Lexical-semantic processing costs are not inherent to intra-sentential code-switching: The role of switching habits

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Abstract:

A bank of past electrophysiological research suggests that code-switching (i.e., the use of multiple languages during a single conversational event) is characterized by increased processing costs. However, the majority of these studies tested bilinguals who did not necessarily code-switch on a regular basis. In order to investigate the impact of switching habits on language processing, two groups of French-English bilinguals (habitual code-switchers and non-habitual code-switchers) read sentences containing unilingual and switched determiner phrases while their EEG was recorded. The findings indicate important processing differences between the groups. Notably, switched trials (particularly those with a French determiner) generated an increased negativity from 300 to 500 ms for non-habitual code-switchers, but not for habitual code-switchers. The veritable impact of switching habits were also supported by a correlation analysis. This finding suggests that code-switching is not inherently effortful to process, but rather, that comprehension costs are related to idiosyncratic factors, such as the extent of prior exposure to code-switched input. An LPC was also observed from 500 to 900 for habitual code-switchers; for non-habitual switchers, this effect may have been attenuated by the long-lasting N400 effect. We advance several possible interpretations for the late positivity. Altogether, the results from the current study support the claim that the code-switching cost observed in previous literature may be linked to the bilingual samples tested in those studies: habitual code-switchers may not find switches effortful to process, but not all bilinguals code-switch. We highlight the importance of experience and individual differences in the study of bilingual cognition.

1. INTRODUCTION

In most societies, bilingualism, and even multilingualism, is prevalent (Tucker, 1999). As such, the act of code-switching, defined as "the alternation of two languages within a single discourse, sentence or constituent" (Poplack, 1980, p.583) is regarded as typical linguistic behaviour for some speakers. While code-switching was originally believed to reflect a lack of competence in one or both languages (see Heredia and Altarriba, 2001), researchers now generally agree that it denotes a bilingual's skillful mastery in both of their languages (e.g., Poplack, 1980; see Yow et al., 2018 for a child study). Code-switching is highly systematic (e.g., Belazi et al., 1994; Di Sciullo, Muysken & Singh, 1986; Joshi, 1985; MacSwan, 2000; Myers-Scotton, 1993; Sankoff and Poplack, 1981) and code-switchers possess community-specific judgements about the acceptability of mixed utterances (e.g., Adamou and Shen, 2019).

A considerable wealth of literature suggests that switching is characterized by heightened processing costs relative to unilingual language, both at the level of production (e.g., Bultena et al., 2015; Costa and Santesteban, 2004; Timmer et al., 2019) and comprehension (Moreno et al., 2002; Ng et al., 2014; Proverbio et al., 2004; van der Meij et al., 2011). For instance, producing switches typically elicits longer response times than staying in a single language (e.g., Bultena et al., 2015). A comparable increase in reaction time (e.g., Burkholder, 2018), as well as differential electrophysiological signatures (e.g., Pérez and Duñabeitia, 2019; van der Meij et al., 2011) have also been observed when bilinguals are processing mixed sentences. These findings introduce a seemingly counter-intuitive paradox: if code-switching incurs cognitive costs, seemingly both at the initiation and the reception of the communicative act, why would code-switching be prevalent in many bilingual communities? The observed processing cost is especially

remarkable, as code-switching has often been characterized by researchers as fluent and smooth (Poplack, 1980), and by speakers as the "most comfortable way" to speak (Dorleijn, 2017, p.12).

The goal of this study is to investigate the processing costs of French-English intra-sentential code-switches (i.e., switches that occur within the sentence boundary) with the Event-Related Potential (ERP) technique. This study also examines whether an individual's mixing habits (habitual vs. non-habitual) impacts the manner in which they process code-switching, particularly in a stable bilingual context (Ottawa, Canada).

1.1. Is code-switching cognitively costly?

1.1.1. Behavioural language- and code-switching research

Early research utilized 'artificial language switching' picture-naming tasks, wherein single-word switches were prompted by a non-linguistic cue (e.g., colour) (see de Bruin et al., 2018; Jevtović, Duñabeitia & de Bruin, 2020 for voluntary switching). These studies vastly indicate that bilinguals take longer to name a picture when they need to shift from one language to the other (e.g., Costa and Santesteban, 2004; Meuter and Allport, 1999; Thomas and Allport, 2000). More recently, research suggests that language switching costs at the level of production may be modulated by individual bilingual experience. For instance, Prior and Gollan (2011) found that more frequent code-switchers exhibited reduced switching costs compared to less experienced bilinguals (see also Soveri et al., 2011 for comparable results).

