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Sensitivity to Inflectional Morphology in a Non-native Language: Evidence From ERPs

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The extent to which non-native speakers are sensitive to morphological structure during language processing remains a matter of debate. The present study used a masked-priming lexical decision task with simultaneous electroencephalographic (EEG) recording to investigate whether native and non-native speakers of French yield similar or different behavioral and brain-level responses to inflected verbs. The results from reaction time and EEG analyses indicate that both native and non-native French speakers were indeed sensitive to morphological structure, and that this sensitivity cannot be explained simply by the presence of orthographic or semantic overlap between prime and target. Moreover, sensitivity to morphological structure in non-native speakers was not influenced by proficiency (as reflected by the N400); lower-level learners show similar sensitivity at the word level as very advanced learners. These results demonstrate that native-like processing of inflectional morphology is possible in adult learners, even at lower levels of proficiency, which runs counter to proposals suggesting that native-like processing of inflection is beyond non-native speakers' reach.

Keywords: morphological priming, inflectional morphology, ERPs, second language, French

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The question of whether or not adult learners of a second language can decompose inflected words (e.g., *walked*) into morphological constituents (*walk+-ed*) and access morphological-level representations in the lexicon has received much attention in recent years. Some researchers propose that, like native speakers, second language (L2) learners are indeed sensitive to the morphological structure of inflected forms, and process complex forms via their morphological constituents (e.g., Basnight-Brown et al., 2007; Feldman et al., 2010; Coughlin and Tremblay, 2015), although it has been suggested that this may only be possible at high levels of proficiency (e.g., Ullman, 2005; Bowden et al., 2010; Babcock et al., 2012). By contrast, other researchers have proposed that adult L2 learners are insensitive to inflectional morphological structure due to a deficient grammar, and this deficiency is not predicted to improve with increased proficiency (e.g., Silva and Clahsen, 2008; Neubauer and Clahsen, 2009; Clahsen et al., 2010; Jacob et al., 2013, 2018). While some studies have found evidence of non-native speakers decomposing derived words (e.g., Silva and Clahsen, 2008; Jacob et al., 2018), many studies fail to find evidence for inflectional morphology decomposition. Given mixed results from recent studies, our current understanding of how non-native speakers process morphologically complex words remains unclear. The present study used a masked-priming lexical decision task during EEG recording to investigate how native and non-native French speakers process verbal inflection morphology. The combined use of masked priming and EEG allows one to test not only whether learners are able to show native-like sensitivity to inflectional morphology in their behavioral responses, but also whether their brain responses are indeed qualitatively similar to those of native speakers.

MORPHOLOGICAL PROCESSING IN BEHAVIORAL AND EEG STUDIES

An increasing body of electrophysiological evidence suggests that native speakers are sensitive to morphological relatedness between inflected words and their morphological stem (e.g., Stockall and Marantz, 2006; Royle et al., 2012). This evidence often comes from priming tasks, in which the presentation of an inflected word like "walked" facilitates the recognition of the stem word "walk." Many priming studies have compared lexical decision latencies in morphologically related prime-target pairs (e.g., walked-WALK) to unrelated pairs (e.g., called-WALK) and found facilitation from word pairs that overlap in morphology, but not in orthography (e.g., sincere-SIN). Such results are often explained by a decomposition mechanism that segments inflected forms into stem and affix prior to lexical access. The prior access to the stem target then allows for faster lexical decision times on the target relative to prime-target pairs that do not share morphology (e.g., Münte et al., 1999; Stockall and Marantz, 2006).

Priming studies have demonstrated facilitation from morphologically related primes, but it is important to consider how well such tasks are able to determine if the priming effect is indeed morphological in nature, or if instead it may be the result of form and meaning overlap between prime and target. Morphologically related words are usually also related orthographically and semantically to their stems, so it is critical to tease apart morphological from form and meaning priming. One such method that has been shown to do so is masked priming. In the masked-priming paradigm (Forster and Davis, 1984), the prime word is presented very briefly (e.g., 30-60 ms) with a preceding (*backward*) or following (*forward*) mask (e.g., ########) with the aim of preventing the participants from consciously perceiving a presented prime. Whereas unmasked priming methods (where the participants are aware of the prime word) often find robust influence of semantic relationships between primes and target words (e.g., Marslen-Wilson et al., 1994; Rastle et al., 2000), semantically-driven priming effects are typically absent in masked priming with short presentation times (e.g., Rastle et al., 2000, 2004; Longtin and Meunier, 2005; see also references in Royle et al., 2012), suggesting that very brief prime exposure is not sufficient for semantic information to be accessed before target recognition takes place (cf. Diependaele et al., 2005; Morris et al., 2007; Feldman et al., 2009).

The potential for the absence (or delay) of semantic priming makes the masked priming method an ideal tool for testing morphological processing by allowing for morphological effects to be separated from those caused by form or meaning overlap between the prime and target. That is, if morphological priming effects are distinct from semantics, then they should be detected even when semantic information is suppressed by the task. If morphological priming effects are instead the result of convergence of form and meaning (Devlin et al., 2004), suppressing semantic priming should also suppress morphological priming or reduce it to the level of orthographic priming effects. The present study's aim is to assess native and non-native sensitivity to morphological structure by examining masked morphological priming effects. In what follows, we will focus on research that uses this method.

Masked-priming tasks with native populations have repeatedly reported evidence of morphological priming that is distinct from orthographic or semantic priming. Rastle et al. (2000) investigated the processing of derivational morphological structure with varied prime presentation durations in a lexical decision task with three different stimulus onset asynchronies (SOA) (230, 72, and 43 ms) to test the effect of morphological, orthographic, and semantic prime-target overlap. When the prime was consciously visible to the participants (i.e., presented on the screen long enough such that participants were aware of its presence), semantic relatedness between prime and target facilitated target recognition in the presence of orthographic and morphological overlap (departure-DEPART), with semantic and orthographic overlap in the absence of morphological overlap (screech-SCREAM), and semantic overlap in the absence of orthographic overlap (cello-VIOLIN). However, when the prime was masked, semantic overlap in the absence of morphological overlap no longer allowed for faster target recognition compared to an unrelated baseline condition. Additionally, at no prime presentation duration did the presence of orthographic overlap alone elicit faster lexical decisions compared to an unrelated condition (e.g., "electrode" never primes "elect"). These findings demonstrate that when a prime is presented very briefly, morphological priming can be distinguished from semantic and orthographic priming.

While many previous masked priming studies, including Rastle et al. (2000) have used derived morphologically complex words in their tasks, a number of studies have used inflected words and found similar morphological priming effects. Fruchter et al. (2013) investigated the priming effect of regular (e.g., jumped-JUMP) and irregular (e.g., fell-FALL) inflected English verbs. Compared to unrelated primes, both the regularly and irregularly inflected primes elicited faster lexical decision times, indicating that morphological priming can be found even when morphological structure is less transparent in the orthography. Similar results were found in an unmasked priming task in Stockall and Marantz (2006) where irregular primes (e.g., gave-GIVE) elicited equal facilitation as identity primes (e.g., boil-BOIL), but no facilitation was found in orthographically related primes (e.g., curt-CART), nor in primes that overlapped semantically and orthographically, but without morphological overlap (broil-BOIL).

