frontiers in Communication

ORIGINAL RESEARCH
published: 06 July 2021
doi: 10.3389/fcomm.2021.597701

What Are the Modulators of Cross-Language Syntactic Activation During Natural Reading?

Naomi Vingron[1], Pauline Palma[1], Jason W. Gullifer[1], Veronica Whitford[2], Deanna Friesen[3], Debra Jared[4] and Debra Titone[1]**

[1]Department of Psychology, McGill University, Montreal, QC, Canada, [2]Department of Psychology, University of New Brunswick, Fredericton, NB, Canada, [3]Faculty of Education, University of Western Ontario, London, ON, Canada, [4]Department of Psychology, University of Western Ontario, London, ON, Canada

Bilinguals juggle knowledge of multiple languages, including syntactic constructions that can mismatch (e.g., the red car, la voiture rouge; Mary sees it, Mary le voit). We used eye-tracking to examine whether French-English (n = 23) and English-French (n = 21) bilingual adults activate non-target language syntax during English L2 (Experiment 1) and L1 (Experiment 2) reading, and whether this differed from functionally monolingual English reading (Experiment 3, n = 26). People read English sentences containing syntactic constructions that were either partially shared across languages (adjective-noun constructions) or completely unshared (object-pronoun constructions). These constructions were presented in an intact form, or in a violated form that was French-consistent or French-inconsistent. For both L2 and L1 reading, bilinguals read French-consistent adjective-noun violations relatively quickly, suggesting cross-language activation. This did not occur when the same people read object-pronoun constructions manipulated in the same manner. Surprisingly, English readers exposed to French in their lifetime but functionally monolingual, also read French-consistent violations for adjective-noun constructions faster, particularly for some items. However, when we controlled for item differences in the L2 and L1 reading data, cross-language effects observed were similar to the original data pattern. Moreover, individual differences in L2 experience modulated both L2 and L1 reading for adjective-noun constructions, consistent with a cross-language activation interpretation of the data. These findings are consistent with the idea of syntactic cross-language activation during reading for some constructions. However, for several reasons, cross-language syntactic activation during comprehension may be overall more variable and challenging to investigate methodologically compared to past work on other forms of cross-language activation (i.e., single words).

Keywords: bilingualism, syntax, cross-language activation, eye movements, reading

OPEN ACCESS

Edited by:
Zofia Wodniecka, Jagiellonian University, Poland

Reviewed by:
Evy Adèle Woumans, Ghent University, Belgium
Aleksandra Tomic, Arctic University of Norway, Norway

****Correspondence:***
Naomi Vingron
naomi.vingron@mail.mcgill.ca
Debra Titone
debra.titone@mcgill.ca

Specialty section:
This article was submitted to Language Sciences, a section of the journal Frontiers in Communication

Received: *21 August 2020*
Accepted: *27 May 2021*
Published: *06 July 2021*

Citation:
Vingron N, Palma P, Gullifer JW, Whitford V, Friesen D, Jared D and Titone D (2021) What Are the Modulators of Cross-Language Syntactic Activation During Natural Reading?. Front. Commun. 6:597701. doi: 10.3389/fcomm.2021.597701

INTRODUCTION

What are the modulators of cross-language syntactic activation during natural reading? Bilinguals juggle multiple languages in everyday communication, yet their ability to produce and comprehend usually proceeds fluently (Grosjean, 2001). Consider the following sentence, "My neighbors had a heated chat about the ousted man's strange Tweets." While interpretation of this sentence is

straightforward, there are several places where a French-English bilingual may have difficulty. First, the word "chat," an interlingual homograph, could simultaneously activate the English meaning "informal conversation" or the French meaning "cat." We know from many studies (reviewed in Van Assche et al., 2012; Lauro and Schwartz, 2017; Palma and Titone, 2020), and leading models of bilingual language processing (e.g., Dijkstra and Van Heuven, 2002; Dijkstra, et al., 2019), that cross-language activation of divergent meanings slows reading for words like "chat." While much is understood about cross-language activation at the single-word level during reading (reviewed in Jared, 2015; Titone et al., 2016; Palma and Titone, 2020), less clear is whether bilingual adults experience cross-language activation for multiword syntactic constructions during reading (see Roberts, 2012, for a review) and whether this activation is modulated by individual differences among bilinguals.

Prior eye-tracking studies of sentence reading (e.g., Titone et al., 2011; Pivneva et al., 2014; Whitford and Titone, 2015; Friesen et al., 2020) and paragraph reading (e.g., Whitford and Titone, 2012; Whitford and Titone, 2015) have highlighted the influence of current L2 exposure on lexical access and reading fluency. Many studies reported bidirectional L1-L2 influences that are modulated by individual differences in current L2 exposure, although these studies were not focused on syntactic processing per se. It is therefore unclear whether, and to what extent, individual differences in bilingual experience modulate cross-language syntactic activation. On the one hand, some studies found that cross-language syntactic activation decreases as L2 experience increases, as individuals rely less on knowledge from their L1 (e.g., Dussias and Sagarra, 2007; Dussias et al., 2015; Kasparian and Steinhauer, 2017; see also; Roberts, 2012). On the other hand, some studies found that greater L2 proficiency is associated with larger cross-language activation effects, as a consequence of more integrated syntactic processing (e.g., Bernolet et al., 2009). Complicating matters is that syntactic processing is variable, even in monolingual individuals. Although formal linguistic approaches predict minimal individual differences in native language syntactic processing (see Kidd et al., 2018), individual differences have been observed both behaviorally and neurally (e.g., Wells et al., 2009; Street and Dabrowska, 2014; Mahowald and Fedorenko, 2016).

To the extent that cross-language activation occurs for syntactic processing, the comprehension of English adjective-noun constructions, such as "interesting chat" and "strange Tweets," might be affected by knowledge of French because the reverse word order is more typical of French: "une conversation intéressante" or "Tweets étranges." Similarly, the comprehension of object-pronoun constructions, such as "Mary sees it" and "They love her", might also be influenced by knowledge of French because object-pronouns are systematically cliticized to the verb in French: "Mary le voit" or "Ils l'aiment." In contrast, English object-pronouns are systematically placed after the verb (e.g., "Mary sees it"). It should be noted that the word order of French adjective-noun constructions is aligned with English for some adjectives (e.g., "la nouvelle maison"), whereas word order in object-pronoun constructions is always different in the two languages.

More generally, adjectives are linguistically optional, in that their omission neither impedes comprehension nor affects grammaticality (e.g., "the balloon"/"le ballon"), whereas omission of object-pronouns in transitive constructions causes ungrammaticality (e.g., "*Mohammed washes"/"*Mohammed lave"). As such, object-pronouns constructions also differ from adjective-noun constructions in their morphosyntactic behavior across languages. Specifically, English object-pronouns are strong pronouns, thus functioning syntactically as a lexical determiner phrases (DPs; Cardinaletti and Starke, 1999), whereas French object-pronouns are clitics, a class of pronouns that differs semantically, morphologically and syntactically from strong pronouns (Cardinaletti and Starke, 1999). In contrast to strong pronouns, clitics never occur in isolation (e.g., "Qui as-tu vu Mary embrasser hier? *La"), cannot be coordinated (e.g., "J'ai vu *la et Mary s'embrasser") or be modified by adverbs (e.g., "Seule *la est assez rapide"). Such differences between the two constructions can potentially impact the relative degree of cross-language activation for the same bilingual readers.

Here, we investigated whether bilingual adults, whose first language was French or English, would experience cross-language syntactic activation during sentence reading for these two types of constructions. To investigate this issue, we used a procedure in which English sentences containing these constructions violated English grammar in a manner that was either consistent or inconsistent with French. Specifically, we created adjective-noun constructions that were consistent with French adjective-noun word order (e.g., "The man saw the vehicle German that was parked on the street."), and sentences containing adjective-noun violations that were inconsistent with French adjective-noun word order (e.g., "The man saw German the vehicle that was parked on the street."). We also created English object-pronoun constructions that were consistent with French object-pronoun word order (e.g., "Leah baked the birthday cake, and she it ate with all her friends"), and sentences containing object-pronoun constructions that were inconsistent with French object-pronoun word order (e.g., "Leah baked the birthday cake, and ate she it with all her friends").

To generate predictions about how people would respond to these grammatical violations, we turned to a prominent model of bilingual sentence processing, the Unified Competition model (UCM; MacWhinney, 2005). It posits that a bilingual's two languages are co-activated and compete for selection to the degree that they mismatch cross-linguistically (MacWhinney, 1987; Frenck-Mestre, 2005; Kroll and Tokowicz, 2005). The UCM predicts that co-activation of similar L1/L2 syntactic constructions should lead to minimal competition and possibly facilitation during L2 reading—a phenomenon called positive transfer. In contrast, co-activation of mismatching syntactic constructions should block positive transfer from L1 to L2, causing L1 activation to impede L2 production or comprehension, and, ultimately, result in cross-language competition (e.g., Tuninetti et al., 2015).

Applied to the experimental manipulation here, the UCM would predict greater tolerance for L2 syntactic violations that are

consistent with L1 French syntax; violations of English sentences that are consistent with French should be read more easily by French L1 participants than violations that are not consistent with French. According to the UCM, both adjective-noun and pronoun constructions differ across English and French, which should lead to greater tolerance of French-consistent violations. It is important to underline that the UCM formulates predictions based on offline behaviors (i.e., grammaticality judgements) and does not make explicit predictions about online behaviors (i.e., eye movements during reading). Finally, the UCM makes predictions about bilinguals in general and not about highly proficient bilinguals in particular, such as the groups tested in this study. In addition, the model does not make predictions about how L2 knowledge may influence L1 syntactic processing. Nevertheless, as mentioned above, several studies involving highly proficient bilinguals have suggested that there is a bidirectional effect of a bilingual's two languages on processing (Van Assche et al., 2009; Titone et al., 2011). Thus, these models remain useful for the purpose of this work.

Very few studies have investigated syntactic-level cross-language activation, and the ones that exist are somewhat variable in outcome. In an event-related potential (ERP) go-no go study, Thierry and Sanoudaki (2012) found that early Welsh-English bilinguals exhibited a modulation of the amplitude of the N2 component when reading English adjective-noun constructions consistent with Welsh word order (e.g., *the book red).[1] This effect, which was not found in English monolingual participants, was interpreted as a consequence of the activation of L1 Welsh grammar during L2 English processing. In an eye-tracking grammaticality judgment study that inspired this investigation, Tuninetti et al. (2015) compared English monolinguals with different groups of bilinguals whose L1 was either consistent with English in terms of adjective-noun word order (Mandarin-English bilinguals) or inconsistent (Arabic-English bilinguals). Critical ungrammatical English sentences varied in their compatibility with these different L1s. On early reading measures, all three groups were equally tolerant of adjective-noun word order violations, suggesting no cross-language syntactic activation. However, they differed in how long it took to repair the violations (i.e., later reading measures).