Although costs appear to be impacted by external factors, they remain present across variations of the classic language switching paradigms (though see Declerck et al., 2019). Given that bilinguals in many communities do indeed mix their languages, and that humans are unlikely to continue to partake in more cognitively taxing behaviours (Dussias et al., 2019), why are these

costs consistently found? It must be stressed that the type of language switching elicited in picture naming (and related) tasks is vastly different from the more fluent and natural code-switching that bilinguals display in their daily life, and consequently retains low ecological validity (see Blanco-Elorrieta and Pylkkänen, 2018 for a discussion).

It is not all that surprising that language switching is cognitively effortful. During language switching experiments, participants must inhibit and activate their languages in turn (Meuter and Allport, 1999), and are thus effectively keeping their languages separate and acting on an externally-induced cue. Contrastively, in some code-switching environments, bilinguals may activate their languages in parallel and use them cooperatively (Green and Abutalebi, 2013; Green and Wei, 2014). Given the distinct mechanisms which underlie language switching and code-switching, it is likely erroneous to relate language switching to code-switching. This means that the classic cost that is nearly always reported in the *language switching* literature does not necessarily constitute as evidence for a *code-switching* processing cost. In fact, switch costs are absent for more natural tasks as opposed to 'artificial' or cued tasks, when switching paradigms ranging from low to high ecological validity are directly compared (Blanco-Elorrieta and Pylkkänen, 2017).

Consequently, researchers have begun to utilize sentential or discourse-level instances of code-switching, particularly in the switching literature related to comprehension costs. For instance, Burkholder (2018), who also tested French-English bilinguals in the Ottawa region, conducted a self-paced reading task. Her stimuli included determiner phrases (DPs) with French determiners (*la* house, 'the.$_{\text{FEM}}$ house') and DPs with English determiners (the *maison*, 'the house'), as Spanish-English production and corpora studies have demonstrated that code-switchers favour using gendered-determiners (e.g., *la/le* house, instead of the *casa*, 'the house')

when they code-switch within DPs (see the Grammatical Feature Spell-Out hypothesis: Liceras et al., 2005). Despite the similar gender systems in Spanish and in French, Burkholder (2018) found no evidence supporting the existence of a directional asymmetry in French-English code-switching. However, mixed DPs elicited longer reaction times (RTs) than single-language DPs, indicating that code-switching may be more cognitively costly even when sentential tasks and stimuli are implemented.

On the other hand, Adamou and Shen (2019) reported no significant switching costs on behalf of habitual Romani-Turkish switchers, once community-specific (i.e., ecologically valid) instances of code-switching were examined. Similarly, an eye-tracking study conducted by Valdés Kroff, Guzzardo Tamargo and Dussias (2018) demonstrated that Spanish-English bilinguals from the US could integrate determiner-noun switches (e.g., *el* windmill, 'the.$_{M}$ windmill') with more ease than bilinguals in Granada, as the former group code-switched more regularly in their daily life. These findings also extend beyond the level of comprehension: Gullifer et al. (2013) presented sentences to Spanish-English bilinguals and prompted them to name target words. While cognate effects were found, there were no costs for code-switched trials compared to unilingual sentences (see also Kheder and Kaan, 2019 for high proficient, habitually code-switching bilinguals).

It appears as though code-switching costs are minimally modulated (and possibly mitigated) by a of range linguistic factors such as proficiency (Kheder and Kaan, 2019) and individual bilingual experience (Adamou and Shen, 2019), which may all play a role in code-switching habits. However, neuroimaging measures are needed in order to examine the more fine-grained underlying costs attributed to code-switching.

1.1.2. ERP code-switching research

Neuroimaging measures, such as ERPs, can shed light on the implicit mechanisms that take place during the real-time processing of code-switched language. ERPs (recorded via EEG) index electrical brain activity with extremely high temporal resolution. Well-known ERP components may indicate specific reactions to linguistics events. Classical 'negativity' components include the N400 and the Left Anterior Negativity (LAN) effects. The N400 component is indexed by an increased negative peak in neural activity around 400 ms and is attributed (among other things) to semantic integration difficulties and semantic abnormality or unexpectedness (e.g., Kutas and Federmeier, 2000; Kutas and Hillyard, 1980; Kutas and Hillyard, 1984). Comparably, the LAN and its early counterpart (ELAN) are marked by a negative peak generally culminating between 150 and 400 ms. These components are believed to reflect difficulties with automatic morpho-syntactic integration processes (e.g., Hahne and Friederici, 2002; Neville et al., 1991). They have also been related to increased memory load (e.g., Kluender and Kutas, 1993).