The masked priming method has been used in previous EEG studies for native speakers (L1), but has not (to our knowledge) been applied to an adult second-language (L2) learner population to investigate non-native morphological processing. Incorporating EEG data enables us to study the time-course of lexical processing, providing insight into its dynamics (e.g., Grainger and Holcomb, 2009). Many previous EEG masked-priming studies on native morphological processing have revealed two EEG components that reflect an earlier orthographic (the N250) and a later morphological processing stage (the N400).

The N250 is a negative-going deflection in the waveform that peaks around 250 ms after stimulus presentation. This EEG component is sensitive to the form overlap between prime and target word such that the negativity amplitude is attenuated when the word pairs have maximal overlap in form (e.g., Morris et al., 2008; Royle et al., 2012). The attenuation has been found to be greatest when the prime and target are identical (e.g., *table-TABLE*), but significant attenuation is also found with non-identical form overlap (e.g., *table-TABLE*, Holcomb and Grainger, 2006). The N400 is also a negative-going deflection in the waveform, and peaks around 400 ms after stimulus presentation. Unlike the N250, the N400 has been shown in many priming studies to be modulated by a range of lexical properties, including morphological relatedness. In priming tasks, the N400 amplitude is greatest when prime and target pairs have no morphological overlap (e.g., *mouth-TABLE*), and is attenuated when word pairs overlap morphologically (e.g., *walked-WALK* and *walk-WALK*) (e.g., Holcomb and Grainger, 2006; Kiyonaga et al., 2007). Given that morphologically related words (like *walked-WALK*) are not only morphologically related but also semantically and orthographically related, many priming studies include separate conditions to assess effects of semantic relatedness (e.g., by having semantically but not morphologically related prime-target pairs such as *violin-cello*) and those assessing orthographic relatedness with pseudo-morphological structure (e.g., *brothel-broth*). A number of priming studies in the native literature have demonstrated masked morphological priming effects for morphologically-related words that cannot be due to semantic or orthographic overlap (e.g., Royle et al., 2012). For further review of these EEG component modulations by priming, the reader is directed to Grainger and Holcomb (2009). These two EEG components are of interest in the present study, which aims to compare L1 and L2 processing of morphologically related prime-target pairs.

MORPHOLOGICAL PROCESSING IN ADULT SECOND-LANGUAGE LEARNERS

Pertaining specifically to non-native populations, Clahsen and colleagues have conducted numerous masked-priming lexical-decision tasks aiming to test whether adult second-language speakers are sensitive to the morphological structure of complex words (for review, see Clahsen et al., 2010). These studies have investigated L2 sensitivity to inflectional as well as derivational morphology. While some studies do suggest that learners may have some (though diminished relative to native speakers) sensitivity to morphological structure in derived complex words (e.g., *boldness*), they consistently find that L2 learners are insensitive to morphological structure in inflected words (e.g., *boiled*) (see Clahsen et al., 2010 and Clahsen and Veríssimo, 2016 for reviews).

Silva and Clahsen (2008), for example, tested three L2 groups of advanced adult learners of English (with German, Mandarin, and Japanese first languages). This study included a number of masked priming experiments where prime-target pairs were either identical in form (e.g., *bold-BOLD*, *boil-BOIL*), morphologically related (e.g., *boldness-BOLD*, *boiled-BOIL*), or completely unrelated (e.g., *rough-BOLD*, *jump-BOIL*). In all tasks, both the native and the non-native groups showed significantly faster lexical decision times when the prime-target pairs were identical (relative to when they were unrelated), but the groups behaved quite differently in the morphologically related items. When the prime-target pairs were morphologically related through derivation (e.g., *boldness-BOLD, acidity-ACID*), native English speakers showed equal priming as compared to the identity condition, indicating that the native English speakers were sensitive to the morphological structure of the derived form. The non-native speakers, however, showed significant priming relative to the unrelated condition, but the derivational priming was not as strong as the identity priming, which was interpreted as a consequence of the non-native speakers having a less effective parser. More remarkable was the difference between native and non-native speakers when prime-target pairs were morphologically related through inflection (e.g., *boiled-BOIL*). The native English speakers again showed equally strong priming between inflected and identity items, but the non-native speakers showed no facilitation compared to the unrelated condition in this condition. That is, there was no difference in lexical decision times for items such as *boiled-BOIL* compared to *jump-BOIL*. The authors posit that this insensitivity to inflection is the consequence of a grammar deficient in its instantiation of inflection. The lack of difference between Japanese, German and Mandarin participants suggests that adult L2 learners are insensitive to inflectional morphology independent of the presence of inflection in their native language. Finally, because the L2 participants in Silva and Clahsen were all advanced learners of the language, results were interpreted by the researchers to suggest that lack of sensitivity to morphological structure is not something that will change with proficiency; insensitivity to inflection is believed to be a permanent state of the L2 grammar.

There have been a number of similar studies using masked-priming tasks to test whether non-native speakers are sensitive to inflectional morphology, using a range of language pairings. Results similar to those of Silva and Clahsen (2008) have been found in Polish learners of German (Neubauer and Clahsen, 2009), and L2 learners of Turkish from a range of L1 backgrounds (Kirkici and Clahsen, 2013). Collectively, these studies by Clahsen and colleagues suggest that, independent of language pairing, adult learners of a second language have a grammar deficient in inflectional structure, and these learners must rely heavily on whole-word storage of complex inflected forms (see Clahsen et al., 2010 for review).

However, not all masked priming studies have given support to the claim that L2 learners are insensitive to inflectional structure. Of particular importance and relevance to the present study, Foote (2015) used a masked-priming lexical-decision task to test if native and intermediate- and advanced-level non-native speakers of Spanish would show evidence of morphological processing in regularly inflected Spanish verbs, where prime-target pairs differed in mood (e.g., *cante-CANTA*, "s/he sings"$_{SUBJ}$ –"s/he sings"$_{PRES-INDIC}$). In addition to including the experimental conditions found in Silva and Clahsen (2008) (identity, morphologically related, unrelated), Foote (2015) also included orthographically related (e.g., *cansa—CANTA*, "s/he tires"—"s/he sings") and semantically related conditions (e.g., *baila—CANTA*, "s/he dances"—"s/he sings"). These additional conditions allowed for any morphological priming to be compared to purely orthographic and purely semantic priming. In both native and non-native speakers, identity items and morphologically-related items elicited significantly faster lexical decision times relative to unrelated items, with no difference between identity and morphological items. Importantly, morphological priming could not be attributed to overlap of form or meaning because neither the orthographically related nor the semantically related items revealed any facilitation, compared to the unrelated items. This suggests that both groups showed evidence of decomposing inflected forms into stem and affix, and accessed a morphological level of representation in the lexicon. Interestingly, proficiency (intermediate vs. advanced levels) did not modulate this ability to process morphological structure in a native-like way.