Although important, the conclusions from these studies are somewhat limited, as they only investigated one type of syntactic construction (adjective-noun constructions), limiting their generality. The use of explicit paradigms (binary decision paradigms, grammaticality judgments) may also have limited the naturalness of their task. Moreover, inspection of Tuninetti et al. (2015) materials reveals that experimental sentences containing violations may not have been matched in other ways, such as the degree of word transpositions across the conditions (i.e., L1 consistent or inconsistent), which is known to impact whether readers even notice word order violations in monolingual reading (reviewed in Snell and Grainger, 2019). Furthermore, bilingual readers may be more likely to tolerate the cross-language condition, not because of cross-language syntactic activation per se, but rather because they are more susceptible to making word transposition errors (as a result of limited proficiency) during comprehension.

For these reasons, increasing the validity of a cross-language syntactic activation experiment would require all cross-language violations (and control violations) to be matched on word transposition characteristics (as well as cues to ungrammaticality, which are likely correlated). It may also be important to examine how the same people read multiple constructions that systematically differ across languages in a manner that could lead to more or less cross-language activation, such as adjective-noun and object-pronoun constructions, even if those two constructions cannot be statistically compared directly because of the myriad ways they differ in a low-level sense (e.g., length and type of words, overall frequency, the kinds of sentence frames in which they are embedded, likelihood of differential parafoveal preview, etc.). Finally, to the extent that cross-language activation results in higher tolerance of French-consistent violations (i.e., faster reading times compared to a French-inconsistent violation), we would expect that reading performance would be modulated by individual differences in bilingual experience, specifically the amount of L2 usage and the likelihood to find oneself in a setting where the two languages are mixed (i.e., in Montreal, both English and French are often used interchangeably in downtown restaurants and stores).

The Present Study

With the above logic in mind, we examined how bilingual adults read sentences that contained word order violations to assess cross-language syntactic activation. Like Tuninetti et al. (2015), we used eye-tracking. Unlike Tuninetti et al. (2015), participants simply read sentences for comprehension rather than making explicit grammaticality judgements. Additionally, object-pronoun constructions were studied for the same people, using the same procedure, alongside adjective-noun constructions.

We posed three main questions: 1) Do bilingual readers show evidence of cross-language syntactic activation during L2 and L1 reading of adjective-noun and object-pronoun constructions? 2) Do individual differences in language mixing and general frequency of L2 speaking modulate cross-language activation patterns during bilingual reading? and 3) How do monolingual reading patterns of adjective-noun and object-pronoun constructions compare to those of bilinguals?

[1]For participants, a go-no go task consists in responding to some visual stimuli (go condition), but to refrain from responding to others (no go condition). A modulation of the N2 component is classically observed in the *no go*, but not in the *go* condition, suggesting that this component is associated with cognitive inhibition (e.g., Falkenstein et al., 1999). Thierry and Sanoudaki (2012) instructed participants to respond only to adjective-noun constructions that corresponded—at least partially—to presented pictures (e.g., blue book, picture of a red book), and to refrain from responding to constructions inconsistent with presented pictures (e.g., green car, picture of a red book). The authors hypothesized that monolingual participants would exhibit a modulation of the N2 when expecting a noun after an adjective (e.g., blue book), whereas the same participants would not expect an adjective after a noun (e.g., *car red). In contrast, bilingual participants were hypothesized to expect both a noun after an adjective (consistent with English grammar) and an adjective following a noun (consistent with Welsh grammar), resulting in a modulation of the N2 component in both cases.

To answer these questions, we conducted three experiments. Experiment 1 tested French-English bilingual adults who read English sentences containing the grammatical violations described above. Experiment 2 tested English-French bilingual adults who read the same English sentences. Experiment 3 tested functionally monolingual English-speaking adults on the same sentences. Across Experiments 1 and 2, we also examined how graded differences in bilingual experience (e.g., general frequency of L2 speaking and degree of language mixing) modulated cross-language activation patterns. Based on previous studies, we further predicted both L2 and L1 reading of these constructions would be modulated by individual differences in language exposure.

EXPERIMENT 1: FRENCH-ENGLISH BILINGUALS READING IN ENGLISH (L2 READING)

Method

Participants. We tested 25 French-English bilinguals (6 men, 19 women) at McGill University and the University of Western Ontario, who did not speak additional languages fluently according to self-report. We tested across two different sites with the hope of maximizing our chances of having a large range of French-English bilinguals with respect to use of English (their L2).

Participants had a mean age of 21.36 years (*SD* = 2.37), with no uncorrected vision, speech, or reading impairments. They were recruited through online advertisements, local posters, and the Psychology Department subject pool. Subject pools participants were given course credit, while the other participants were paid $10/hour.

All participants completed a language history questionnaire (Marian et al., 2007), which included self-reported frequency of reading, writing, listening, and speaking in L1 and L2 (where applicable), language mixing, and acquisition history. General frequency of L1 and L2 speaking, listening, writing, and reading were reported in percentages (e.g., What percentage of the time do you speak French?). Participants reported speaking their L2, English, 57.83% (*SD* = 23.60; Min = 20; Max = 90) of the time. On average, they rated their likelihood to mix French and English (e.g., situations where the two languages can be used in a complementary or interchangeable way) as 4.60 out of 7 (*SD* = 1.41; Min = 2; Max = 7).[2]

Materials. Materials consisted of 63 sentences containing adjective-noun constructions and 54 sentences containing object-pronoun constructions. Of note, three of the items containing adjective-noun constructions were excluded from the analyses because the manipulation did not appear as intended (e.g., "The picture captured the [father's proud smile] that cheered the runner." when presented in the French-inconsistent condition read "The picture captured the [proud father's smile] that cheered the runner", which is grammatical). Assignment of sentences to experimental conditions was counterbalanced so that each participant only saw each sentence in one condition. Exemplar sentences for each experimental condition are presented in **Table 1**. In addition to the experimental sentences, materials also included 78 sentences containing a verb particle construction that appeared either in intact or in violated form. As well, we included 90 random filler sentences, of which ten were ungrammatical jabberwocky sentences.

In creating the experimental sentences containing adjective-noun and object-pronoun constructions, our aim was to minimize bias and ensure that the manipulation was as natural sounding as possible. Importantly, the creation of materials for this experiment was guided by well-established findings regarding eye movements during sentence reading (see Clifton et al., 2007). As such, the experimental sentences were consistent in length and complexity. The region of interest containing the manipulated syntactic construction was always placed in the middle of the sentence and was never immediately followed by any punctuation so as to avoid sentence wrap-up effects (Hirotani et al., 2006).

Procedure. Participants first completed the eye-tracking reading task, followed by the language background questionnaire. For the reading task, participants read each sentence (presented one at a time) silently for comprehension and indicated *via* button-press when they finished reading each one. Sentences were displayed in 10-point, yellow Monaco font on a black background. Participants were asked to respond to 21 yes/no comprehension questions on filler trials to ensure participants were attentive throughout the experiment.

Apparatus. Eye-movement data were acquired at a rate of 1,000 Hz from the right eye using an EyeLink 1,000 desktop mounted system (SR-Research, Ontario, Canada). Sentences were displayed on a 21-inch ViewSonic CRT monitor, positioned 57 cm from the participant. We presented sentences using UMass EyeTrack software (downloadable from: https://blogs.umass.edu/eyelab/software/). Participants eyes were calibrated using a 9-point calibration. On each trial, a gaze contingent yellow box was presented on the left of the screen before the sentence appeared.

Data preprocessing and analytic approach. We used the UMass Amherst EyeTrack software to manually clean and extract eye movement data. We first viewed each trial in the EyeDoctor program and removed blinks and trials containing evidence of track loss. Finally, we used EyeDry to extract the eye movement reports that would be used for analysis.

We analyzed both early and late eye movement measures for the entire determiner-adjective-noun region and object-pronoun region. Specifically, we considered first pass gaze duration, which describes the amount of time (in ms) that the eye is in a critical region before exiting it to the right for the first time and total reading time, which refers to the total amount of time the eye spends in a critical region during a trial, including regressions. For example, in the sentence "The man saw the German vehicle that was parked on the street," containing an adjective-noun construction, the region of interest was defined as "the German vehicle" In the sentence "Leah baked the birthday cake, and she

[2]Of note, the language mixing variable used here differs from a more traditional measure of code switching. Specifically, code switching usually refers to bilingual speakers inserting single words or phrases from one language into utterances in another language or alternating between different languages from one sentence to the next (Green and Wei, 2014; Green and Wei, 2016). Language mixing is understood as a more general measure that refers to situations in which a bilingual individual may use their languages in a more integrated or complementary way.

TABLE 1 | Sample sentences containing adjective-noun and object-pronoun constructions across conditions.

Sentence type	Adjective-noun constructions	Object-pronoun constructions
English intact	The man saw the German vehicle that was parked on the street.	Mark orders a chicken, and *he serves it* to his friends while they watch a movie
French-consistent	The man saw the vehicle German that was parked on the street.	Mark orders a chicken, and *he it serves* to his friends while they watch a movie
French-inconsistent	The man saw German the vehicle that was parked on the street.	Mark orders a chicken, and *serves he it* to his friends while they watch a movie

ate it with all her friends," which contains an object-pronoun construction, the region of interest was defined as "she ate it."

Included in the analysis were only observations with first pass gaze durations or reading times on the three-word region of interest lasting longer than 80 ms in total. When fixation durations were below this cut-off, the region was considered skipped. In the adjective-noun experiment, this led to the exclusion of six observations from the first pass gaze duration analysis and three observations from the total reading time analysis.[3] In the object-pronoun experiment, this led us to exclude sixteen observations from the first pass gaze duration analysis and eight observations from the total reading time analysis.[4] An upper cut-off of 10,000 ms was applied, but no observations exceeded this.

First pass gaze duration and total reading time data were log-transformed, analyzed using linear mixed-effects (LME) models, and plotted in R (R Core Team, 2017) using the following packages: lme4 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017), ggplot2 (Wickham, 2016), and effects (Fox and Weisberg, 2018). We first computed a set of core models, where the goal was to assess the core manipulation of the experiment (i.e., French-consistent and -inconsistent manipulations) across all participants. Here, the categorical independent variable (IV), sentence type, was treatment coded (0, 1), where the French-consistent sentence type served as the baseline against comparisons with the English intact and French-inconsistent sentence types. In all core models, trial order (continuous, *z*-scored) was a control variable, and we used maximal random effects as supported by the data. When a model did not converge, we followed the procedures outlined in Barr et al. (2013) to simplify the random effects structure.

We next fit separate models to evaluate whether individual differences among bilinguals in either the general frequency of L2 speaking (which we took as a general usage measure) or language mixing interacted with sentence type across the different reading measures (i.e., gaze duration and total reading time of the region). We computed an additional model for each measure that included the interaction of language mixing (continuous, *z*-scored) with sentence type, as well as trial order and general frequency of L2 speaking as control variables and using random intercepts only. We used the same procedure to investigate the impact of general frequency of L2 speaking in an interaction with sentence type, in which we also controlled for language mixing and trial order.

Across all models, we evaluated significance using Satterthwaite approximations, implemented in the lmerTest package (Kuznetsova et al., 2017). **Table 2** and **Table 3** present the descriptive statistics for the eye movement measures. Full datasets and output of all subsequently reported models are available from the OSF repository (https://osf.io/jec5s/?view_only=a9d0ad4f9b994cd9b93371d2a2089cf1).