Alternatively, well-known 'positivity' components include the P600 effect or Late Positive Component (LPC). The P600 component is indexed by an increased positive peak in neural activity around 600 ms and is most often attributed to structure violation and/or reanalysis (e.g., Hagoort and Brown, 1999; Kaan and Swaab, 2003; Osterhout and Holcomb, 1992). Original literature links the LPC, peaking parietally between 600 and 800 ms, to processes related to memory (e.g., Münte et al., 2000). More often than not, the LPC is collapsed with the P600, particularly in linguistic research.

The presence of such ERP components during the processing of switched sentences, but not unilingual sentences (i.e., ERP code-switching effects) provides evidence for a reliable

processing cost attributed to code-switching. Initial research has indeed demonstrated that code-switching appears to elicit differential comprehension-related ERP signatures relative to unilingual sentences (e.g., Moreno et al., 2002; van der Meij et al., 2011). These costs have been reported for single-word switches at the sentential level (e.g., in Moreno et al., 2002: She put on her high heeled *zapatos*. 'Shoes'; see also Proverbio et al., 2004; van der Meij et al., 2011) and at the discourse level (Ng et al., 2014).

In particular, code-switched words were indexed by increased negativities (Moreno et al., 2002; Ng et al., 2014; Proverbio et al., 2004; van der Meij et al., 2011), both when the switch occurred from the L1 into the L2 (Moreno et al., 2002), from the L2 into the L1 (van der Meij et al., 2011), or when both directions were examined, though costs were asymmetrical (Proverbio et al., 2004). Additionally, code-switches elicited LPC effects, once again regardless of switching direction (Proverbio et al., 2004; see also Kaan et al., 2020; Moreno et al., 2002; van der Meij et al., 2011) and remained present even for balanced bilinguals (Ng et al., 2014). In this regard, code-switches are processed similarly to low-cloze words; some authors conclude that switching is experienced as an unexpected event, therefore requiring revisions in memory (e.g., Moreno et al., 2002; van der Meij et al., 2011; though see Proverbio et al., 2004 for other conclusions).

More recent ERP research challenges the processing costs attributed to code-switching. For instance, Litcofsky and van Hell (2017) examined the effects of switching directionality on intra-sentential Spanish-English code-switching. Participants silently read single-language sentences, and sentences that contained a multi-word switch at the DP boundary. Contrary to the results reported by van der Meij et al. (2011), no ERP effects were found when switches were accomplished from the weaker language into the more dominant language. On the other hand, switching in the dominant-to-weak direction generated an LPC. The authors concluded that code-

switching "into the weaker language requires sentence-level restructuring and activation of that weaker language." (p.125). However, Kaan et al. (2020) found that even an LPC generated by a dominant-to-weaker switch may be modulated: when a bilingual code-switcher was present with the participant being tested, their increased positive responses were significantly attenuated. Strikingly, unlike all other previous ERP studies, code-switches in Litcofsky and van Hell and Kaan et al. (2020) did not elicit any negativities. Interestingly, the absence of negative ERP components was observed even though code-switches yielded a significant *behavioural* switch cost (Litcofsky and van Hell, 2017).

1.2. Not all bilinguals code-switch: considerations and implications

The question might be asked as to why the results from Litcofsky and van Hell (2017) (and, in part, Kaan et al., 2020) are so distinct from earlier comprehension-related findings in the literature. It appears that code-switching can indeed incur processing costs for *some* bilinguals, but not necessarily for *all* bilinguals (see also Beatty-Martínez and Dussias, 2017). The reason for this difference seems to lie with the participants being tested (for reviews see Beatty-Martínez et al., 2018; González-Vilbazo et al., 2013; van Hell et al., 2018).

Crucially, early ERP studies examining switching did not test habitual code-switchers. Proverbio et al. (2004) tested professional polyglot interpreters, while van der Meij et al. (2011) tested individuals who did not report frequent switching. Ng et al. (2014) tested bilinguals from a community in which code-switching was commonplace but did not report on participants' actual switching habits (similar to Moreno et al., 2002). The inclusion of high-proficient bilinguals in previous studies does not necessarily imply that these participants mixed their languages on a

daily basis, since not all bilinguals code-switch. Importantly, all of these authors observed N400-like responses (or a LAN effect, in the case of Moreno et al., 2002) for switching.