As the review of the L2 masked-priming literature above demonstrates, it remains a matter of debate whether adult L2 learners are able to process inflected words via morphological decomposition. Moreover, despite the number of existing L2 masked-priming studies, not all of them include the types of comparison conditions (e.g., for form or semantic priming) that Foote (2015) included, existing studies have typically relied on relatively small stimulus sets and have generally not utilized statistical approaches that can best capture potential sources of variability (e.g., by modeling proficiency as a continuous variable); see Clahsen and Veríssimo (2016) and Veríssimo et al. (2016) for discussion of similar methodological concerns. Finally, to our knowledge, the existing L2 masked-priming literature has, to date, solely utilized behavioral measures (e.g., response time and accuracy). While behavioral responses provide a critically important source of evidence regarding whether or not L2 learners are sensitive to morphological structure in inflected words, recording brain activity using EEG during the masked-priming task allows one to test not only whether L2 learners show sensitivity, but also to what extent they rely on the underlying neurocognitive mechanisms used for native morphological processing, and to what extent their lexical processing speed is similar to that of native speakers.

PRESENT STUDY

To address the above-mentioned concerns, the present study uses a masked-priming lexical decision task during EEG recording to investigate if native and non-native speakers of French are able to show behavioral- and brain-level evidence of inflected French verb processing via morphological constituents. The morphologically-complex words in the present study carry the first-person plural inflection *-ons*, which is phonologically realized as [ɔ]. This inflection is orthographically and phonologically distinct from other inflections in the regular verb paradigm, unlike other present-indicative inflections that overlap orthographically or phonologically with other forms. One important feature of *-ons* is that that when a verb stem carries this inflection, the surface frequency of that word-form is very low[1]. This is a critical feature of the stimuli in a study aiming to test for morphological processing because some researchers have hypothesized that inflected forms of high-enough surface frequency will not be processed via an otherwise available decomposition mechanism, but will instead be processed in their whole form (e.g., Alegre and Gordon, 1999). Given that this study aims to test whether L2 learners can or cannot decompose inflected words in a native-like way, choosing stimuli where the surface frequency of morphologically complex words is kept low makes it highly unlikely that any participant (native or non-native) would be storing a whole-form of the stimuli when they may in fact have decomposition mechanisms available to them.

MATERIALS

The test items in this experiment were created in four conditions: identity, morphologically related, orthographically related, and semantically related, and their unrelated controls. Each condition had 36 different target words, each paired with two primes: an unrelated prime and a related prime (see **Table 1** below for sample stimuli). Each condition had its own unique target words. The target words were the 1st/3rd person singular form of regular *–er* verbs[2]. All primes other than the related identity prime carried the *–ons* inflection. The orthographically related primes were created with French verbs that overlapped in all but the stem-final letter. Semantically related primes were synonyms of the target, as rated as four or above on a scale of one (completely unrelated) to six (perfect synonym) by two native French speakers who did not participate in the study. There were a total of 144 target words, each seen twice throughout the experiment (once with an unrelated prime, once with a related prime). Each target type (identical, morphological, orthographic, semantic) had 36 targets, which were not repeated across conditions. There was an additional 144 nonce target items in lists. Test items and nonce items are provided in the **Datasheet 6**. The computer program Mix (van Casteren and Davis, 2006) was used to create pseudo-randomized stimulus lists for each participant in which there where at least 100 trials between the two presentations of a given target word. The primes and targets appeared in different letter case within a given trial to minimize purely visual priming effects (i.e., lower case prime with uppercase target, or vice versa) (e.g., Chauncey et al., 2008; Royle et al., 2012).

Target items were controlled across conditions for letter length [$F_{(3,140)} < 1, p > 0.62$] and frequency (in written-word lexeme frequency per million), from the Lexique database [(New et al.,

[1]Note that in spoken French, the 1st-person plural form is very often replaced by the 3rd-person singular (e.g., on mange for 'we are eating'), so spoken frequency of verbs carrying –ons is even lower than the written frequency reported below.

[2]The true verb stem of regular default *–er* verbs (e.g., parl /paʁl/ for 'to speak') is not a word, and thus not suitable for a lexical decision task. The 1st/3rd person homographic/homophonous singular form (e.g., parle /paʁl/) is used as the target instead. Similar decisions were made for French in Royle et al. (2012) and for Spanish in Foote (2015).

TABLE 1 | Stimuli with Mean (SD) Letter Length (top row) and Frequency (bottom row).

Condition	Target		Related prime		Unrelated prime	
Morph	*PENSE*	5.25 (1.02)	*pensons*	7.25 (1.02)	*brûlons*	7.25 (1.02)
	"think"	22.48 (31.63)	"think"	0.86 (1.66)	"burn"	0.28 (0.57)
Orth	*BOUGE*	5.03 (0.75)	*boudons*	7.11 (0.89)	*tissons*	7.14 (0.87)
	"move"	27.44 (51.26)	"avoid"	0.59 (2.69)	"weave"	0.36 (0.60)
Sem	*HURLE*	5.46 (0.89)	*crions*	7.31 (1.01)	*bayons*	7.33 (0.96)
	"yell"	33.44 (44.52)	"scream"	0.91 (2.14)	"open wide"	0.48 (1.57)
ID	*DANSE*	5.25 (1.11)	*danse*	5.25 (1.11)	*prônons*	7.25 (1.11)
	"dance"	23.98 (37.37)	"dance"	23.98 (37.37)	"advocate"	0.65 (0.97)

2004), $F_{(3, 140)} < 1, p > 0.69$]. Primes were controlled within and across conditions for length [$F_{(2, 105)} < 1, p > 0.68$] and frequency [$F_{(2, 105)} < 1, p = 0.8$]. A summary of the stimulus properties is provided in **Table 1**.

Each of the 144 nonce targets was paired with two real-word prime words that were inflected with *–ons*. Using real-word primes ensures that the lexical status of the prime does not predict the lexical status of the target. The nonce targets were orthographically and phonologically possible French words that did not differ in letter length compared to the real-word targets. The nonce targets were also created to resemble the 1st/3rd person singular form of a regular *–er* verb (i.e., they all ended with *–e*). This design ensures that the only way to distinguish real targets from nonce targets was lexical knowledge.

PROCEDURES

The study was carried out in accordance with the Faculty of Medicine Institutional Review Board at the McGill University. The protocol was approved by the Institutional Review board. All participants gave written informed consent to participate in the study. Testing took place at the Neurocognition of Language Lab, McGill University in Montreal Quebec, Canada. Participants were fitted with an elastic cap with embedded electrodes and seated in front of a computer monitor in a quiet room. They read instructions in French informing them that they would be seeing a string of letters on a computer screen and were to decide if they were real words in French or not. They indicated their decision using a computer mouse, clicking the left button to indicate "word" and the right button to indicate "non-word." All participants were given the opportunity to ask questions about the task in their preferred language (French or English).

Figure 1 shows the sequence of events on the screen for a given trial. Participants were instructed to blink when they saw (–) on the screen, and to do their best to not blink at other times during a trial. Participants were told to make their lexical decision for each target word, but were not given explicit instructions to respond as quickly as possible, though they were encouraged to do their best to keep up with the pace of the experiment if they asked about response speed. The experiment was divided into 4 blocks, each lasting about 9 min, with a break provided between blocks. Most participants finished the entire experiment in about 45 min.

In addition to the lexical decision task, all participants filled out the Edinburgh handedness questionnaire (Oldfield, 1971) and a short language background questionnaire where they provided background information such as age, languages they spoke, when and how they learned their languages, self-rated proficiency, and percent weekly use of each language. The French learners were also asked how long they had been living in Montreal at the time of testing, and the number of months they had spent in other French-speaking environments. Both the handedness and background questionnaire were provided in the native language (French or English) of the participant.