Results

Sentence comprehension. Sentence comprehension accuracy was 90% among French-English bilinguals, indicating that they were attentive during the reading task.

Adjective-Noun Constructions

Core models. A treatment coded model with French-consistent as the baseline showed that constructions embedded in French-consistent sentences and English intact sentences had similar first pass gaze durations ($\beta = -0.01$, $SE = 0.02$, $t = -0.70$, $p = 0.48$). In contrast, constructions embedded in French-consistent sentences had significantly shorter first pass gaze durations compared than those embedded in French-inconsistent sentences ($\beta = 0.07$, $SE = 0.02$, $t = 3.41$, $p < 0.01$).[5]

For total reading time, a treatment coded model with French-consistent as the baseline showed that constructions embedded in French-consistent sentences were read significantly faster than those embedded in French-inconsistent sentences ($\beta = 0.15$, $SE = 0.02$, $t = 5.69$, $p < 0.01$), but slower than English intact sentences ($\beta = -0.13$, $SE = 0.02$, $t = -4.94$, $p < 0.01$).[6]

Effects of bilingual language experience. We next evaluated whether performance interacted with individual differences in L2 (English) experience (i.e., language mixing and general frequency of L2 speaking). Accordingly, we reran the above models including general frequency of L2 speaking as an interaction term and language mixing as a control variable, and vice versa. We discuss only significant interaction effects with these variables if they also involve condition. Across these models, individual

[3]Of the observations excluded from the first pass gaze duration analysis, three were presented in the English intact condition, two in the French-consistent and one in the French-inconsistent condition. Of those, only the observations presented in the French-consistent and French-inconsistent conditions were also excluded from the total reading time analysis.

[4]Of the observations excluded from the first pass gaze duration analysis, five were presented in the English intact condition, four in the French-consistent and seven in the French-inconsistent condition. Of those, two of the observations presented in the English intact condition, three of the French-consistent and three of the observations presented in the French-inconsistent condition were also excluded from the total reading time analysis.

[5]A refit model with the reference level set at French-inconsistent showed that first pass gaze durations for French-inconsistent constructions were longer than those embedded in English intact constructions ($\beta = -0.09$, SE = 0.02, t = −4.12, $p < 0.01$).

[6]A refit model with the reference level set at French-inconsistent showed that total reading time for French-inconsistent constructions were longer than those embedded in English intact constructions ($\beta = -0.29$, $SE = 0.02$, $t = -10.65$, $p < 0.01$).

TABLE 2 | Descriptive statistics for all dependent measures of adjective-noun constructions for Experiment 1 (left), Experiment 2 (center) and Experiment 3 (right).

	Adjective-noun constructions											
	French-English bilinguals (L2 reading)				English-French bilinguals (L1 reading)				English monolinguals			
Sentence type	FPGD		TRT		FPGD		TRT		FPGD		TRT	
	Mean[a]	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
English intact (the sunny room)	591	228	709	336	511	244	614	358	523	216	605	396
French-consistent (the room sunny)	605	246	850	512	551	255	831	538	552	241	746	424
French-inconsistent (sunny the room)	647	251	1,000	611	583	298	962	665	593	279	867	527

[a]*All means and SD are in* ms.

TABLE 3 | Descriptive statistics for all dependent measures of object-pronoun constructions for Experiment 1 (left), Experiment 2 (center) and Experiment 3 (right).

	Object-pronoun constructions											
	French-English bilinguals (L2 reading)				English-French bilinguals (L1 reading)				English monolinguals			
Sentence type	FPGD		TRT		FPGD		TRT		FPGD		TRT	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
English intact (she ate it)	421[a]	224	499	262	417	204	476	274	387	183	442	226
French-consistent (she it ate)	521	304	759	535	464	340	659	559	427	211	575	388
French-inconsistent (ate she it)	508	298	749	628	446	261	720	556	448	243	625	441

[a]*All means and SD are in* ms.

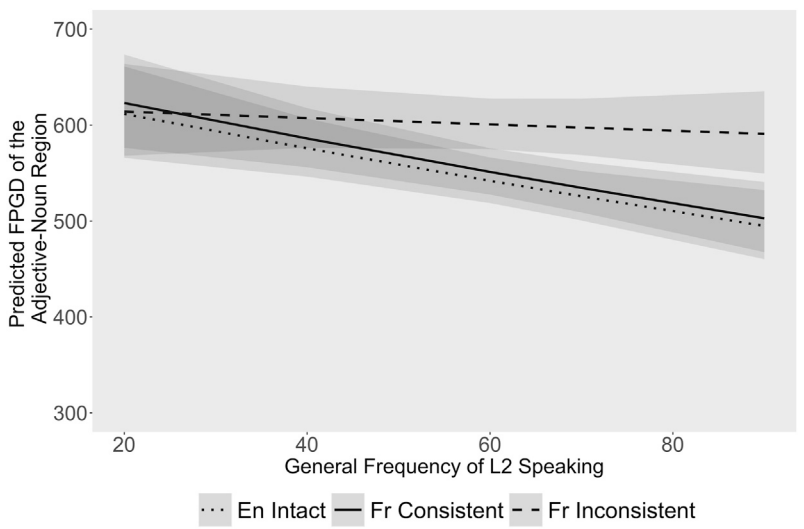

FIGURE 1 | Experiment 1 (French-English bilinguals reading in L2), interaction effect of general frequency of L2 speaking (out of 100%) on predicted first pass gaze duration (in ms) of the adjective-noun region. Shaded area represents plus/minus one standard error of the mean.

differences in general frequency of L2 speaking interacted with the French-inconsistent condition for first pass gaze duration. Specifically, there was a significant interaction between the French-inconsistent vs. French-consistent contrast and general frequency of L2 speaking (β = 0.06, SE = 0.02, t = 2.70, p < 0.01; see **Figure 1**). When the baseline was set to French-inconsistent, there was a significant interaction between the French-inconsistent vs. English intact contrast and general frequency of L2 speaking (β = −0.05, SE = 0.02, t = −2.67, p < 0.01). This suggests that when L2 experience is low, French-English bilingual participants do not

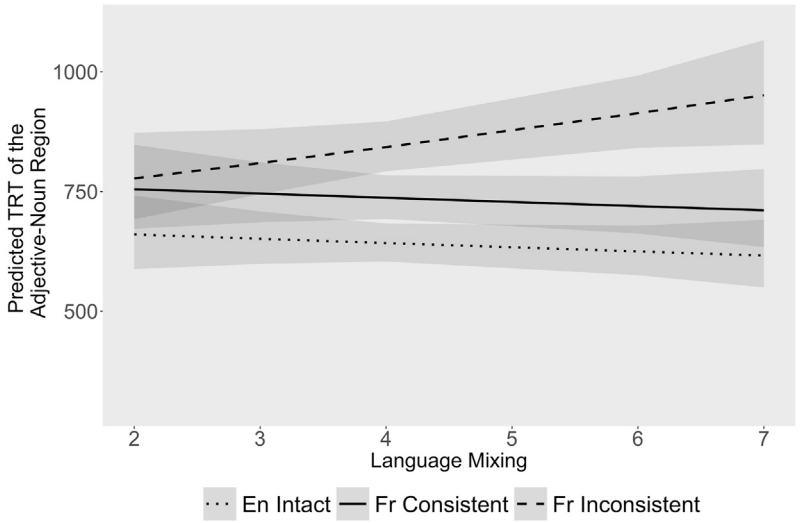

FIGURE 2 | Experiment 1 (French-English bilinguals reading in L2), interaction effect of language mixing (out of 7) on predicted total reading time (in ms) of the adjective-noun region. Shaded area represents plus/minus one standard error of the mean.

distinguish between the three sentence types. As L2 experience increases, readers are able to differentiate between French-inconsistent ungrammatical sentences and the other two sentence types (which were processed more readily). Importantly, there were no differences between French-consistent sentences and English intact sentences.

In contrast with L2 speaking that impacted first pass gaze duration, individual differences in language mixing impacted total reading time. When the baseline was set to French-consistent, we found a significant interaction between the French-inconsistent vs. French-consistent contrast and language mixing (β = 0.07, SE = 0.02, t = 2.69, p < 0.01; see **Figure 2**). When the baseline was set to French-inconsistent, there was a significant interaction between the French-inconsistent vs. English intact contrast and language mixing (β = 0.07, SE = 0.02, t = −2.79, p < 0.01). These significant interactions suggest that a higher frequency of mixing French and English was associated with a greater difference in total reading times between English intact constructions and French-inconsistent constructions, as well as between French-consistent constructions and French-inconsistent constructions.

Object-Pronoun Constructions

Core models. A treatment coded model with French-consistent as the baseline showed that constructions embedded in French-consistent sentences had significantly longer gaze durations than those embedded in English intact sentences (β = −0.18, SE = 0.02, t = −6.60, p < 0.01). However, there was no significant difference between French-consistent and French-inconsistent constructions (β = −0.02, SE = 0.02, t = −0.98, p = 0.32).[7]

For total reading time, a treatment coded model with French-consistent as the baseline showed that constructions embedded in French-consistent sentences were read significantly slower than those embedded in English intact sentences (β = −0.33, SE = 0.03, t = −10.08, p < 0.01). However, there was no significant difference between French-consistent and French-inconsistent constructions (β = −0.03, SE = 0.03, t = −1.20, p = 0.22).[8]

Effects of bilingual language experience. Similar to the analyses for adjective-noun constructions, we reran the above models including language mixing as an interaction term and general L2 (English) speaking as a control variable, and vice versa. Again, we discuss only significant interaction effects involving condition. Individual differences in general frequency of L2 speaking interacted with the English intact condition for total reading time. Specifically, there was a significant interaction for total reading time between the French-consistent vs. English intact contrast and general frequency of L2 speaking (β = 0.08, SE = 0.03, t = 2.67, p < 0.01) (see **Figure 3**). This interaction suggests that the more one speaks their L2, the less they experience processing costs for sentences that contain word order violations that are either consistent or inconsistent with French.

Furthermore, there was a significant interaction for total reading time between the French-inconsistent vs. English intact and language mixing (β = −0.07, SE = 0.03, t = −2.16, p = 0.03) (see **Figure 4**). This interaction suggests that the more one is exposed to environments where both English and French are used in daily life, the more they experience processing costs for sentences that contain word order violations.

[7]A refit model with the reference level set at French-inconsistent showed that first pass gaze durations for French-inconsistent constructions were longer than those embedded in English intact constructions (β = −0.16, SE = 0.02, t = −5.60, p < 0.01).

[8]A refit model with the reference level set at French-inconsistent showed that total reading time for French-inconsistent constructions were longer than those embedded in English intact constructions (β = −0.29, SE = 0.03, t = −8.88, p < 0.01).