On the other hand, Litcofsky and van Hell (2017) explicitly stated that their participants frequently code-switched; Kaan et al. (2020) report an average code-switching frequency between 3.31 and 3.82 (out of 5) for their participants. Crucially, they are also the only authors who did not observe any negativity effects. The link between the observed ERP component and the sample being studied points towards the idea that the lexical-semantic processing cost for switching reflects the reality of non-habitual code-switchers only.

Green and Abutalebi's (2013) Adaptive Control Hypothesis supports the idea that switching habits affect switching-related processing costs. These authors identified three possible interactional contexts for bilinguals, which may result in different types of processing costs: a single-language context, a dual-language context and a dense code-switching context. Bilinguals who frequently employ each of their languages independently (dual-language context) possesses competing languages, while bilinguals who regularly switch between their languages within a single utterance (dense code-switching context) possess co-operating languages. To this effect, while switching may not lead to processing difficulties for speakers who are from a dense codeswitching context, it likely *will* give rise to processing costs for speakers from a dual-language context.

In summary, it is possible that the presence of code-switching processing costs (particularly those indexed by negative ERP components) may depend on the participant sample under study. The present study empirically verifies this presupposition.

1.3. Present study

The present study investigates the supposed processing costs attributed to code-switching. We carry out this goal by measuring the electrophysiological responses to French-English DPs among two bilingual groups: habitual and non-habitual code-switchers. This study verifies whether online results regarding switching-related processing costs hold true for *all* bilinguals, or whether they are contingent on the participants' code-switching habits. As such, the current project examines the impact of a bilingual's experience (in this case, frequency of code-switching) during language processing. We also investigate the possible effect of determiner-noun switching directionality, as has been done in similar past research (e.g., Burkholder, 2018). In other words, we examine whether switched DPs containing a French gendered determiner and an English noun (e.g., '*la* house', '*le* sun') elicit similar processing mechanisms (or costs) to switched DPs involving an English genderless determiner and a French noun (e.g., 'the *maison'*, 'the *soleil'*).

For individuals who report frequent code-switching, we expected that switched DPs (e.g., *la* house, the *maison*; 'the house') would not generate processing costs (no LPC nor N400 effect), as these bilinguals are highly experienced with such stimuli. On the other hand, we anticipated that switched DPs would be characterized by an N400 and an LPC for bilingual individuals who did not report habitual code-switching (similar to Proverbio et al., 2004; van der Meij et al., 2011). The bilinguals tested in this study were balanced (see Section 2.1); we therefore did not expect to find any effect of language dominance on switching directionality, contra Litcofsky and van Hell (2017).

Regarding switching direction, past research has shown that Spanish-English bilinguals tend to prefer using gendered Spanish determiners with English nouns when they mix within the

determiner phrase (Liceras et al., 2005). However, given Burkholder's (2018) null result for French-English code-switched DPs, we did not expect to find any evidence of a directional asymmetry in the current study. Altogether, we hypothesized that switched DPs would elicit switching effects for non-habitual, but not habitual code-switchers, regardless of the language of the determiner (or the direction) of the switch.

2. METHODS

2.1. Participants

This study was carried out with the approval of University of Ottawa's Research Ethics Board (file #11-17-06). Participants were recruited through the Integrated System of Participant Research at the University of Ottawa, a database which allows students to participate in research for course credit. Ottawa is located near the border which separates the English-dominant province of Ontario from the French-dominant province of Québec. The University of Ottawa is officially bilingual. Furthermore, the capital region is a known hub for code-switching activity (e.g., Poplack, 1989; Poplack et al., 2012).

Forty-eight French-English bilinguals gave informed consent and participated in the study. All participants were exposed to and immersed in both English and French before the age of six. Left-handed individuals, individuals with vision problems or a history of language disorders, and those who had previous traumatic head injuries were ineligible to participate. Of the individuals who were tested, five participants did not qualify for the inclusion criteria, due to native or high proficiency in another language, or immersion in French/English only after 6 years. As such, 43 data sets were included in the final analyses (35 women, 8 men; *M* age =19.5 years, range = 17 – 28).