The French learners also completed a short proficiency test adapted to French from LexTALE (Lemhöfer and Broersma, 2012) to evaluate their level of French. This proficiency test is a short, but very difficult self-paced lexical decision task including 80 real words that vary in syntactic category and word frequency. In addition to the real words, there were 40 pseudowords that were orthographically and phonologically possible French words, which mimicked the orthographic appearance of various morphological structures (e.g., **mouer* which resembles an infinitive verb). Scores are calculated by averaging together the accuracy rate for correctly identifying real words, and the accuracy rate for correctly rejecting nonce words. The maximum score on the LexTALE test is 1.0, and the minimum is 0. Scores from the French LexTALE task have been found to be correlated with scores on a French cloze test (Tremblay, 2011).

Participants

The L1 group consisted of 29 right-handed native French speakers (28 females) who grew up either in Québec, Canada ($n = 27$) or France ($n = 2$). All participants grew up in households where French was the only spoken language and all were currently enrolled as undergraduate or graduate students in a French-speaking university in Montreal. All participants spoke at least some English, with English proficiency self-ratings ranging from beginner to near-native[3]. Some participants spoke additional non-native languages. **Table 2** below provides a summary of the native French speakers' background information, including age, percent weekly usage of French, and percent weekly usage of English.

[3]English self-rating was coded numerically (beginner = 1, intermediate = 2, advanced = 3, near-native = 4), and was included in statistical models to check if it modulated any priming effects. There was no influence of English proficiency on priming in behavioral or EEG data for the native French speakers.

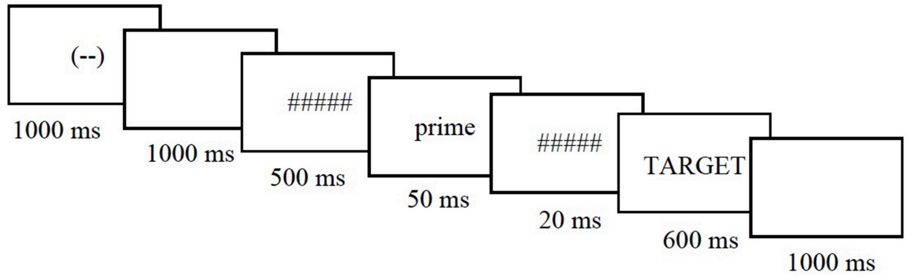

FIGURE 1 | Trial structure.

TABLE 2 | Native French speakers.

	Age	% French	% English
Mean	22.3	82.8	12.2
St. Dev.	4.7	20.3	14.6
Range	19–41	30–100	0–60

TABLE 3 | Non-native French speakers.

	Age	AoE	Yrs Inst	%French	Yrs Montreal	LexTALE
Mean	22.6	13.7	5.6	13.1	3.1	0.63
St. Dev	5.4	3.7	3.2	10.4	2.6	0.08
Range	18–42	10–26	1–14	1–30	0.25–10	0.49–0.8

The L2 group consisted of 24 native English speakers who learned French as a second language (13 females). The L2 French speakers grew up in the United States ($n = 9$) or an English-speaking Canadian province ($n = 15$) in households where English was the only spoken language. None of the French learners began learning French before age 10. Many of the participants were currently enrolled as undergraduate or graduate students at English-speaking universities in Montreal, and other participants were working professionals living in Montreal ($n = 4$). A summary of the L2 French group is provided in **Table 3** showing age, age of first exposure to French (AoE), years of French classroom instruction (YrsInst), weekly use of French, years spent living in Montreal, and LexTale scores. The proficiency scores for the group can be described as ranging from low-level to very high level.

Given previous EEG studies (on native speakers), it is predicted that the native French speakers will show significant N400 attenuation when the prime is morphologically related only (identity and morphological conditions). While to our knowledge there is no relevant EEG data on this topic on adult L2 learners, previous behavioral studies (e.g., Foote, 2015) lead us to predict that non-native speakers will show similar attenuation to the N400, and this effect will possibly not be modulated by proficiency (as was the case in Foote, 2015). It is also predicted that, in line with previous native literature, native French speakers will show an attenuation of the N250 when primes overlap in orthography with the target (identity, morphological, and orthographic conditions). As it is difficult to generate predictions on the early stages of orthographic processing in non-native speakers based on the existing behavioral data, we make no prediction as to what will happen to the N250 in the non-native speakers. If they are able to process words in similar ways as native speakers, we would expect attenuation of the N250. However, if they have processing routines that differ from native speakers in the early stages of lexical access, there may be no N250 attenuation.

EEG Recording

The EEG signal was recorded continuously at 512 Hz with an online band-pass filter of 0.05–100 Hz. Participants wore a 64 channel WaveGuard EEG Cap (eemagine Medical Imaging Solutions, Germany) with embedded Ag/AgCl scalp and mastoid electrodes with noise-shielded cables. Twenty-three of the 64 electrodes embedded in the cap were used for recording: Fp1/2, Fpz, F7/8, F3/4, Fz, T3/4, C3/4, Cz, T5/6, P3/4, Pz, O1/2, Oz, A1/2 (mastoids). This is a typical electrode montage used in many EEG studies that is based on the standard 10–20 system (Jasper, 1958). All other electrodes in the cap were deactivated during recording. Impedance for all electrodes was kept below 5 KΩ. The EEG signal was amplified with an ANT amplifier (ANT-Neuro), referenced online to the left mastoid.

All offline EEG signal processing was carried out using the EEProbe analysis software (ANT; Enschede, Netherlands). After recording, the EEG signal was re-referenced offline to the average of both mastoid electrodes (A1 and A2). The data were then filtered with a band-pass filter of 0.3–30 Hz Eye-blinks and other artifacts were rejected using a 30 μV standard deviation criterion with a 200 ms moving-window method. This resulted in removing 6.8% of the native French speaker data and 11.2% of the non-native French data. The data were analyzed in epochs from −470 to 700 ms relative to the onset of the target word. The baseline correction applied to the EEG signal was −470 to −270 ms, the point in each trial where the initial mask is still on the screen when the two conditions that would be compared (i.e., related vs. unrelated primes) did not differ (for discussion, see Steinhauer and Drury, 2012). Finally, waveforms were averaged within conditions for each participant.

TABLE 4 | Lexical decision accuracy (SD) by condition and relatedness (percent).

Condition	L1 French related	L1 French unrelated	L2 French related	L2 French unrelated
Identity	95 (22)	94 (24)	86 (35)	83 (38)
Morphological	96 (20)	95 (22)	87 (33)	83 (37)
Orthographic	91 (29)	90 (30)	80 (40)	80 (40)
Semantic	96 (20)	96 (21)	84 (36)	83 (38)

TABLE 5 | Mean reaction times (SD) and priming effects (ms).

Condition	Relatedness	L1 French	Priming (L1)	L2 French	Priming (L2)
Identity	Related	652 (193)	23	636 (186)	47
	Unrelated	675 (171)		683 (190)	
Morphology	Related	656 (191)	24	642 (185)	35
	Unrelated	680 (169)		677 (185)	
Orthographic	Related	675 (181)	6	659 (193)	17
	Unrelated	681 (180)		676 (191)	
Semantic	Related	669 (171)	5	669 (178)	−2
	Unrelated	674 (169)		667 (178)	

RESULTS

Accuracy and Reaction Time Data

Accuracy results are reported by condition for each group in **Table 4** (data are available in **Datasheet 3**).