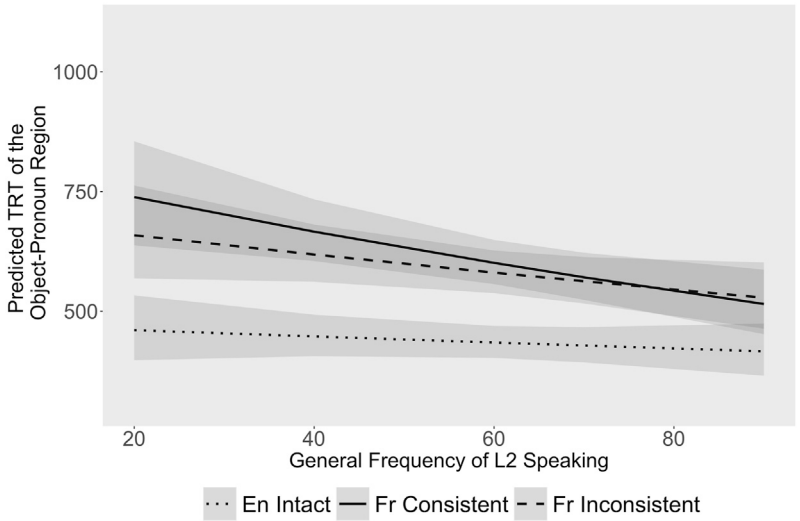

FIGURE 3 | Experiment 1 (French-English bilinguals reading in L2), interaction effect of general frequency of L2 speaking (out of 100%) on predicted total reading time (in ms) of the object-pronoun region. Shaded area represents plus/minus one standard error of the mean.

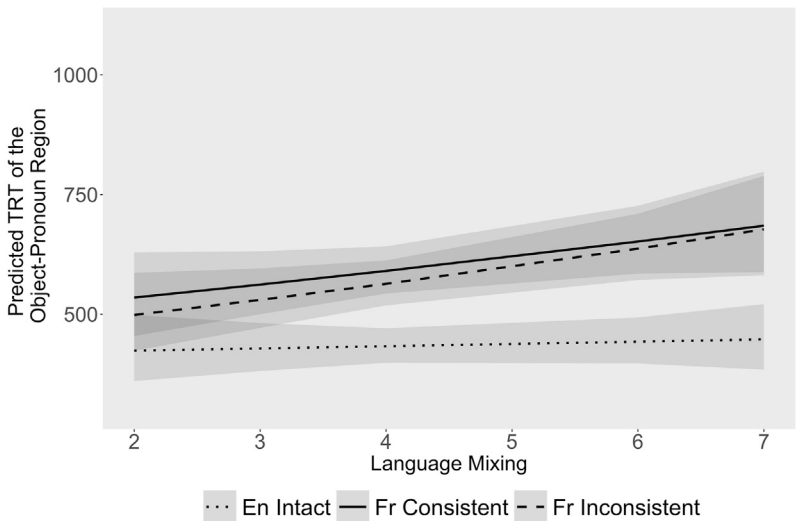

FIGURE 4 | Experiment 1 (French-English bilinguals reading in L2), interaction effect of language mixing (out of 7) on predicted total reading time (in ms) of the object-pronoun region. Shaded area represents plus/minus one standard error of the mean.

Discussion

The results of Experiment 1 were consistent with the idea that bilinguals activated L1 (French) adjective-noun word order when reading in their L2 (English) during early stages of sentence processing. Specifically, when bilinguals read adjective-noun constructions that were ungrammatical in English but felicitous in French, reading times were comparable to intact English sentences, and faster than sentences containing French-inconsistent violations, which may index cross-language syntactic activation. Further, this difference for adjective-noun constructions was reduced for later reading measures, suggesting that early cross-language activation occurred and was later resolved.

In contrast, object-pronoun constructions showed a different pattern. Here, gaze durations and total reading times for both French-consistent and -inconsistent constructions were longer than gaze durations and total reading times for English intact constructions. Thus, when reading object-pronoun constructions, French-English bilingual participants reading in their L2 showed less tolerance of violations overall. Taken together, the L2 readers tested here appeared to show early syntactic cross-language activation of adjective-noun

constructions that was attenuated for later reading measures, but they never showed cross-language activation of object-pronoun constructions for any reading measure.

Interestingly, individual differences in the general frequency of L2 English speaking and language mixing modulated reading behavior for both constructions. For Adjective-Noun constructions, as can be seen in **Figure 1**, the interaction on early reading measures was driven by the finding that bilingual readers with low general frequency of L2 speaking experience did not show evidence of discriminating between the three conditions at this stage of processing. However, as the general frequency of L2 speaking increased, both intact and French-consistent sentences were read more quickly than the French-inconsistent sentences. This suggests that L2 readers who had less experience with English were less able to distinguish between grammatically correct vs. incorrect sentences, whereas readers with more L2 English experience had comparable gaze durations for both intact and French-consistent sentences that were shorter than for French-inconsistent sentences. Thus, compared to readers with low general frequency of English L2 speaking, they were better able to differentiate intact sentences from sentences that are completely wrong early on.

Moreover, individual differences in general frequency of L2 speaking also played a role during late stages of processing object-pronoun constructions. Total reading times for French-English bilinguals who spoke their L2 frequently suggested greater tolerance of manipulated sentences. In contrast, French-English bilinguals with low frequency of L2 speaking showed a larger preference for the intact condition compared to both other conditions in overall total reading time. This pattern of results may be explained by an association of increased L2 exposure with greater reading fluency, with more fluent readers being able to covertly repair the word order issues in the moment. These readers were quicker at integrating constructions featuring violations than those with lower frequency of English L2 speaking—regardless of consistency with L1 French. Thus, across both constructions, readers who had greater L2 experience generally repaired grammatical violations more easily.

Individual differences in language mixing also modulated later measures of reading for both adjective-noun and object-pronoun constructions. Specifically, for adjective-noun constructions, higher exposure to bilingual discourse was associated with French-consistent violations being processed more similarly to intact sentences. In contrast, for object-pronoun constructions, the same was associated with French-consistent violations being processed more similarly to French-inconsistent constructions. The findings for French-English bilinguals reading in their L2 have implications for sentence processing models, as described in the introduction. Recall that the UCM would predict cross-language activation for both adjective-noun and object-pronoun constructions, because both constructions conflict across languages. Thus, the pattern found for adjective-noun constructions in Experiment 1 (L2 reading), but not the one found for object-pronoun construction, was consistent with the predictions of the UCM.

While the findings of Experiment 1 (L2 reading) suggest that cross-language activation occurs to some extent when bilinguals read sentences containing violations of adjective-noun structures, it is unclear whether the same pattern of results would occur when bilinguals read in their L1. Some past research has suggested that cross-language activation at a lexical level is less likely to occur during L1 sentence reading (Schwartz and Kroll, 2006; Libben and Titone, 2009; Titone et al., 2011). However, a recent study by Gullifer and Titone (2019) found that under certain circumstances, cross-language activation may in fact be greater for L1 reading because of reduced vigilance with respect to bilingual language control compared to L2 reading. To further investigate these issues within the context of the current experimental design, we investigated the L1 (English) reading patterns of English-French bilinguals, using the same materials and procedures as in Experiment 1.

EXPERIMENT 2: ENGLISH-FRENCH BILINGUALS READING IN ENGLISH (L1 READING)

Method

Participants. We tested 21 English-French bilinguals (3 men, 18 women) at McGill University and the University of Western Ontario, who did not speak additional languages fluently according to self-report. Participants had a mean age of 21.18 years (*SD* = 4.12), with no uncorrected vision, speech, or reading impairments. Participant recruitment and compensation were as in Experiment 1. Participants reported speaking their L2, French, 20.22% (*SD* = 13.97; Min = 0; Max = 50) of the time. On average, they rated their likelihood to mix French and English as 3.28 out of 7 (*SD* = 1.03; Min = 1; Max = 5).

Materials. The materials were the same as in Experiment 1.

Procedure. The procedure was the same as in Experiment 1.

Apparatus. The apparatus was the same as in Experiment 1.

Data preprocessing and analytic approach. The data preprocessing was conducted in the same way and the analytic approach was the same as in Experiment 1.

We excluded observations where the region of interest was skipped. In the adjective-noun experiment, this led us to exclude 19 observations from the first pass gaze duration analysis and 13 observations from the total reading time analysis.[9] In the object-pronoun experiment, this led us to exclude 27 observations from the first pass gaze duration analysis and ten observations from the total reading time analysis.[10] No observations exceeded the upper cut-off.

[9]Of the observations excluded from the first pass gaze duration analysis, eight were presented in the English intact condition, nine in the French-consistent and two in the French-inconsistent condition. Of those, seven of the observations presented in the English intact condition, five of the French-consistent and one of the observations presented in the French-inconsistent condition were also excluded from the total reading time analysis.

[10]Of the observations excluded from the first pass gaze duration analysis, four were presented in the English intact condition, ten in the French-consistent and 13 in the French-inconsistent condition. Of those, one of the observations presented in the English intact condition, five of the French-consistent and four of the observations presented in the French-inconsistent condition were also excluded from the total reading time analysis.

Results

Sentence Comprehension. Sentence comprehension accuracy was 91% among English-French bilinguals, indicating that they were attentive during the reading task.

Adjective-Noun Constructions

Core models. A treatment coded model with French-consistent as the baseline showed that gaze durations for French-consistent constructions were significantly longer than those for English intact constructions ($\beta = -0.08$, $SE = 0.02$, $t = -3.04$, $p < 0.01$), but similar to those for French-inconsistent constructions ($\beta = 0.03$, $SE = 0.02$, $t = 1.10$, $p = 0.27$).[11]

A treatment coded model with French-consistent as the baseline showed that total reading times for French-consistent constructions were longer than those for English intact constructions ($\beta = -0.26$, $SE = 0.03$, $t = -8.45$, $p < 0.01$), but shorter than those for French-inconsistent constructions ($\beta = 0.11$, $SE = 0.03$, $t = 3.77$, $p < 0.01$).[12]

Effects of bilingual language experience. Similar to Experiment 1, we reran the above models including language mixing as an interaction term and general frequency of L2 (French) speaking as a control variable, and vice versa. Below, we discuss only significant interaction effects if they involved condition. There was no significant interaction involving language mixing. There was no significant interaction for gaze duration involving general frequency of L2 speaking. There was a significant interaction for total reading time between the French-consistent vs. English intact contrast and L2 speaking ($\beta = 0.09$, $SE = 0.03$, $t = 2.83$, $p < 0.01$), and between the French-inconsistent vs. English intact contrast ($\beta = 0.07$, $SE = 0.03$, $t = 2.43$, $p = 0.01$) (see **Figure 5**). These interactions suggest that the more one speaks their L2 (French), the less they experience processing costs for L1 (English) sentences that contain any word order violations (i.e., whether they are consistent or inconsistent with French).