Table 1. *Participant's language backgrounds and responses to code-switching questionnaire (1= 'very true', 7= 'never') according to group. Means shown, standard deviations in parentheses.*

		Habitual	Non-habitual	*p* value
English	**AoE (yrs)**	0.57 (1.47)	0.59 (1.40)	.97
	AoI (yrs)	1.24 (1.79)	1.23 (2.16)	.99
	Current prof. /5	4.70 (.64)	4.67 (.55)	.88
	% Expos. (0-2 yrs)	42.86 (29.69)	42.27 (30.31)	.95
	% Current interactions	59.76 (14.87)	60.00 (20.64)	.97
French	**AoE (yrs)**	0.62 (1.32)	0.64 (1.43)	.97
	AoI (yrs)	0.81 (1.50)	0.96 (1.65)	.77
	Current prof. /5	4.79 (.46)	4.64 (.58)	.36
	% Expos. (0-2 yrs)	55.24 (28.74)	57.27 (29.71)	.82
	% Current interactions	40.24 (14.87)	40.00 (20.64)	.97
Switching	**English " French**	2.71 (1.19)	4.86 (1.25)	<.001
	French " English	2.14 (.91)	4.14 (1.64)	<.001
Borrowing	**French word**	1.71 (.96)	4.23 (1.60)	<.001
	English word	1.52 (.81)	3.14 (1.65)	<.001
Overall mixing		1.57 (.98)	3.77 (1.54)	<.001
Average switching score		1.93 (.49)	4.03 (.81)	<.001

These individuals were sorted into two groups, corresponding to habitual code-switchers (*n*=21) and non-habitual code-switchers (*n*=22). Classification into groups was done according to responses provided on a Language mixing questionnaire (adapted from Byers-Heinlein, 2013), in which participants were prompted to report the frequency of their various code-switching habits on a scale of 1–7 (with 1 corresponding to "very true" and 7 corresponding to "never"). Individuals with an average score below 3 were classified as habitual code-switchers (*M*=1.93), while participants with an average score above 3 were classified as non-habitual code-switchers (*M*=4.03). Note that recent research supports the idea that self-reported code-switching habits adequately reflect genuine language use (Cox et al., 2020). A post-hoc power analysis (G*power, 3.1; Heinrich Heine University Düsseldorf, Germany) confirms satisfactory statistical power for

this participant sample: assuming an effect size of 0.25, the probability for a type I error is below 0.4%.

Average responses to the switching questionnaire and other relevant language background characteristics of the participants (assessed via a language background questionnaire; Sabourin et al., 2016) are listed in Table 1. Two-tailed independent sample t-tests established that the two groups were well-matched in terms of their self-reported language backgrounds. The proportion of current daily interactions in French or English was also matched for both groups (approximately 60% in English and 40% in French for both groups, $p > .97$), indicating that both groups consisted of relatively balanced bilinguals.

2.2. Materials

Stimuli were originally used in Burkholder's (2018) behavioural study on French-English code-switching in Ottawa. Sentences were verified by habitual code-switchers from the region and did not contain any violations. An additional 12 critical sentence frames were created in the same format (see Supplementary Material for complete list). Each frame contained multiple intra-sentential code-switching points. Early work from Poplack (1988) in the Ottawa region illustrates that speakers do indeed switch from one language into another multiple times within a single utterance (see (1), from Poplack, 1988, p.59). For this reason, we expect that our stimuli are reasonably ecologically valid.

(1) *Les français apprennent l'allemand parce que* they have to deal with them *économiquement là* (JB/756). "The French learn German because they have to deal with them economically."

2.2.1. Critical sentences

The critical stimuli consisted of 60 sentence frames. Every sentence frame possessed six separate conditions (*M* length =11.55 words, range=9–15), for a total of 360 items. The conditions varied according to the characteristics of a critical determiner phrase (see Table 2): Context (switched or unilingual), Language of Determiner (French or English) and Gender Congruency (congruent or incongruent). Participants saw only one condition from every sentence frame. There were an equal number of feminine and masculine nouns and translation equivalents. The critical constituent was fixed at the DP-level, just like in Litcofsky and van Hell (2017), since switching is widely attested at this position (e.g., *le* month; 'the month') (e.g., Guzzardo Tamargo, Valdés Kroff & Dussias, 2016).

The noun within the critical DP appeared between the sixth and the eleventh word of each trial (*M*=8.30). Note that all stimuli (even sentences containing a unilingual DP, such as '*the* month') were composed of both English and French words; there were no fully unilingual sentences. That is, the critical DP always followed a prior code-switching point (*M* position =3.50, range =3–5), as this is believed to mitigate possible processing cost on the critical DP (Burkholder, 2018) and introduce the bilingual mode (Beatty-Martínez and Dussias, 2017). In sentences with switched DPs, the words preceding the determiner were in the same language as the determiner, while the words following the noun were in the same language as the noun. Moreover, the noun from the critical DP was never the last word in the sentence, in order to prevent sentence wrap-up effects.