Accuracy data were analyzed using a mixed-effects logistic regression model in R (*lme4* package, Bates et al., 2015). The model included condition (identity, morphological, orthographic, semantic), prime relatedness (related, unrelated), language group (L1, L2), and the interaction of condition × prime relatedness as fixed effects. Item and subject were included as random intercepts[4].

Categorical variables were dummy coded, which requires that one level of a given categorical variable is treated as the reference level to which other levels are compared. The reference levels in the accuracy model were Identity for the condition variable, Unrelated for the relatedness variable, and L1 French for the group variable. These reference levels are used consistently throughout all analyses. The results reveal a simple effect of relatedness (estimate = 0.327, SE = 0.126, $z = 2.593$, $p < 0.01$), indicating that targets preceded by a related prime have higher accuracy than targets preceded by unrelated primes. There was an effect of group (estimate = −1.337, SE = 0.282, $z = -4.743$, $p < 0.001$), indicating that the non-native group had lower accuracy than the native group. There was also a marginal interaction of condition×relatedness for the orthographic items (estimate = −0.333, SE = 0.172, $z = -1.944$, $p = 0.052$) suggesting that for orthographic items, prime relatedness is not a significant predictor of accuracy. This was confirmed in a follow-up model on orthographic items only.

To analyze the reaction time data, items with incorrect responses were removed from the dataset. This resulted in a loss of 5.8% of the native speaker data and 16% of the non-native data. Reaction times shorter than 300 ms or longer than 3,000 ms were removed. Reaction times were then converted to z-scores for each participant, and reaction times 2.5 standard deviations or above a participant's mean were removed from the dataset. This resulted in an additional loss of 3% of the L1 speakers' data, and an additional loss of 3.3% of the L2 speakers' data. **Table 5** below shows the mean reaction times (in ms) for the related and unrelated items in each condition. The priming effect (unrelated minus related) is also given for each condition. Positive priming values indicate facilitation of target recognition for the related primes relative to the unrelated primes.

[4]A larger model with a three-way interaction of condition × relatedness × group did not converge, but models run separately for each group reveal similar effects.

Analyses for the reaction time data were run as linear mixed-effects models, using the *lmer* function in the *lme4* R package (Bates et al., 2015). The R package *lmerTest* (Kuznetsova et al., 2017) was used to obtain p-values for the models, and the R package *LMERConvenienceFunctions* (Tremblay and Ransijn, 2015) was used for backwards stepwise model selection. The dependent variable in the models was the log-transformed reaction times. Model fitting began with fixed effects for condition, relatedness, and group, as well as all two-way and three-way interaction terms, and log-transformed target frequency as fixed effects. Subject and item were included as random intercepts, and relatedness was included as a random slope on the subject random intercept. The *bfFixefLMER_F* function was used to remove terms one at a time and compare simpler models to more complex ones using the Akaike Information Criterion (AIC)[5]. This allowed for the simplest model that best fit the data to be automatically selected. The final model included condition, relatedness, group, and log-transformed target frequency, as well as the interaction of condition × relatedness, as fixed effects. Subject and item were included as random intercepts with relatedness as a random slope.

Results reveal a significant effect of relatedness (estimate = −0.057, SE = 0.007, $t = -7.94$, $p < 0.001$), indicating that, in the identity condition, related primes elicited significantly faster reaction times compared to unrelated primes. There was a significant effect of log-transformed target frequency (estimate = −0.026, SE = 0.002, $t = -11.312$, $p < 0.001$), indicating that increased target frequency elicits faster reaction times. There was a significant interaction of condition × relatedness for the orthographic condition (estimate = 0.039, SE = 0.009, $t = 4.261$, $p < 0.001$), as well as a significant interaction of condition × relatedness for the semantic condition (estimate = 0.055, SE = 0.009, $t = 6.12$, $p < 0.001$). These two interactions indicated that the effect of relatedness in the identity condition was different in the orthographic and semantic conditions. Follow-up models for orthographic and semantic items on their own reveal no effect of prime relatedness. The lack of interaction of

[5]The function used for model selection in the reaction time models was the same method as what was manually done in the accuracy models. The automatic function is only available in R for linear models (like lmer), not logistic models (like glmer) at the time of running the analyses.

relatedness × condition for the morphological items indicates that the effect of relatedness in the identity conditions is similar to the morphological condition. There was no effect of group, indicating that the native and non-native speakers behaved similarly.

To investigate the potential effect of proficiency on morphological processing in the L2 French group, proficiency scores (as measured by the LexTALE task) were first log-transformed to approximate a normal distribution. A linear mixed-effects model for the L2 learners only was initially fit with log-transformed reaction times for the L2 participants only as the dependent variable, and condition, relatedness, and log-transformed proficiency, as well as all two-way and three-way interactions, and log-transformed target frequency as fixed effects. Subject and item were included as random intercepts with relatedness included as a random slope on the subject random intercept. As was done in previous analyses, final model selection was carried out using the *bfFixefLMER_F* function in the *LMERConvenienceFunctions* R package by way of AIC comparison. The final model included condition, relatedness, log-transformed proficiency, log-transformed target frequency, and the interaction of condition × relatedness as fixed effects, and subject and item as random effects.

The final model revealed a significant effect of relatedness (estimate = −0.073, SE = −0.011, $t = -6.846$, $p < 0.001$), indicating that, in the identity condition, the related primes elicited faster lexical decisions than unrelated primes. There was a significant effect of log-transformed target frequency (estimate = −0.022, SE = 0.002, $t = -8.688$, $p < 0.001$), indicating that increased target frequency elicits faster reaction times. There was an interaction of condition × relatedness for the orthographic items (estimate = 0.05, SE = 0.014, $t = 3.5$, $p < 0.01$), as well as an interaction of condition × relatedness for the semantic items (estimate = 0.075, SE = 0.014, $t = 5.417$, $p < 0.001$). Follow-up models on the orthographic and semantic conditions revealed no effect of prime relatedness on reaction times. There was no effect of proficiency. The analyses on the L2 French group revealed the same pattern of identity and morphological priming that was found in the model with L1 and L2 French groups together. Importantly, it revealed that proficiency does not modulate priming effects. These findings suggest that morphological priming can be found across the wide range of L2 proficiency levels we studied.

The reaction time analysis reveals behavioral evidence of morphological priming in both L1 and L2 French speakers. When the prime shared a morpheme with the target (identity and morphological conditions), the reaction times were significantly faster than when the prime was unrelated. Of interest, L2 proficiency did not influence the results.