Object-Pronoun Constructions

Core models. A treatment coded model with French-consistent as the baseline showed that gaze durations for French-consistent constructions were longer than those for English intact constructions ($\beta = -0.05$, $SE = 0.03$, $t = -1.96$, $p = 0.04$), but no different from those for French-inconsistent constructions ($\beta = -0.01$, $SE = 0.03$, $t = -0.62$, $p = 0.53$).[13]

A treatment coded model with French-consistent as the baseline showed that total reading times for French-consistent constructions were longer than those for English intact constructions ($\beta = -0.21$, $SE = 0.03$, $t = -6.11$, $p < 0.01$), but shorter than those for French-inconsistent constructions ($\beta = 0.08$, $SE = 0.03$, $t = 2.47$, $p = 0.01$).[14]

Effects of bilingual language experience. We reran the models above including language mixing as an interaction term and general frequency of L2 speaking as a control variable, and vice versa. There was no significant interaction involving language mixing. Individual differences in general frequency of L2 speaking interacted with the English intact condition for gaze duration. Specifically, there was a significant interaction for gaze duration between the French-consistent vs. English intact contrast and general frequency of L2 speaking ($\beta = -0.05$, SE = 0.03, $t = 1.98$, $p = 0.04$) (see **Figure 6**). This interaction suggests that the more English-French bilinguals speak their L2, the more they experience processing costs for L1 sentences that contain word order violations that are consistent with French.

Discussion

English-French bilinguals reading in their L1 (English) showed limited evidence of cross-language syntactic activation for both construction types. For both adjective-noun and object-pronoun constructions, there was no significant difference between French-consistent and French-inconsistent violations in early measures, whereas for late reading measures, French-consistent violations were read more quickly than French-inconsistent violations, and more slowly than English intact sentences. This suggests that English-French bilinguals were initially sensitive to any violation. However, they were faster overall at integrating both adjective-noun and object-pronoun constructions when they included a violation consistent with their L2 (French) than when the violation was inconsistent with their L2.

Furthermore, individual differences in general frequency of L2 speaking modulated later measures of reading for adjective-noun, whereas it was only associated with early sensitivity to violations of object-pronoun constructions. Total reading times for English-French bilinguals who spoke their L2 frequently exhibited less of a difference between manipulated sentences containing adjective-noun constructions. As can be seen in **Figure 5**, L1 readers who used their L2 about half of the time were quicker at integrating constructions featuring adjective-noun violations than those who spoke their L2 less frequently—regardless of consistency with French.

Of note, the range of general frequency of L2 speaking was greater for the group of French-English bilinguals tested in Experiment 1 who spoke English between 20 and 90% of the time, whereas the English-French bilinguals tested in Experiment 2 spoke French between 0 and 50% of the time. This suggests that English-French bilinguals on the higher end of this spectrum might be balanced bilinguals, whereas French-English on the higher end of the spectrum may be reverse

[11]A refit model with the reference level set at French-inconsistent showed that first pass gaze durations for French-inconsistent constructions were longer than those English intact constructions ($\beta = -0.11$, $SE = 0.02$, $t = -4.16$, $p < 0.01$).

[12]A refit model with the reference level set at French-inconsistent showed that total reading times for French-inconsistent constructions were longer than those in English intact constructions ($\beta = -0.38$, $SE = 0.03$, $t = -12.24$, $p < 0.01$).

[13]A refit model with the reference level set at French-inconsistent showed no significant differences in first pass gaze duration among the sentence types ($t < 1.96$, $p > 0.05$).

[14]A refit model with the reference level set at French-inconsistent showed that total reading times for French-inconsistent constructions were longer than those in English intact constructions ($\beta = -0.30$, $SE = 0.03$, $t = -8.59$, $p < 0.01$).

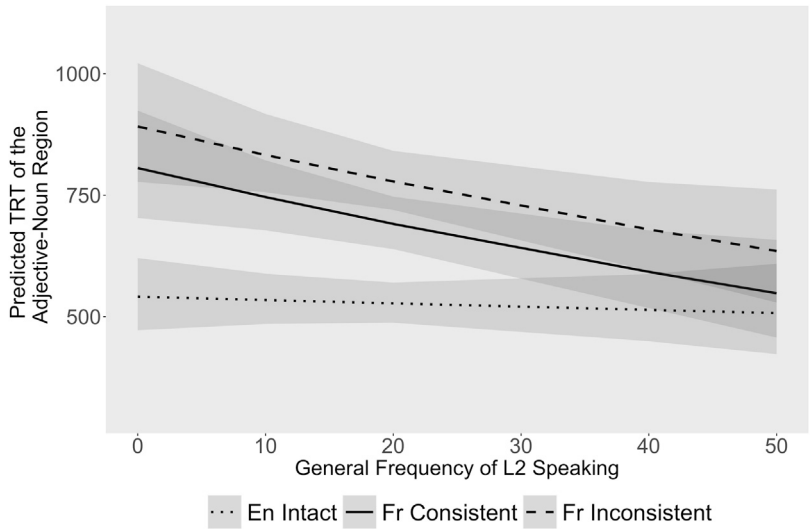

FIGURE 5 | Experiment 2 (English-French bilinguals reading in L1), interaction effect of general frequency of L2 speaking (out of 100%) on predicted total reading time (in ms) of the adjective-noun region. Shaded area represents plus/minus one standard error of the mean.

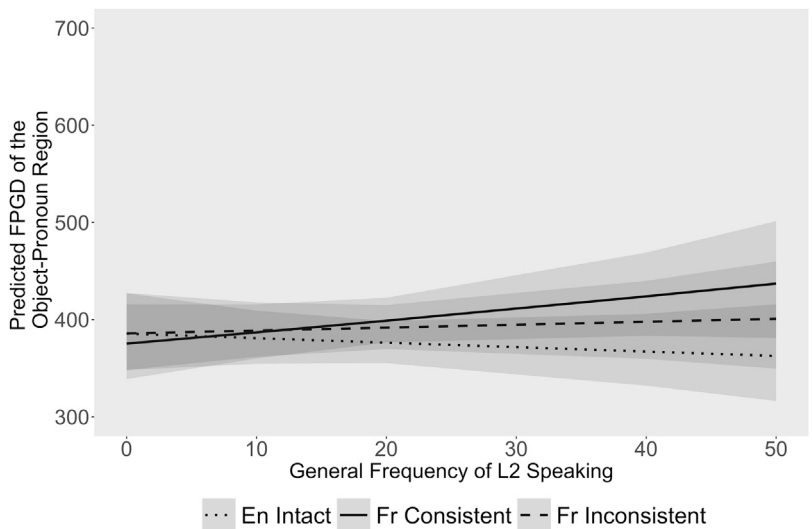

FIGURE 6 | Experiment 2 (English-French bilinguals reading in L1), interaction effect of general frequency of L2 speaking (out of 100%) on predicted first pass gaze duration (in ms) of the object-pronoun region. Shaded area represents plus/minus one standard error of the mean.

dominant. This may help explain the different patterns of results found across Experiments 1 and 2. More specifically, the pattern of results observed here may be explained by an association of increased L2 exposure with greater reading fluency and ability to repair violations, whether these stems from intrusion from the L2 or not.

Taken together, the L1 reading data suggested some degree of cross-language syntactic activation for both adjective-noun and object-pronoun constructions during later stages of processing. An extension of the UCM to highly proficient bilinguals predicted that all bilingual readers would exhibit cross-language activation during L1 reading when the constructions are unshared across the two known languages. However, crucial to the interpretations generated here, tolerance of a violation (i.e., faster reading times) may not only be a result of cross-language influence, but also the number, strength, and position of cues to ungrammaticality. Thus, in Experiment 3, we tested English monolingual reading for the same sentences. To the extent that the above-described results are due to cross-language syntactic activation, people who are functionally monolingual (but may be ambiently exposed to French) should differ to a much lesser degree in their processing of French-consistent and French-inconsistent violations.

EXPERIMENT 3: FUNCTIONALLY MONOLINGUAL ADULTS READING IN ENGLISH

Method

Participants. We tested 26 functionally English monolingual adults (8 men, 18 women) at the University of Western Ontario. Participants had a mean age of 20.27 years (SD = 3.52), with no uncorrected vision, speech, or reading impairments. Participant recruitment and compensation were as in Experiments 1 and 2. Participants had little to no French proficiency (or other languages) based on self-report on the language history questionnaire (Marian et al., 2007), as well as performance on a semantic decision task on French and English words (i.e., animate vs. inanimate judgment; Segalowitz et al., 1995).

Materials. The materials were the same as in Experiments 1 and 2.

Procedure. The procedure was the same as in Experiments 1 and 2.

Apparatus. The apparatus was the same as in Experiments 1 and 2.

Data preprocessing and analytic approach. The data preprocessing was conducted in the same way and the analytic approach was the same as in Experiments 1 and 2.

We excluded observations where the region of interest was skipped. In the adjective-noun experiment, this led us to exclude 17 observations from the first pass gaze duration analysis and two observations from the total reading time analysis.[15] In the object-pronoun experiment, this led us to exclude 40 observations from the first pass gaze duration analysis and 27 observations from the total reading time analysis.[16] No observations exceeded the upper cut-off.

Results

Sentence Comprehension. Sentence comprehension accuracy was 90% among English monolingual participants, indicating that they were attentive during the reading task.

Adjective-Noun Constructions

Core models. A treatment coded model with French-consistent as the baseline showed that constructions embedded in French-consistent sentences had significantly shorter gaze durations than those embedded in French-inconsistent sentences (β = 0.05, SE = 0.02, t = 2.12, p = 0.03). However, there was only a marginally significant difference between English intact and French-consistent constructions (β = −0.04, SE = 0.02, t = −1.78, p = 0.07).[17]

For total reading time, a treatment coded model with French-consistent as the baseline showed that total reading times for constructions embedded in French-consistent sentences were longer than that for English intact sentences (β = −0.16, SE = 0.02, t = −5.89 p < 0.01) but shorter for French-inconsistent sentences (β = 0.13, SE = 0.02, t = 4.73, p < 0.01).[18]

Object-Pronoun Constructions

Core models. A treatment coded model with French-consistent as the baseline showed that gaze durations for French-consistent constructions were longer than those for English intact constructions (β = −0.08, SE = 0.02, t = −2.99, p < 0.01), but not different from those for French-inconsistent constructions (β = 0.0, SE = 0.02, t = 0.89, p = 0.37).[19]

A treatment coded model with French-consistent as the baseline showed that total reading times for French-consistent constructions were longer than those for English intact constructions (β = −0.19, SE = 0.03, t = −5.90, p < 0.01), but only marginally significantly different from French-inconsistent constructions (β = 0.60, SE = 0.03, t = 1.81, p = 0.06).[20]

Discussion

The results of Experiment 3 suggest that English speakers who were functionally monolingual were nevertheless sensitive to syntactic violations overall but differed in how sensitive they were to violations of adjective-noun and object-pronoun word order. Overall, this group was less sensitive to violations of adjective-noun constructions than object-pronoun constructions (consistent with the bilingual data reported in Experiments 1 and 2). For adjective-noun constructions, early reading measures suggested instant sensitivity to violations that were inconsistent with French, but not to those consistent with French. Later measures suggested increased sensitivity to both types of violations. For object-pronoun constructions, self-described monolingual readers were consistently sensitive to any type of violation. In sum, these effects suggest that while monolinguals are sensitive to syntactic violations overall, the time course of sensitivity to violations of adjective-noun and object-pronoun constructions differs, independently of any substantial influence of cross-language activation.