All critical nouns consisted of one single morpheme each and none of the critical nouns were cognates or loan words. In addition, nouns which began by a vowel in either French or English were not included. This restriction was established in order to avoid the possible gender-

neutralized elision of the French definite Ds (i.e., *l'*apple vs. **le*.$_{\text{MASC}}$ apple). Most of the critical DPs involved a definite determiner (*n*=53 out of the 60 sentence frames). However, an indefinite counterpart was applied when it was more appropriate for the context.

Information on frequency was collected from the Lexique 3 database for the French nouns (see New, 2006) and the SubtlexUS database (see Brysbaert and New, 2009) for the English nouns. Two-tailed paired t-tests established that French and English words were well matched in terms of frequency ($t(59) = 0.50$, $p = .62$). Results also showed that French words were significantly longer than English words ($t(59) = 3.78$, $p < .001$). However, note that all critical nouns are relatively short, with 8 graphemes as a maximum.

Table 2. *Example of a sentence frame. The critical DP is bolded (Translation: 'Eric bought three books during the month of May.').*

Det. Language	Gender Congruency	Context	Sentence
French	Congruent	Uniling.	**1.** Eric bought trois livres pendant **le mois** de mai.
	Incongruent	Uniling.	**2.** Eric bought trois livres pendant **la mois** de mai.
	Congruent	Switch	**3.** Eric bought trois livres pendant **le month** of May.
	Incongruent	Switch	**4.** Eric bought trois livres pendant **la month** of May.
English	--	Uniling.	**5.** Eric a acheté three books during **the month** of May.
	--	Switch	**6.** Eric a acheté three books during **the mois** de mai.

2.2.2. Filler sentences

The 40 code-switched filler sentences were also those originally used in Burkholder (2018). Participants saw all 40 of these items. The filler sentences ranged from 7 to 15 words

(*M*=10.94) and included sentences with morphosyntactic violations, ungrammatical switching sites, or code-switching involving segments other than determiner-noun pairs. They were not included in the analysis.

2.3. Procedure

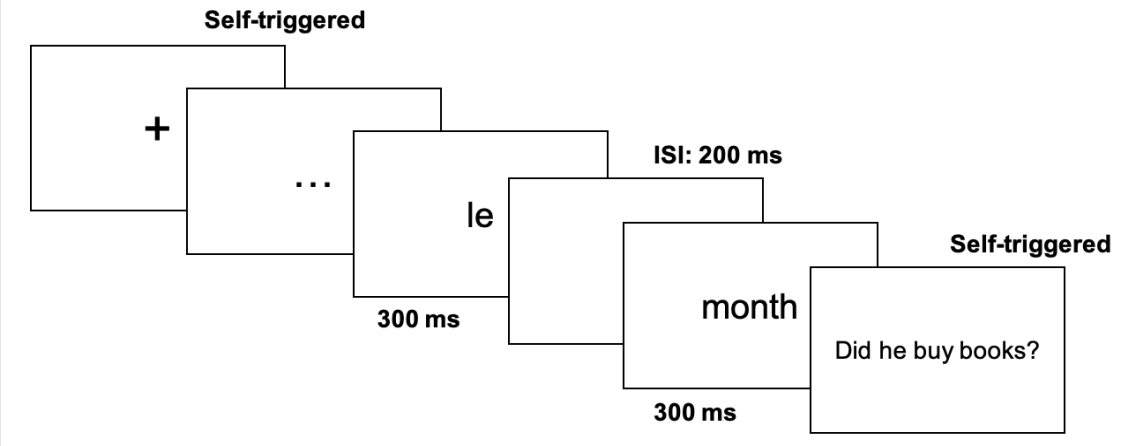
Participants began by filling out the detailed language background questionnaire and a language mixing questionnaire. Once the ERP cap and facial electrodes were fitted to the participants' head and face, they entered a sound attenuated room and sat approximately 1 m away from a 20 inch (31.5 X 38 cm) computer screen. Words were presented in black font on a white screen. The experimenter (the first author) spoke and responded to the participants in the language that they initiated (English, French, or code-switched French-English), as she belonged to the same code-switching community as them. Participants were instructed to silently read the sentences for meaning while their EEG was recorded. They were encouraged to keep their facial movement minimal.

A single trial is depicted in Fig. 1. Each trial began with a fixation cross. When ready, participants self-triggered the beginning of the sentence. Items were presented via the Rapid Serial Visual Presentation (RSVP) paradigm through version 17.2 of Presentation (Neurobehavioral Systems). Every word was displayed for 300 ms, with a 200 ms interstimulus interval. These durations (or their approximations) have commonly been used in this type of research (e.g., Litcofsky and van Hell, 2017; Ng et al., 2014; van der Meij et al., 2011). This length of presentation is ample, as duration of fixation for a single word is approximately 225–250 ms during silent reading (Proaps and Bliss, 2014; Rayner and Castelhano, 2008). It has been

shown that this particular way of reading sentences does not affect comprehension (Hester et al., 2016).