EEG Data

EEG amplitude data were analyzed on all trials in two time-windows, 100–300 and 300–500 ms post-target onset. These time-windows are characteristic time-windows for, respectively, the N250 and N400 ERP components of interest in this study. Recall that the N400 component is where effects of morphology are predicted to appear and where semantic effects would be observed if they were to appear, whereas the N250 is predicted to show effects of orthographic overlap between prime and target. For each time-window, the mean amplitude was calculated for each condition, for each participant. Electrodes were dummy coded for hemisphere (left, midline, right) and for anteriority (anterior, central, posterior), with midline and central serving as reference levels for their respective variable. Linear mixed-effects models were used to analyze the amplitude data for each time window. Models were initially fit with condition (identity, morphological, orthographic, semantic), relatedness (unrelated, related), group (L1, L2), hemisphere (left, midline, right), and anteriority (anterior, central, posterior) as fixed effects, along with all interaction terms for the five variables. Subject was included as a random intercept, along with relatedness as a random slope. The model was initially fit with all fixed effects and all possible interactions and was then progressively minimized using the *LMERConvenienceFunctions* R package, using AIC to compare more complex models to simpler models. The final models that best fit the data for each time-window are described in the sections below.

The waveform plots for the midline electrodes (Fz, Cz, Pz, Oz) are provided in **Figure 2** for the grand average of all 53 participants for all four conditions. These plots reflect the group mean voltage, and were created using the *ggplot2* package in R (Wickham and Chang, 2016). All participants are plotted together because the statistical analyses reveal no group effect. Similar plots with groups plotted separately can be found in **Supplementary Materials** (**Datasheet 1**). Mean voltage data available in **Datasheet 4**.

N250 Analysis

The N250 amplitude was calculated by averaging each participants' mean amplitude for all time points within the N250 window (100–300 ms). The model analyzing the N250 time-window included as fixed effects the following factors and their interactions: condition, relatedness, language group, hemisphere, and anteriority, as well as a number of two-way and three-way interactions (see full model structure in **Table S1**). Only relevant interactions will be discussed here. Subject was included as a random intercept with relatedness as a random slope. This model showed a simple effect of relatedness (*estimate* = 1.01, *SE* = 0.203, $t = 4.973$, $p < 0.05$), reflecting reduced amplitudes with related primes vs. unrelated ones for the native group. There was no significant interaction of relatedness × group, indicating the same pattern of relatedness for identity items is found in both groups. As seen in the plots, orthographic and morphological conditions resulted in similar attenuations of the N250 as the identity ones in the N250 time window, while the semantic priming condition did not. This is confirmed by an interaction of condition × relatedness for the semantic items (*estimiate* = −0.803, SE = 0.1*80*, $t = -3.252$, $p < 0.01$) and a lack of interaction of condition × relatedness for the morphological or orthographic items. A follow-up model on semantic items revealed no significant effect of relatedness. There were no other relevant interactions in the N250 model, indicating that the native and non-native groups both show effects of orthographic and morphological overlap in this time window, and the effect is

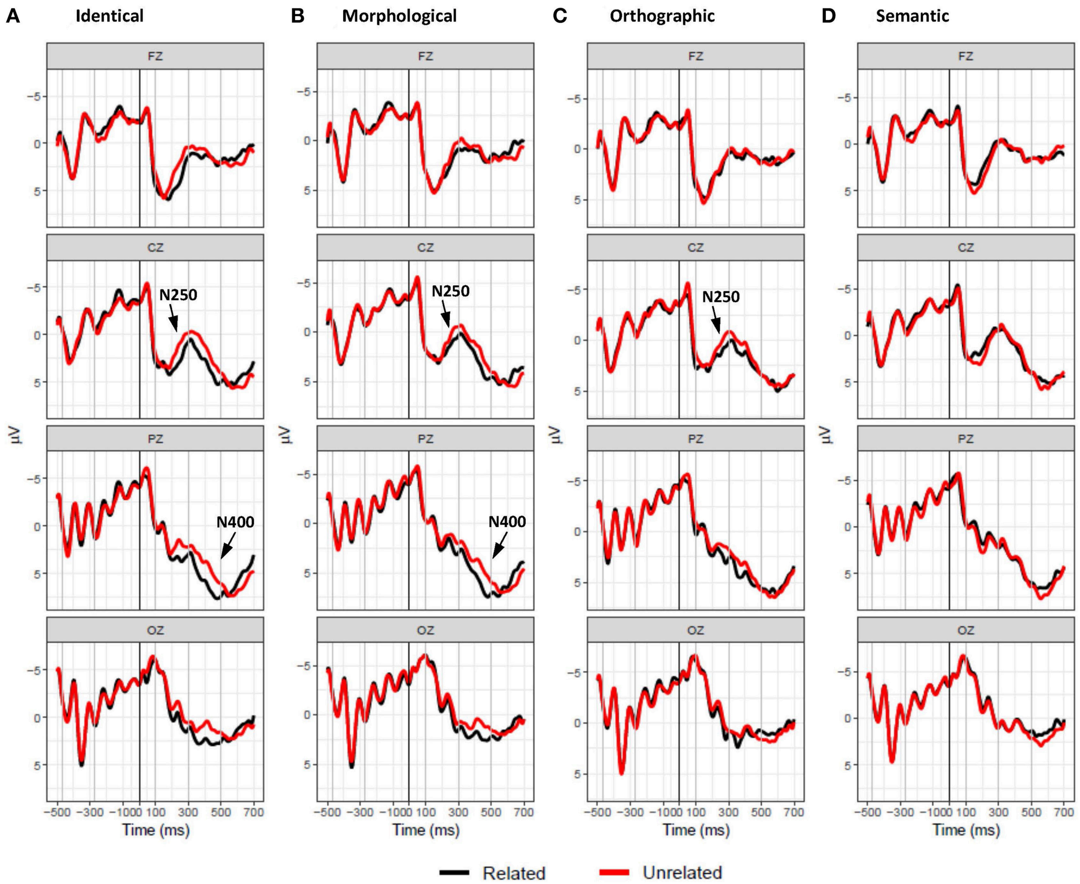

FIGURE 2 | Grand average ERPs at midline electrodes for **(A)** identity, **(B)** morphological, **(C)** orthographic, and **(D)** semantic conditions. The averages include data from all participants, L1 and L2. Black lines for related conditions, red lines for unrelated conditions. The baseline is −470 to −270 ms (shown with gray lines). The prime appeared −70 to −20 ms, followed by a mask −20 to 0 ms, and the target word, 0 to 600 ms.

global in its scalp distribution. Voltage maps are available in the **Supplementary Material** (**Datasheet 2**).

An additional model was run on non-native speakers' data to test if the N250 priming effect was influenced by proficiency. The model included condition, relatedness, proficiency, hemisphere, and anteriority as fixed effects, along with interaction terms for condition × relatedness, relatedness × proficiency, relatedness × anteriority, proficiency × anteriority, hemisphere × anteriority, and condition × relatedness × proficiency. The model revealed a marginal simple effect of relatedness (*estimate* $= -2.358$, *SE* $= 1.221$, $t = -1.931$, $p = 0.054$), a significant interaction of relatedness × proficiency (*estimate* $= 2.06$, *SE* $= 1.811$, $t = 2.648$, $p < 0.01$), and a significant interaction of condition × relatedness for the semantic items (*estimate* $= 4.183$, *SE* $= 1.716$, $t = 2.438$, $p < 0.02$). A follow-up model on semantic items revealed no effect of prime relatedness. L2 voltage maps are available in **Datasheet 5**.

The above analyses reveal that the N250 component is marginally attenuated by identity, morphological, and orthographically related primes, whereas no attenuation was found in the semantic condition. While both L1 and L2 groups showed similar attenuation patterns, for the L2 group this effect is influenced by proficiency, with greater attenuation as proficiency increases.