[15]Of the observations excluded from the FPGD analysis, six were presented in the English intact condition, six in the French-consistent and five in the French-inconsistent condition. Of those, one of the observations presented in the English intact condition and one of the observations presented in the French-inconsistent condition were also excluded from the TRT analysis.

[16]Of the observations excluded from the FPGD analysis, fourteen were presented in the English intact condition, thirteen in the French-consistent and 13 in the French-inconsistent condition. Of those, ten of the observations presented in the English intact condition, eight of the French-consistent and nine of the observations presented in the French-inconsistent condition were also excluded from the TRT analysis.

[17]A refit model with the reference level set at French-inconsistent showed first pass gaze durations for French-inconsistent constructions were longer than those embedded in English intact constructions (β = −0.10, SE = 0.02, t = −3.91, p < 0.01).

[18]A refit model with the reference level set at French-inconsistent showed that total reading time for French-inconsistent constructions were longer than those in English intact constructions (β = −0.30, SE = 0.02, t = −10.63, p < 0.01).

[19]A refit model with the reference level set at French-inconsistent showed that first pass gaze durations for French-inconsistent constructions were longer than English intact constructions (β = −0.11, SE = 0.02, t = −3.89, p < 0.01).

[20]A refit model with the reference level set at French-inconsistent showed that total reading times for French-inconsistent constructions were longer than those in English intact constructions (β = −0.25, SE = 0.03, t = −7.71, p < 0.01).

The finding that reading patterns for functional monolingual readers were similar to those exhibited by L2 readers (Experiment 1), clouds our prior interpretation of cross-language activation in Experiments 1 and 2, and suggests that those differences may in fact be a result of certain violations being easier to process than others (i.e., "the car red" is easier to process than "red the car") because the former is more akin to a simple word transposition error than the latter. These similarities may also stem from the presence of cues to ungrammaticality and their position in the sentence (i.e., "red the car" becomes ungrammatical at "the", which is earlier than "the car red", which becomes ungrammatical at "red"). To explore this possibility, we conducted supplementary analyses.

Supplementary Analyses. Because readers environmentally exposed to English and French but functionally monolingual exhibited a pattern of results consistent with bilingual adults (but potentially arising from the increased likelihood of word transposition errors for particular items), we conducted an additional analysis to verify the effect of the experimental manipulation for the data in Experiments 1 and 2 (respectively, L2 and L1 reading). Specifically, we verified that the observed effects were not merely due to between-item differences in the strength of the syntactic violation. It is possible that for some items, particular violations were more salient than others, which would be likely to increase reading times for those violations. In order to assess this, we calculated a difference score for each item by subtracting monolinguals' first pass gaze durations of French-consistent constructions from monolinguals' first pass gaze durations of English intact constructions. If this yielded a negative difference (i.e., English intact first pass gaze durations < French-consistent first pass gaze durations), we would conclude that this particular item was not susceptible to word transposition errors (i.e., the French-consistent construction was harder to process than the English intact construction).

After doing this, we reran the analyses from Experiment 1 and 2 involving the bilingual samples, controlling for this item-level difference score in the base models. Crucially, the pattern of results was comparable to the original ones, suggesting that they were due to the experimental manipulation. Model comparisons also showed that controlling for the difference score did not improve the fit of any models. However, this exercise highlights one of the challenges that must be addressed when studying multiword constructions in this manner.

In addition, closer inspection of items containing an adjective-noun construction also revealed some ambiguous or alternative interpretations of the sentences, which may have contributed to the observed reading patterns (we thank a careful reviewer for raising this point). First, fifteen of the French-consistent sentences could have potentially been grammatically correct under a set of circumstances that were not true of our sentence materials. For example, the sentence "He seized the shirt wrinkled that needed to be ironed" is ungrammatical because the adjective-noun phrase is followed by the conjunction that. This means that the sentence only becomes ungrammatical after the region of interest. Indeed, had the sentence featured an adjectival phrase (e.g., "He seized the shirt wrinkled by the cats that needed to be ironed"), the adjective-noun word order would have been grammatical. Second, 11 of the French-consistent sentences could have been grammatically correct, assuming that the sentence ended immediately following the region of interest, which was also not true of our sentence materials. For example, the sentence "The father left the house empty that needed to be cleaned" would be grammatical if it had read only "The father left the house empty", as it may be interpreted as a resultative construction.

To ensure that this serendipitous variability across items did not systematically impact the results, we took the following steps. First, we coded the items to be "as intended", "not as intended". We then reran our analysis on only the 34 items labeled "as intended", while still controlling for the above-described item-level difference score (i.e., subtracting monolinguals' first pass gaze durations of French-consistent constructions from monolinguals' gaze durations of English intact constructions). Crucially, this did not substantially change the results, suggesting that the patterns of results observed in Experiments 1 and 2 were not likely driven by these problematic items. A summary of the models used in both supplementary analyses can be found in the OSF repository (https://osf.io/jec5s/?view_only=a9d0ad4f9b994cd9b93371d2a2089cf1).

GENERAL DISCUSSION

In this study, we addressed the following questions: 1) Do bilingual readers show evidence of cross-language syntactic activation during L2 and L1 reading of adjective-noun and object-pronoun constructions (Experiments 1 and 2); 2) Do individual differences in language mixing and general frequency of L2 speaking modulate cross-language activation patterns during bilingual reading (Experiments 1 and 2); and 3) How do monolingual reading patterns of adjective-noun and object-pronoun constructions compare to those of bilinguals (Experiment 3). We discuss each in turn.

1) Do bilingual readers show evidence of cross-language syntactic activation during L2 and L1 reading of adjective-noun and object-pronoun constructions (Experiments 1 and 2)

In L2 reading (Experiment 1), we found that French-English bilinguals reading sentences that contained adjective-noun constructions were less sensitive to the French-consistent violation during early stage reading, as evidenced by comparable gaze durations for English intact and French-consistent constructions. Sensitivity increased during later stages of reading, where French-consistent constructions were "in the middle"; they were slower than English intact constructions, but faster than French-inconsistent constructions. This pattern suggests that L1 French adjective-noun syntactic frame was active during early stages of L2 English processing, and to a lesser extent, during late stages. When the same participants read sentences containing object-pronoun constructions, a French-consistent violation did not behave the same way. Specifically, there was no difference in how French-

English bilinguals read French-consistent vs. inconsistent violations, suggesting that no cross-language activation of the L1 French object-pronoun construction occurred during L2 English processing.

In L1 reading (Experiment 2), English-French bilinguals were initially sensitive to all violations, whether these were consistent with their L2 (French) or not. For both adjective-noun and object-pronoun constructions, there was no difference between French-consistent and French-inconsistent violations in early measures. During later stages of processing, L1 readers were somewhat less sensitive to violations that were consistent with their L2 (French), reading them more quickly than French-inconsistent violations. Overall, this pattern suggests some degree of activation of the L2 syntactic frames during late stages of L1 processing.

Existing models of bilingual sentence processing, such as the UCM, predict reduced sensitivity to syntactic violations that are consistent with the other known language as a result of cross-language activation (to the extent that the constructions conflict across languages). Moreover, a strict interpretation of the UCM would predict even greater tolerance for violations of the object-pronoun construction, as these constructions conflict across English and French to a greater degree than adjective-noun constructions. Here, this would have resulted in faster reading times for French-consistent compared to French-inconsistent violations, for adjective-noun constructions, and even more so for object-pronoun constructions. However, our results only partially align with these predictions as increased tolerance for French-consistent vs. French-inconsistent violations was only observed for adjective-noun constructions in both experiments, but not for object-pronoun constructions. Interestingly, tolerance for French-consistent violations was more apparent at early stages of processing for French L1 bilinguals, while it was present only during late stages of processing for English L1 bilinguals. This finding suggests that to the extent that cross-language activation of non-target constructions occurs, it may impact different aspects of processing—initial lexical processing of the construction for L2 readers, ambiguity resolution/error repair processes for L1 readers.

We emphasize here that the UCM formulates predictions based on offline behaviors (i.e., grammaticality judgements) and does not make explicit predictions about online behavior (i.e., eye movements of reading). Here, rather than looking at the impact of cross-language activation on an explicit grammaticality judgement, we investigated the time course of cross-language activation during natural reading in the absence of explicit grammaticality judgements. Thus, in applying this model here, we are assuming that comprehension outcome and process are related to some degree. Additionally, the UCM model makes no specific predictions regarding the dynamic manipulation of cues during processing, which makes it difficult to formulate clear predictions about online sensitivity during various stages of processing, and thus may explain a lack of alignment of our results with model predictions.

2) Do individual differences in language mixing and general frequency of L2 speaking modulate cross-language activation patterns during bilingual reading (Experiments 1 and 2)

In addition to examining reading time differences across the sentence conditions at the group level, we also examined whether individual differences in L2 experience among readers modulated cross-language activation. When French-English bilinguals (L2 reading) read adjective-noun constructions, more frequent English L2 speaking was associated with increased tolerance to the French-consistent violation on early measures of reading, whereas for object-pronoun constructions, the same was associated with higher tolerance to violations overall on late measures of reading. Among the same participants, late measures of reading showed that higher language mixing was associated with more similar processing of English intact and French-consistent adjective-noun constructions, whereas the same was associated with reduced overall tolerance to any type of violation of object-pronoun constructions. When English-French bilinguals (L1 reading) read adjective-noun constructions, late measures showed that higher frequency of French L2 speaking was associated with increased tolerance to either type of violation. When the same participants read object-pronoun constructions, early measures showed that higher frequency of French L2 speaking was associated with somewhat decreased tolerance to violations consistent with French.

In the literature, there is some empirical evidence suggesting that syntactic structures for each language are represented separately for bilinguals at low levels of proficiency, whereas syntactic representations may become increasingly shared for proficient bilinguals, leading to greater cross-language syntactic activation (Bernolet et al., 2009; reviewed in; Hartsuiker and Pickering, 2008). This may explain why French-English bilinguals with high frequency of L2 English usage were more tolerant of French-consistent violations of the adjective-noun constructions.[21] Moreover, as we also found increased tolerance to these violations for French-English bilinguals with high frequency of language mixing, language mixing may also contribute to the integration of syntactic representations across languages. In contrast, as high frequency of L2 French speaking was associated with increased tolerance of all types of violations of the adjective-noun in English-French bilinguals, it may suggest that high levels of experience with L2 may enhance flexibility in processing syntactic violations during L1 reading independently of whether these are consistent with L2.

In contrast with adjective-noun constructions, the individual differences pattern for object-pronoun constructions suggests that not all constructions have a comparable status in the bilingual mind as bilingual experience never uniquely impacted the processing of French-consistent violations of object-pronoun constructions, it is possible that these constructions, which conflict maximally in word order across English and French, are stored separately (see Loebell and Bock, 2003). In contrast, constructions with word order overlap may become increasingly shared as bilingual experience increases

[21]It should be noted, however, that these results contradict earlier findings suggesting that age of acquisition is more critical for syntactic representation than proficiency (e.g., Wartenberger et al., 2003).