One third of trials were followed by comprehension questions: participants were prompted to answer yes/no type questions about the content of the sentence they had just read. The questions were exclusively in English and appeared entirely at once on the screen. Each participant was randomly assigned to one of six lists (according to a counterbalanced Latin-square design of the different versions for each sentence frame) and saw 100 sentences (60 critical and 40 filler). Of the 60 critical trials, half contained a switch at the critical DP (n =30); the critical DP was unilingual in the other 30 trials. Trials were pseudo- randomized, such that participants saw no more than two sentences from the same condition, no more than four filler sentences, and no more than two comprehension questions consecutively. The experimental task lasted approximately 15 min and all participants completed all one hundred trials.

Figure 1. *Rapid serial visual presentation procedure (including only the fixation cross, the critical DP, and the comprehension question).* [single-column fitting image]



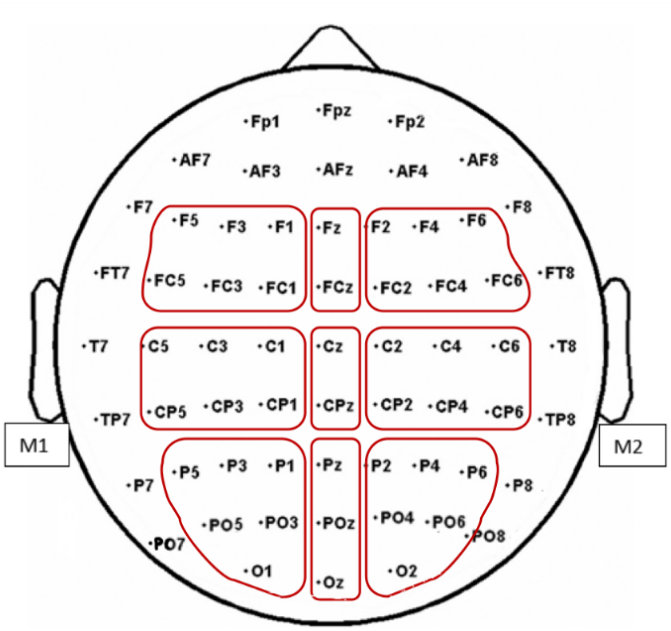
2.4. EEG system

A 64-channel 10/20 Quik-Cap by Compumedics Neuroscan (North Carolina, USA) was used for ERP collection. Facial electrodes were located on both temples (hEOGr and hEOGl), above and below the left eye (vEOGu and vEOGl) and on both mastoids (M1 and M2). Impedances were kept below 10 KΩ. Data was continuously recorded with Scan version 4.5 (Compumedics Neuroscan) at a sampling rate of 1000 Hz. An amplifier (SynAmps) applied an online low-pass filter of 200 Hz; no online high-pass filter was employed. The original reference electrode was between Cz and CPz on the center line. The data was subsequently re-referenced offline to the average of right and left mastoid electrodes.

Data pre-processing was performed in version 2.2 of the Brain Vision Analyzer software (Brain Products GmbH, Herrsching, Germany). The data was filtered offline with a low-pass filter of 30 Hz and a high-pass filer of 0.01 Hz. Vertical and horizontal eye movements contaminating the head electrodes were corrected with the use of an Independent Components Analysis (see Hoffmann and Falkenstein, 2008). This method decomposes the EEG signal into individual frequencies in order to isolate (and subtract) the component that best account for the vertical and the horizontal muscle movements during blinks, as indexed by the eye electrodes. Semi-automatic artifact rejection was subsequently computed, wherein EEG peaks surpassing ± 100 μV were rejected. Epochs were time-locked the noun in each critical DP (see Supplementary material for an additional analysis on the first switching point of each trial). They were established according to a 200 ms pre-stimulus corrected baseline and ended at 1000 ms post-stimulus. As a result of these methods, less than 1% of trials were discarded, with no difference across conditions (critical DP: $F(1,5) = 1.218$, $p = .30$).