N400 Analysis

The N400 amplitude was calculated by averaging each participants' mean amplitude for all time points within the N400 window (300–500 ms). The final model for the N400 time-window included condition, relatedness, group, anteriority, and hemisphere as fixed effects. It also included interaction terms of condition × relatedness, relatedness × anteriority, language group × anteriority, language group × hemisphere, and anteriority × hemisphere as fixed effects. Subject was included as a random intercept with relatedness as a random slope. The results of the model showed a simple effect of relatedness (*estimate* $= 1.01$, *SE* $= 0.203$, $t = 4.973$, $p < 0.001$), indicating that at the reference levels in the model (unrelated, identity, midline, central), related primes elicit more attenuation of the N400 than unrelated primes. There was no interaction of relatedness × group indicating that the pattern of relatedness was found in both groups at these reference levels. There was an interaction of condition × relatedness for both the orthographic (*estimate* $= -0.67$, *SE* $= 0.18$, $t = -3.71$, $p < 0.01$) and semantic levels (*estimate* $= -0.803$, *SE* $= 0.18$, $t = -4.454$, $p < 0.01$), which indicates that the effect of relatedness found in the reference level (identity) is different from the orthographic and semantic levels. There was no interaction of condition × relatedness for the morphological level of the condition variable, indicating a similar effect of relatedness in the identity and morphological conditions. Two follow-up models where orthographic and semantic items were isolated to further probe the interaction of condition × relatedness revealed no effect of prime relatedness for either language group. The main model that included all conditions also revealed an interaction of relatedness × anteriority for the anterior level (estimate $= -0.644$, SE $= 0.167$, $t = -3.857$, $p < 0.001$), indicating that the effect of relatedness found at the reference level (central) was different at anterior sites. Follow-up models revealed no significant effect of relatedness at the frontal sites, for any condition, in either language group. There were no interactions involving hemisphere. Crucially, the main model revealed no interaction of the effect of relatedness and language group (for any condition). This indicates that that the pattern of related identity and related morphological primes eliciting greater N400 attenuation than unrelated primes (in their respective conditions) is similar in both the L1 and L2 French groups. Results of the N400 analysis indicate that both native and non-native French speakers show similar N400 attenuations when primes are morphologically related to their target words (in either identity or morphological conditions), and this effect is found at central and posterior electrode sites (the typical scalp distribution of N400 effects). Voltage maps are available in the **Supplementary Material** (**Datasheet 2**).

To test whether proficiency contributes to a non-native speaker's ability to process morphological information in a native-like way, the non-native French speakers' EEG data in the N400 time-window were analyzed separately, with the participants' proficiency score included as a continuous variable in the model. The initial non-native N400 model revealed an effect of relatedness (estimate $= 0.768$, SE $= 0.303$, $t = 2.533$, $p < 0.01$), indicating that at the reference levels the related primes reduced the N400 amplitude more than unrelated primes. There was an interaction of condition × relatedness (for the other three levels of condition), as well as an interaction of relatedness × anteriority (for the anterior and posterior levels of anteriority). This indicates that at the central sites, for the non-native speakers, only identity priming effects are found. Follow-up models that probed the interaction of anteriority revealed that, at posterior electrode sites, there was an effect of relatedness (for the reference identity condition) (*estimate* $= 1.302$, *SE* $=$ 0.289, $t = 4.503$, $p < 0.01$), and interactions of condition × relatedness for the orthographic level (*estimate* $= -1.02$, *SE* $=$ 0.319, $t = -3.197$, $p < 0.01$) and semantic level (*estimate* $=$ -1.307, *SE* $= 0.319$, $t = -4.094$, $p < 0.001$). There was no interaction of condition × relatedness for the morphological level ($p > 0.48$) in the posterior electrodes. This indicates that at posterior sites, the effect of relatedness was similar for the identity and morphological items. The follow-up models at anterior sites revealed no effect of relatedness in any condition. Crucially, proficiency never interacted with priming effects (for any condition).

In summary, analyses of the non-native data for the N400 time-window revealed similar results as were found when all participants were included in the analyses, though the effect of morphological priming was localized at posterior, rather than central and posterior, electrode sites. The lack of interaction with proficiency indicates that the priming effect is found across the proficiency levels tested.

DISCUSSION

The present study examined whether native and non-native speakers of French process inflected words according to their morphological structure. Previous research investigating non-native processing of inflected words has been inconclusive as to whether adult learners of a language are sensitive to the morphological structure of words carrying inflection.

The results of the present study revealed behavioral- and electrophysiological evidence of morphological processing in both language groups. The reaction time data from the masked priming lexical decision task revealed that L1 and L2 groups show similar sensitivity to morphological structure in inflected words. For both groups, lexical decision times were significantly faster for the identity and morphologically related primes compared to unrelated primes. This facilitation can be attributed to the shared morphology between prime and target in these conditions rather than to the shared orthography and semantics, as the orthographically related and semantically related primes offered no facilitation in lexical decision times compared to unrelated primes. When looking at the L2 French group alone, the results revealed that proficiency in French did not affect their ability to show morphological facilitation in the behavioral task. This suggests that morphological processing may be available to L2 learners at an early stage of proficiency. The behavioral results in the present study are similar to those found in English learners of Spanish in Foote (2015), who used a very similar priming task. In both studies, the L2 groups showed morphological processing that is qualitatively similar to native speakers, and in both studies, proficiency in the L2 group did not modulate this ability.

The EEG results revealed that the L2 learners were able to show qualitatively native-like neurocognitive priming effects in real-time. The N400 findings for the native French speakers in the present study demonstrate a priming effect for morphological relatedness that cannot be reduced to effects of shared orthography or semantics (see e.g., Royle et al., 2012 for similar findings for native French speakers). The non-native French speakers in the present study showed qualitatively similar N400 priming patterns to the native speakers. These results suggest that, like native French speakers, L2 learners are able to decompose inflected words into morphological constituents, and access a morphological level of representation in the lexicon whereby the stripped stem primes the target word. These findings indicate that non-native speakers are in fact sensitive to the morphological structure of inflected words, and accomplish morphological processing within the same time-windows as native speakers.

While the EEG component associated with morphological sensitivity (N400) displayed similar effects in both language groups (independent of L2 proficiency), there was one interesting difference between the groups in the N250 component, namely the effect of proficiency. The N250 component is associated with early form mapping, and the results suggest that native-like sensitivity to early orthographic processing may only be available to learners who have reached a higher level of proficiency.

One interesting finding in the present study is that a qualitatively native-like sensitivity to morphological structure was found across the range of French proficiencies tested here. In the L2 literature, native-like processing is often only found at very advanced levels of proficiencies (e.g., morphosyntactic) abilities in Hopp (2010), yet the present study and Foote (2015) demonstrate that proficiency may not be a limit to morphological sensitivity. There are key differences between the present study and Hopp (2010) to keep in mind. Hopp (2010) investigated gender inflection at the sentence level. One possible reason that proficiency may be a limit to native-like performance in Hopp's study could be that it has been argued that gender is a non-interpretable feature (e.g., Baker, 2003), whereas that is not the case for the verbal inflections for person and number tested in the present study. There is also the difference in the presentation context of the stimuli (within a sentence vs. in isolation), which may contribute to the differences in proficiency effects found in Hopp (2010) compared to the present study. However, if we take the view of questioning if proficiency is always a barrier to native-like processing, the findings of the present study (along with those in Foote, 2015) suggest that morphological processing may, in fact, be available at early stages of non-native language learning, at least for regular inflection in the language pairings tested in the current study and in Foote (2015).

