we did not find significant morphologically-related-root priming in the gender and number category of morphological relatedness, suggesting that decomposition of adjectives may not always occur. This leads us to our second research question, which asked whether type of agreement morphology affects the segmentation of adjectives into their stems and affixes; the answer seems to be that it does. While participants did seem to segment adjectives differing only on gender into their stems and affixes, they did not do so with adjectives that differed both on gender and on number. To give a concrete example using the example stimuli from Table 2, when participants saw واسعة (waasiʕa "spacious" - feminine) as a prime, and واسع (waasiʕ "spacious" – masculine) as a target, they stripped the feminine gender affix from the stem during the process of lexical access. However, when participants saw نظيفات (naðˤiifaat "clean" – feminine, plural) as a prime, and نظيف (naðˤiif "clean" – masculine, singular) as a target, they did not seem to strip the affix from the stem, as they failed to identify the stem in the two words as being the same. It is not clear why this would be the case. If this result had applied just to the L2 learner group, or both the L2 learners and heritage speakers, then it could have been that these groups are simply less familiar with plural forms of adjectives than with singular forms, and therefore were delayed in their affix-stripping procedures. Such a delay could then lead to reduced or no priming of the target, since there was not enough time to access the stem of the prime before the target was processed. However, this does not seem as though it should apply to native speakers. One other possible explanation that might be applied to all three groups could be that there was a delay in affix stripping because of a difference in not just one, but two inflectional features across the prime and target. In most studies that use masked priming to investigate morphological decomposition, either the prime or the target is often a root or stem form that is paired with either a prime or target inflected form, so that prime and target differ only on one inflectional feature (for example, present versus past tense), not two as in the current case (both gender and number). It may be that it takes longer to process affixes that represent two inflectional features than it does affixes that represent just one, which could lead to a delay in prime stem access. If this is true, then a study with a longer stimulus onset asynchrony (SOA: time between the presentation of the prime and target) should be more likely to show priming when primes and targets differ on more than one inflectional feature. One other thing to note with respect to the morphologically-related-root condition is that, numerically, the L2 learners' response times actually suggest priming in this condition, not just in the gender category, but also in the gender and number category, with similar priming magnitudes in the identity and the morphologically-related-root conditions (134 ms – identity, 155 ms – root). In line with the affix-stripping delay explanation of a lack of priming in the native speakers, it is possible that the L2 learners did show priming even when having to process affixes representing two inflectional features because they had sufficient time to process them. Their response times were approximately twice those of native speakers (for example, 1462 ms in the identity condition in comparison to only 730 ms in the same condition for natives). They were also slower to respond than heritage speakers for the most part, but not to the same extent (heritage speakers' RTs in the identity condition were 1239 ms). Again, experiments with longer SOAs are needed to determine whether this explanation of the lack of priming in the gender and number category is valid.

Another finding of note in this study is that when primes and targets did not share all three root letters, but did share the same word pattern and inflectional affixes, there was no statistically significant priming. As mentioned above, in addition to shared root priming, some studies indicate that native speakers of Arabic show priming when only word patterns are shared across prime and target (e.g., Boudelaa & Marslen-Wilson, 2005). However, to our knowledge, there are no studies that have examined priming in adjectives. The occurrence of word pattern priming in Semitic languages can vary based on word class (Deutsch et al., 1998), so the finding that word pattern priming did not occur in this study does not contradict previous research. It does, however, suggest that the priming that occurred in the morphologically-related-root condition cannot be attributed to orthographic similarity alone. Even though the primes and targets in the morphologically-related-pattern condition differed in just one root letter and nothing else, participants did not respond significantly faster to targets preceded by these primes than they did to targets preceded by primes that were completely unrelated in form. When we look at the numerical data, however, we see that heritage speakers did seem to show priming in the morphologically-related-pattern condition across both categories of morphological relatedness, with similar priming magnitudes as in the identity condition (gender category: 176 ms – identity, 202 ms – pattern; gender and number: 249 ms – identity, 242 ms – pattern). This suggests either that these speakers were sensitive to shared word patterns as some previous research shows for native speakers, or that they were more influenced by similarities in orthographic form than the natives and the late L2 learners. The latter explanation is consistent with what Jacob and Kirkici (2016) found for heritage speakers of Turkish: in contrast to both native speakers and L2 learners of Turkish, heritage speakers showed priming with primes and targets whose only relationship was orthographic in nature. Jacob and Kirkici attribute this to a heavier reliance by this type of speakers on surface form properties of words during the earlier stages of lexical processing, possibly due to differences in the way heritage speakers acquire the written form of the language – specifically, while they acquire the written form of the dominant language in school, they are not ever explicitly taught the orthography-phonology mapping of their heritage language (p. 324). This reliance on orthography in visual word recognition also seems to hold true for the present study.

Conclusion and Implications

In conclusion, in this study we used a masked priming task to investigate the morphological decomposition of adjectival forms in Arabic in three populations: native speakers, heritage speakers, and late L2 learners. We asked whether all three populations would show priming patterns consistent with morphological decomposition, and whether this would be the case across three different types of agreement morphology and morphological relationships. Our findings indicate that all three of these populations do segment adjectives in Arabic into their stems and agreement affixes and then access their roots, although segmentation may differ based on type of morphological relationship between targets and primes. This assumption of affix stripping with subsequent root access is based on the hypothesized model of morphological decomposition presented in Figure 1. Further research will be needed to determine whether affix stripping and root access occur as two separate processes or whether they are part of one process of decomposition, as the design of the present study does not allow us to get at this issue. However, regardless of the nature of these processes, the finding of decomposition in all three populations contradicts hypotheses that claim that late learners of a language do not have as detailed a representation of morphologically-complex words as native speakers do. It also suggests that, in spite of reduced input, heritage speakers are also sensitive to morphology, although they may also rely more heavily on orthography during lexical processing than native speakers and L2 learners.

In terms of implications for the teaching of Arabic as an L2 and a heritage language, this study illustrates the importance of developing students' morphological awareness and drawing their attention to various morphological aspects that are Arabic-specific, especially when tackling such a morphologically rich language. From a teaching standpoint, this targeted effort is necessary in order to show students how words change meaning with various suffixation processes. Moreover, students need to learn how new words are formed from the very early stages when Arabic is first introduced, as this will ultimately help them to expand their vocabulary. Oftentimes, learners of Arabic lack a clear understanding of what prefixes and suffixes are and what they do to English words, so making sure to clarify these aspects early on will facilitate the comprehension and application of these concepts to Arabic. Skilled language teachers should present those concepts in various contexts so students become familiar with them, and are able to easily recognize them with time. They also need to drill their students to apply this knowledge early on. Therefore, teachers should exert exceptional efforts to use effective instructional strategies at the very early stages right when vocabulary is introduced. An interesting avenue for further research is the examination of how this type of pedagogical emphasis may increase learner sensitivity to morphology during language processing, both for L2 and heritage learners.

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