(Hartsuiker et al., 2004; Bernolet et al., 2009). We discuss other differences between the two constructions that may have contributed to this effect below.

3) How do monolingual reading patterns of adjective-noun and object-pronoun constructions compare to those of bilinguals (Experiment 3)

Functionally monolingual readers were somewhat more tolerant of French-consistent violations to adjective-noun word order than they were of French-inconsistent violations, especially during early reading measures. However, no such tolerance was observed for violations of object-pronoun word order. For object-pronoun word order, functional monolinguals read both French-consistent and French-inconsistent constructions more slowly than English intact constructions, across early and late reading measures.

The observed reading patterns suggest that while monolinguals are sensitive to syntactic violations overall, the time course of sensitivity to violations of adjective-noun and object-pronoun constructions differs, independently of any substantial influence of cross-language activation. The difference in processing patterns across the two types of syntactic constructions may be a result of the cues to ungrammaticality that each construction provides. Thus, it is possible that the violation to adjective-noun word order was noticeable but did not impact readers' ability to comprehend the sentence, as adjectives are not crucial to sentence grammaticality. In contrast, the violation may have been more harmful to the comprehension of sentences containing an object-pronoun construction, as omission of object-pronouns in transitive clauses directly causes ungrammaticality.

While monolingual reading patterns cannot be influenced by cross-language activation, we did find that the reading patterns of functional English monolinguals resembled those exhibited by French-English bilinguals reading in their L2 (Experiment 1). Specifically, both functionally monolingual and L2 readers showed initial tolerance of the French-consistent violation that was attenuated during later stages of processing, whereas English-French bilinguals reading in their L1 showed no tolerance on early measures of processing and only limited tolerance of the French-consistent violations on late stages of processing.

It is important to acknowledge several limitations in the selection of stimuli in the adjective-noun experiment that may have contributed to the first pass gaze duration patterns of monolingual and L2 readers. Specifically, some of the French-consistent sentences included in our experiment do not become ungrammatical until after the region of interest. This could have led to the increased tolerance of the French-consistent violation during the early stages of reading. However, the results of our supplemental analysis reproduced the above-described effect with a subset of only those items that included an unambiguous violation, this does not appear to be driving the observed pattern of effects. Nevertheless, it remains possible that idiosyncratic aspects of the particular sentences we used could have impacted the results in some fashion. Thus, future work should more carefully consider the interaction of grammatical structure and lexical choice with respect to these issues.

Perhaps, the observed pattern of results could be explained by the common observation that for functionally monolingual readers, processing of frequent constructions, such as adjective-noun and object-pronoun constructions, may be automatic and effortless. There is also evidence that monolinguals have a larger perceptual span or area of effective visual perception during reading, which means that they likely make fewer fixations to comprehend a phrase (Whitford and Titone, 2012; Whitford and Titone 2015). Both of these factors may lead to higher tolerance of syntactic violations, because their efficient processing capacity facilitates recovery from errors. L2 readers show similar patterns, though potentially for a different reason. Their reduced proficiency/relative exposure to the L2 may result in a smaller perceptual span (Whitford and Titone, 2015) and less automatized L2 syntactic processing compared to L1 (Favreau and Segalowitz, 1983). This, combined with non-selective activation, is likely to impact L2 processing, resulting ultimately in higher tolerance of violations. Lastly, L1 reading (Experiment 2) may also be affected by non-selective activation, in that increased control is required to suppress transfer from the L2 (see Gullifer and Titone, 2019), while also benefitting from stronger activation of the L1 syntactic frames and a perceptual span similar to the one exhibited by monolinguals (Whitford and Titone, 2012; Whitford and Titone 2015). Ultimately, this may result in decreased tolerance to violations when reading in L1.

As this account suggests, it is possible that the reading patterns observed across all three experiments were not exclusively a result of the presence or absence of cross-language activation, but rather a result of an interplay of factors, including word transposition characteristics as well as cues to ungrammaticality, which are likely correlated. For example, a recent study found that French monolingual participants were slow and generally inaccurate when judging the grammaticality of sentences with transposed words (Mirault et al., 2018). Importantly, these transposition effects were more salient for function words (e.g., pronouns) compared to content words (e.g., adjectives and nouns). The researchers suggest that this pattern is linked to the role each type of word plays in making up a grammatical sentence. Specifically, function words allow the reader to quickly build a syntactic frame, which is then filled in with content words. Thus, a violation of the structure of the frame (i.e., pronoun word-order violation) may be more detrimental to perceived grammaticality than a violation of the content word position. This interpretation is in line with what we have found for both monolingual and bilingual reading in that across groups, tolerance of violations was generally lower for object-pronoun constructions than adjective-noun constructions.

Given this account, the processing pattern we observed in this study point to the presence of word transposition effects. Some languages, such as German, which rely heavily on a case system (Bornkessel and Schlesewsky, 2006), are highly flexible in their word order and as a result, their speakers may be less sensitive to word order transpositions. In both English and French, however, word order is crucial to comprehension. Thus, the overall sensitivity to

word transpositions in this experiment should be comparable across the types of constructions and groups of readers, hence it is critical that a monolingual control group be included. There may be less transfer between language systems when word order is a reliable indicator of grammatical function across the L1 and L2. Indeed, our pattern of results suggests that any possible effects of cross-language activation may be diminished in the presence of a cue as strong as word order in English and French. Thus, when investigating cross-linguistic effects, it is crucial to consider strength of grammatical cues across language pairs (see Mirault et al., 2018, for a similar argument).

Another intriguing possibility is that in multilingual communities where particular languages routinely converge and mix (e.g., English and French in Montreal), the ambient linguistic environment is more likely to contain language-mixed constructions (i.e., syntactic "accents") produced by people who are prone to making such errors. For example, in Montreal a frequent example of such a syntactic accent is when English speakers say, "close the lights" vs. "shut the lights". What makes this example compelling is that "close the lights" is not normative for English, however, because it is the English translation equivalent of the normative French construction "fermer la lumière", French-English bilinguals routinely produce that utterance. In turn, because that utterance finds itself in the linguistic environment, that makes it more frequently encountered for all language users, including language users who are functionally monolingual. Indeed, recent work by Bice and Kroll (2019), compared monolinguals who live in a linguistically diverse context (i.e., California) with monolinguals living in a linguistically homogenous context (i.e., Pennsylvania) on their abilities to learn vowel harmony in Finnish. Their findings suggest that exposure to linguistic diversity promotes new language learning. In other words, there can be "bilingual effects" on functional monolinguals within a geographic multilingual community.

In fact, bilinguals' tolerance of cross-language patterns may be similarly affected by linguistic diversity in their environment. As such, tolerance to violations might not be due to something internal to bilinguals' language representation, but rather a result of the input they receive from other bilinguals in their community that includes these wrong patterns. Thus, in a usage-based fashion, some French-consistent patterns in English might become more acceptable over time (e.g., close the lights in Quebec) leading to the development of "syntactic accents". Importantly, to the extent that such effects can occur, it would lead to complexities in perfectly isolating pure "cross-language activation" of any type of construction. Thus, while we cannot directly address this issue currently in this particular study, we are mindful that such effects may be at play in a manner that is highly worthy of future investigation.

Lastly, it is important to keep in mind that most studies have employed offline tasks (such as grammaticality judgements), rather than online tasks (such as eye tracking). Thus, future studies may benefit from an approach combining these two measures to investigate which parts of a construction cause a sentence to be perceived as ungrammatical. As such, fixations on individual words within a construction, and their relationship to accuracy in grammatical judgements, should be investigated. As well, the between-group differences in this study point to a potential role for non-target language control in resolving syntactic violations. Investigating the impact of individual differences in executive control on bilingual syntactic processing is a desirable avenue for future work.

To conclude, the experiments presented in this manuscript provide some evidence about the presence of cross-language syntactic activation. For both L2 and L1 reading, we observed patterns consistent with cross-language influence for adjective-noun constructions, after item-level variability derived from monolingual readers was taken into account. Moreover, individual differences in L2 experience modulated both L2 and L1 reading for adjective-noun constructions. However, none of these effects emerged when the same participants read object-pronoun constructions. Thus, the totality of evidence leads us to tentatively conclude the presence of cross-language activation for adjective-noun constructions. Nevertheless, we caution future researchers examining this issue to be mindful of the many methodological complexities associated with investigating multiword constructions of this type using the violation method, and specifically attend to the fact that a lot more could be going on in these and other past reports than simply "pure" cross-language syntactic activation.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary Material. Data and code can be accessed from https://osf.io/jec5s/?view_ 1807onlya9d0ad4f9b994cd9b93371d2a2089cf1.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the McGill University Research Ethics Board and the University of Western Ontario Ethics Board. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DT designed the experiment. DT created the items and VW modified them. VW created the eye-tracking scripts to enable data collection. NV, JG, VW, DF, DJ, and DT contributed to the data acquisition. NV, PP, JG, and DT processed, analyzed, and interpreted the data. NV and PP drafted the final version of the manuscript, DT supervised the writing, and the remaining authors reviewed and provided critical feedback. All authors thus made a substantial and direct contribution to the work, and all have approved it for publication.

FUNDING

This work was supported by an NSERC Discovery Grant and Canada Research Chair Award to DT and an NSERC Discovery Grant to DJ.

REFERENCES

Barr, D. J., Levy, R., Scheepers, C., and Tily, H. J. (2013). Random Effects Structure for Confirmatory Hypothesis Testing: Keep it Maximal. *J. Mem. Lang.* 68 (3), 255–278. doi:10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., and Walker, S. (2015). Fitting Linear Mixed-Effects Models Usinglme4. *J. Stat. Soft.* 67 (1), 1–48. doi:10.18637/jss.v067.i01

Bernolet, S., Hartsuiker, R. J., and Pickering, M. J. (2009). Persistence of Emphasis in Language Production: A Cross-Linguistic Approach. *Cognition* 112 (2), 300–317. doi:10.1016/j.cognition.2009.05.013

Bice, K., and Kroll, J. F. (2019). English Only? Monolinguals in Linguistically Diverse Contexts Have an Edge in Language Learning. *Brain Lang.* 196, 104644. doi:10.1016/j.bandl.2019.104644

Bornkessel, I., and Schlesewsky, M. (2006). The Extended Argument Dependency Model: A Neurocognitive Approach to Sentence Comprehension across Languages. *Psychol. Rev.* 113 (4), 787–821. doi:10.1037/0033-295X.113.4.787

Clifton, C., Jr, Staub, A., and Rayner, K. (2007). "Eye Movements in reading Words and Sentences," in *Eye movements: A window on mind and brain*. Editors R. van Gompel, M. H. Fischer, W. S. Murray, and R. L. Hill (Oxford, United Kingdom. Elsevier), 341–372. doi:10.1016/b978-008044980-7/50017-3

Dijkstra, T., and Van Heuven, W. J. B. (2002). The Architecture of the Bilingual Word Recognition System: From Identification to Decision. *Bilingualism* 5 (3), 175–197. doi:10.1017/S1366728902003012