The results of the present study run counter to proposals by Clahsen and colleagues whereby adult learners of a second language are claimed to be insensitive to the morphological structure of inflected words due to a deficient grammar. The present study shows that in both behavioral and EEG data, adult learners of French are sensitive to the morphological structure of regularly inflected French verbs. Similar to native speakers, L2 learners showed significant and equivalent priming in the lexical decision latencies in both identity and morphological conditions but importantly not orthographic ones, indicating that the source of the priming effect is morphological in nature. The EEG data showed qualitatively similar morphological priming effects in native and non-native speakers in that the negativity in the N400 time-window was significantly and equally attenuated when the prime and target overlapped in morphology. In both the behavioral and EEG data, the morphological priming effect is distinct from any orthographic or semantic priming, in that there was no orthographic or semantic priming. The findings in the present study are inconsistent with claims that adult L2 learners are insensitive to the morphological structure of inflected words. Additionally, the findings in the present study suggest that sensitivity to inflectional structure may be available to learners at early stages of learning.

One potential explanation as to why native and non-native speakers showed similar ability to process inflection in the present study (and in Foote, 2015), but not in many studies by Clahsen and colleagues may be (at least partially) due to the nature of the stimuli used. In the present study, the inflected stimuli were of extremely low surface frequency, whereas that may not be the case in English studies by Clahsen and colleagues. It has been proposed that inflected forms of sufficiently high surface frequency could be stored and accessed as whole-words instead of decomposed into morphological constituents, while low frequency words promote morphological parsing (Alegre and Gordon, 1999). Stimuli can easily be created with extremely low surface frequency in morphologically richer languages (e.g., French and Spanish) as compared to morphologically impoverished languages (e.g., English). For example, the forms we used such as (*nous*) *mangeons* /mãʒɔ̃/ "(we) eat" are often replaced in the oral language and informal French by the third person (*on*) *mange* /mãʒ/ "(one/we) eat/s" and is thus a low frequency form in the paradigm, compared to English past tense forms used in Silva and Clahsen (2008). This made it highly unlikely that any participant would access our stimuli via whole-word representations, and this promoted a morphological processing pathway. It is possible that the surface frequency of the test items used in Clahsen and colleagues were of high enough frequency that some participants stored some of the test words in their whole-form, making it very difficult to capture any ability to decompose inflected forms. More research would be needed to test this potential explanation of differences between the present study and the many studies by Clahsen and colleagues.

The lack of interaction between morphological priming and French proficiency is an interesting finding to consider in light of a proposal put forward by Ullman (2005) regarding the role of proficiency in L2 morphological processing. Ullman posits that non-native speakers with low proficiency levels are heavily dependent on whole-word storage for the processing of morphologically complex words, due to diminished availability of the procedural memory system at early stages of learning. Ullman hypothesizes that with sufficient experience with the language and high proficiency, learners are able to gain access to the procedural memory system that is believed to subserve grammatical procedures, such as inflection. The present study tested a wide range of L2 proficiency yet failed to find evidence of a qualitative shift between lower- and higher-levels of proficiency in the N400 time window. It is possible that the participants in the present study had undergone this shift prior to participation, but recent work by Ullman and his colleagues suggests that the qualitative shift may only happen at very advanced levels of proficiency (Bowden et al., 2010; Babcock et al., 2012); in the current study, most participants would not be considered very advanced learners of French. However, it is important to consider the task used in these studies compared to the present one. Babcock et al. (2012) presented their inflected stimuli in a sentential context, which may be in part responsible for why their participants failed to show sensitivity to inflection. In Bowden et al. (2010) the participants were presented with a verb in isolation and asked to produce an inflected form as quickly as possible. More research is needed to understand if the ability to process inflection in a native-like way is affected by the task. It is indeed possible that task may influence linguistic processing, as has been found in experiments testing native French speakers' ability to perceive certain sounds in English at sentence vs. word level (e.g., Mah et al., 2016; White et al., 2017). What the present study does contribute (alongside Foote, 2015) is that some tasks do indeed allow for non-native speakers to demonstrate their native-like sensitivity to inflection, and that proficiency is not a barrier to this ability.

Beyond masked-priming studies, there is additional neurolinguistic evidence that lower level L2 learners can show native-like processing of inflection. For example, Osterhout et al. (2008) found that some English-native speaking L2 learners' brain responses to French subject-verb agreement violations begin to resemble native-like responses within their first year of university classroom instruction in French, well-before an advanced level of proficiency was attained. Although the current study demonstrated native-like sensitivity to L2 inflection by native English-speaking adult learners across proficiency levels, one question that remains is whether the learners' success may be due, at least in part, to the properties of the L1 (e.g., Yuan, 1994; White, 2003). One may consider that certain properties of the L1 influence how the L2 is processed. For example, could the fact that the French learners in the present study are native speakers of English (and presumably decompose English inflected words) influence their ability to decompose in their L2 French? Clahsen and colleagues argue that L1-L2 pairings do not affect the ability to decompose (e.g., Silva and Clahsen, 2008; Clahsen et al., 2010), but clearly this question deserves more attention as others argue that pairing does indeed matter (e.g., Macwhinney, 2005; Tokowicz and MacWhinney, 2005; Steinhauer et al., 2009; Steinhauer, 2014. One may also consider that instruction methods may influence a learner's ability to process inflection (e.g., Morgan-Short et al., 2012). All the learners in the present study learned French in North American classrooms where they most likely received at least some explicit instruction on verb conjugation. Further research on the effect of instructional method may reveal interesting results about the conditions under which learners are able to demonstrate native-like sensitivity to inflectional morphology. Additionally. research on other types of morphological processing within the sentence might highlight structure-specific variability that does not lead to simple generalizations about L2 learning. For example, Fromont et al. (2017; under review) show that even advanced L2 learners of French might have difficulties processing ambiguous clitics/determiners in sentences.

CONCLUSIONS

Similar to studies at the sentence-level (Osterhout et al., 2008; Steinhauer et al., 2009; White et al., 2012; Tanner et al., 2013; Steinhauer, 2014), results of the present study indicate that adult learners of a second language can demonstrate sensitivity to regularly inflected words that is qualitatively similar to native speakers' sensitivity. Moreover, advanced proficiency in the second language may *not* be a prerequisite to demonstrate qualitatively native-like levels of morphological processing in the masked priming paradigm for studies investigating decomposition. That is, for the structures investigated here—regular verb morphology in French—morphological processing may be available at the early stages of language learning.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of McGill University Faculty of Medicine Institutional Review Board at the McGill University with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by McGill University Faculty of Medicine Institutional Review Board.

AUTHOR CONTRIBUTIONS

CC conceptualized and designed the study, collected the data, analyzed the data, and wrote the manuscript. RF supervised, conceptualized, and designed the study, and edited the manuscript. PR supervised, designed the study, and edited the manuscript. KS supervised, provided lab space and lab equipment, analyzed the data, and edited the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2019.00021/full#supplementary-material

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