Dijkstra, T., Wahl, A., Buytenhuijs, F., Van Halem, N., Al-Jibouri, Z., De Korte, M., et al. (2019). Multilink: a Computational Model for Bilingual Word Recognition and Word Translation. *Bilingualism* 22 (4), 657–679. doi:10.1017/S1366728918000287

Dussias, P. E., and Sagarra, N. (2007). The Effect of Exposure on Syntactic Parsing in Spanish-English Bilinguals. *Bilingualism* 10 (1), 101–116. doi:10.1017/S1366728906002847

Dussias, P., Dietrich, A. J., and Villegas, Á. (2015). "Cross-language Interactions during Bilingual Sentence Processing," in *The Cambridge Handbook of Bilingual Processing*. Editor J. Schwieter (Cambridge: Cambridge University Press), 349–366. doi:10.1017/CBO9781107447257.016

Falkenstein, M., Hoormann, J., and Hohnsbein, J. (1999). ERP Components in Go/Nogo Tasks and Their Relation to Inhibition. *Acta Psychologica* 101 (2-3), 267–291. doi:10.1016/S0001-6918(99)00008-6

Favreau, M., and Segalowitz, N. S. (1983). Automatic and Controlled Processes in the First- and Second-Language reading of Fluent Bilinguals. *Mem. Cogn.* 11, 565–574. doi:10.3758/bf03198281

Fox, J., and Weisberg, S. (2018). Visualizing Fit and Lack of Fit in Complex Regression Models with Predictor Effect Plots and Partial Residuals. *J. Stat. Soft.* 87 (9), 1–27. doi:10.18637/jss.v087.i09

Frenck-Mestre, C. (2005). Eye-movement Recording as a Tool for Studying Syntactic Processing in a Second Language: A Review of Methodologies and Experimental Findings. *Second Lang. Res.* 21 (2), 175–198. doi:10.1191/0267658305sr257oa

Friesen, D. C., Ward, O., Bohnet, J., Cormier, P., and Jared, D. (2020). Early Activation of Cross-Language Meaning from Phonology during Sentence Processing. *J. Exp. Psychol. Learn. Mem. Cogn.* 46 (9), 1754–1767. doi:10.1037/xlm0000849

Green, D. W., and Wei, L. (2014). A Control Process Model of Code-Switching. *Lang. Cogn. Neurosci.* 29 (4), 499–511. doi:10.1080/23273798.2014.882515

Green, D. W., and Wei, L. (2016). Code-switching and Language Control. *Bilingualism* 19 (5), 883–884. doi:10.1017/s1366728916000018

Grosjean, F. (2001). "The Bilingual's Language Modes," in *One Mind, Two Languages: Bilingual Language Processing*. Editor J. Nicol (Oxford, UK: Blackwell), 1–22.

Gullifer, J. W., and Titone, D. (2019). The Impact of a Momentary Language Switch on Bilingual reading: Intense at the Switch but Merciful Downstream for L2 but Not L1 Readers. *J. Exp. Psychol. Learn. Mem. Cogn.* 45 (11), 2036–2050. doi:10.1037/xlm0000695

Hartsuiker, R. J., and Pickering, M. J. (2008). Language Integration in Bilingual Sentence Production. *Acta Psychologica* 128 (3), 479–489. doi:10.1016/j.actpsy.2007.08.005

Hartsuiker, R. J., Pickering, M. J., and Veltkamp, E. (2004). Is Syntax Separate or Shared between Languages?. *Psychol. Sci.* 15 (6), 409–414. doi:10.1111/j.0956-7976.2004.00693.x

Hirotani, M., Frazier, L., and Rayner, K. (2006). Punctuation and Intonation Effects on Clause and Sentence Wrap-Up: Evidence from Eye Movements. *J. Mem. Lang.* 54 (3), 425–443. doi:10.1016/j.jml.2005.12.001

Jared, D. (2015). "Literacy and Literacy Development in Bilinguals," in *Oxford Library of Psychology. The Oxford Handbook of reading*. Editors A. Pollatsek and R. Treiman (Oxford, UK: University Press), 165–182.

Kasparian, K., and Steinhauer, K. (2017). When the Second Language Takes the lead: Neurocognitive Processing Changes in the First Language of Adult Attriters. *Front. Psychol.* 08, 389. doi:10.3389/fpsyg.2017.00389

Kidd, E., Donnelly, S., and Christiansen, M. H. (2018). Individual Differences in Language Acquisition and Processing. *Trends Cogn. Sci.* 22 (2), 154–169. doi:10.1016/j.tics.2017.11.006

Kroll, J. F., and Tokowicz, N. (2005). "Models of Bilingual Representation and Processing," in *Handbook of Bilingualism: Psycholinguistic Approaches*. Editors J. F. Kroll and A. M. B. de Groot (New York, NY: Oxford University Press), 531–553.

Kuznetsova, A., Brockhoff, P. B., and Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *J. Stat. Soft.* 82 (13), 1–26. doi:10.18637/jss.v082.i13

Lauro, J., and Schwartz, A. I. (2017). Bilingual Non-selective Lexical Access in Sentence Contexts: A Meta-Analytic Review. *J. Mem. Lang.* 92, 217–233. doi:10.1016/j.jml.2016.06.010

Libben, M. R., and Titone, D. A. (2009). Bilingual Lexical Access in Context: Evidence from Eye Movements during reading. *J. Exp. Psychol. Learn. Mem. Cogn.* 35 (2), 381–390. doi:10.1037/a0014875

Loebell, H., and Bock, K. (2003). Structural Priming across Languages. *Linguistics* 41 (5), 791–824. doi:10.1515/ling.2003.026

MacWhinney, B. (1987). "The Competition Model," in *Mechanisms of Language Acquisition*. Editor B. MacWhinney (Hillsdale, NJ: Lawrence Erlbaum), 249–308.

MacWhinney, B. (2005). "A Unified Model of Language Acquisition," in *Handbook of Bilingualism: Psycholinguistic Approaches*. Editors J. F. Kroll and A. M. B. de Groot (New York, NY: Oxford University Press), 49–67.

Mahowald, K., and Fedorenko, E. (2016). Reliable Individual-Level Neural Markers of High-Level Language Processing: A Necessary Precursor for Relating Neural Variability to Behavioral and Genetic Variability. *NeuroImage* 139, 74–93. doi:10.1016/j.neuroimage.2016.05.073

Mirault, J., Snell, J., and Grainger, J. (2018). You that Read Wrong Again! A Transposed-word Effect in Grammaticality Judgments. *Psychol. Sci.* 29 (12), 1922–1929. doi:10.1177/0956797618806296

Palma, P., and Titone, D. (2020). "Bilingual Lexical Access and reading," in *Bilingual Lexical Ambiguity Resolution*. Editors R. R. Heredia and A. M. B. Cieślicka (New York, NY: Cambridge University Press), 159–183. doi:10.1017/9781316535967.008

Pivneva, I., Mercier, J., and Titone, D. (2014). Executive Control Modulates Cross-Language Lexical Activation during L2 reading: Evidence from Eye Movements. *J. Exp. Psychol. Learn. Mem. Cogn.* 40 (3), 787–796. doi:10.1037/a0035583

Roberts, L. (2012). Individual Differences in Second Language Sentence Processing. *Lang. Learn.* 62, 172–188. doi:10.1111/j.1467-9922.2012.00711.x

Schwartz, A. I., and Kroll, J. F. (2006). Bilingual Lexical Activation in Sentence Context. *J. Mem. Lang.* 55 (2), 197–212. doi:10.1016/j.jml.2006.03.004

Segalowitz, N., Watson, V., and Segalowitz, S. (1995). Vocabulary Skill: Single-Case Assessment of Automaticity of Word Recognition in a Timed Lexical Decision Task. *Sec. Lang. Res.* 11 (2), 121–136.

Snell, J., and Grainger, J. (2019). Word Position Coding in reading Is Noisy. *Psychon. Bull. Rev.* 26 (2), 609–615. doi:10.3758/s13423-019-01574-0

Street, J. A., and Dąbrowska, E. (2014). Lexically Specific Knowledge and Individual Differences in Adult Native Speakers' Processing of the English Passive. *Appl. Psycholinguistics* 35 (1), 97–118. doi:10.1017/S0142716412000367

Thierry, G., and Sanoudaki, E. (2012). Activation syntaxique non-sélective à la langue chez le bilingue précoce. *Revue Française de Linguistique Appliquée* 17 (2), 33–48. doi:10.3917/rfla.172.0033

Titone, D., Libben, M., Mercier, J., Whitford, V., and Pivneva, I. (2011). Bilingual Lexical Access during L1 Sentence reading: The Effects of L2 Knowledge, Semantic Constraint, and L1-L2 Intermixing. *J. Exp. Psychol. Learn. Mem. Cogn.* 37 (6), 1412–1431. doi:10.1037/a0024492

Titone, D., Whitford, V., Lijewska, A., and Itzhak, I. (2016). "Chapter 1. Bilingualism, Executive Control, and Eye Movement Measures of reading," in *Cognitive Control*

and Consequences of Multilingualism. Editor J. W. Schwieter (Amsterdam/Philadelphia: John Benjamins Publishing Company), 11–46. doi:10.1075/bpa.2.02tit

Tuninetti, A., Warren, T., and Tokowicz, N. (2015). Cue Strength in Second-Language Processing: An Eye-Tracking Study. *Q. J. Exp. Psychol.* 68 (3), 568–584. doi:10.1080/17470218.2014.961934

Van Assche, E., Duyck, W., Hartsuiker, R. J., and Diependaele, K. (2009). Does Bilingualism Change Native-Language Reading? *Psychol. Sci.* 20 (8), 923–927. doi:10.1111/j.1467-9280.2009.02389.x

Assche, E. V., Duyck, W., and Hartsuiker, R. J. (2012). Bilingual Word Recognition in a Sentence Context. *Front. Psychol.* 3, 174. doi:10.3389/fpsyg.2012.00174

Wartenburger, I., Heekeren, H. R., Abutalebi, J., Cappa, S. F., Villringer, A., and Perani, D. (2003). Early Setting of Grammatical Processing in the Bilingual Brain. *Neuron* 37 (1), 159–170. doi:10.1016/50896-6273(02)01150-910.1016/s0896-6273(02)01150-9

Wells, J., Christiansen, M., Race, D., Acheson, D., and MacDonald, M. (2009). Experience and Sentence Processing: Statistical Learning and Relative Clause Comprehension. *Cogn. Psychol.* 58 (2), 250–271. doi:10.1016/j.cogpsych.2008.08.002

Whitford, V., and Titone, D. (2012). Second-language Experience Modulates First- and Second-Language Word Frequency Effects: Evidence from Eye Movement Measures of Natural Paragraph reading. *Psychon. Bull. Rev.* 19 (1), 73–80. doi:10.3758/s13423-011-0179-5

Whitford, V., and Titone, D. (2015). Second-language Experience Modulates Eye Movements during First- and Second-Language Sentence reading: Evidence from a Gaze-Contingent Moving Window Paradigm. *J. Exp. Psychol. Learn. Mem. Cogn.* 41 (4), 1118–1129. doi:10.1037/xlm0000093

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. New York: Springer-Verlag.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.