Forty-three electrodes are included in the analyses. These electrodes were divided into nine regions of interest (ROIs), an analysis that is adapted from Meulman, Stowe, Sprenger, Bresser and Schmid's (2014) procedure (see also Fraga et al., 2017; Loerts et al., 2013). In order to ensure statistical homogeneity, excessively noisy electrodes (n =1–2) from eight participants (4 habitual code-switchers) were interpolated by pooling two neighbouring electrodes in the same ROI (see Supplementary Material for a complete list). The ROIs and their corresponding electrodes are presented in Fig. 2. They are named as follows: frontal-left (FL: F5, F3, F1, FC5, FC3, FC1), frontal-medial (FM: Fz, FCz), frontal-right (FR: F2, F4, F6, FC2, FC4, FC6), central-left (CL: C5, C3, C1, CP5, CP3, CP1), central-medial (CM: Cz, CPz), central-right (CR: C2, C4, C6, CP2, CP4, CP6), parietal-left (LP: P5, P3, P1, PO5, PO3, O1), parietal-medial (PM: Pz, POz, Oz) and parietal-right (PR: P2, P4, P6, PO4, PO6, O2). The value of all electrodes within an ROI are averaged across trials of a given condition.

Figure 2. *Electrodes included in each region of interest in the analyses.* [single-column fitting image]



2.5. Analysis

We conducted two separate analyses; in each analysis (see Sections 2.5.1; 2.5.2), we report frequentist and Bayesian statistics. Frequentist statistics were obtained by performing linear mixed-effect analyses using version 1.1–25 of the *lme4* package (Bates, Mäechler, Bolker & Walker, 2015) in R 4.0.2 (R Development Core Team, 2015). We opted to conduct linear mixed effects as these analyses account for inter-subject variability, which can be quite large in language research (e.g., Cunnings, 2012) [NOTE 1]. Fixed and random effects were determined a priori and fixed effects were deviation coded (i.e., sum-to-zero contrasts). Given the modest sample size in the current study, the models were fit using restricted maximum likelihood estimation method (Bates et al., 2015) and Satterthwaite's approximation technique (see Luke, 2017). In the case of significant main effects or interactions in each model, planned pairwise comparisons (confidence level =0.95) were computed by examining estimated marginal means with version 1.5.3 of the *emmeans* package (Searle et al., 1980). The degrees of freedom of these comparisons were estimated using the Kenward-Roger technique (Kenward and Roger, 1997; see Luke, 2017). In order to control for family-wise error rates, *p* values in multiple comparisons were Tukey-adjusted (Hayter, 1984).

To supplement these statistical analyses, Bayesian repeated-measures ANOVAs were computed in JASP 0.13 (University of Amsterdam, Netherlands; see Rouder et al., 2017). After visually inspecting the residuals to ensure approximate normal distribution, analyses of effects across matched models were assessed (see van den Bergh et al., 2019). Bayesian analysis of effects tables are useful when an analysis features numerous predictors and individual models are difficult to interpret. Instead of considering each model independently, analyses of effects appraise the impact for each predictor by considering all the models which contain this predictor.

The model-averaged result for each predictor yields the Bayes inclusion factor (BF_{incl}; see Jarosz and Wiley, 2014), which is interpreted as "the evidence in the data for including a predictor" (van den Bergh et al., 2019: 11). In the case of interactions, the analysis of effects *across matched models* compares a given model with an interaction to models containing the main effect of the variables within the interaction of interest, not to an absolute null. A BF_{incl} factor below 1 indicates that the data is more likely to occur under the null hypothesis (i.e., within models stripped of a given critical predictor); a Bayes inclusion factor of 10 would indicated that the data is 10 times more likely under the alternate hypothesis (i.e., that a given predictor or interaction likely modulates the data) (see van den Bergh et al., 2019).

These analyses were computed for three different time-windows: 200–300 ms, 300–500 ms, and 500–900 ms (in line with most recent similar research; Kaan et al., 2020; Litcofsky and van Hell, 2017). The first two time-windows gauge the presence of any N400-like or LAN effects, while the last time-window substantiates possible LPC effects.

2.5.1. Validity analysis: unilingual DPs

The first analysis was conducted solely on the sentences containing unilingual French DPs (in Table 2, conditions 1–2); it was performed to verify whether our stimuli retained satisfactory validity. The mixed model contained the fixed factors of Group (between-subject: habitual= −1, non-habitual code-switchers =1), Gender Congruency (within-subject: incongruent = −1, congruent =1), Gender of the Noun (within-subject: masculine = −1, feminine =1), as well as the topographic factors of Anteriority (frontal =0/1, central =1/0, or parietal = −1) and Laterality (left =1/0, medial =0/1, or right = −1). The (continuous) dependent variable was the participants' mean EEG response in each condition, averaged within ROIs. During model specification, we

first tested a maximal random structure with by-subject intercepts and slopes [NOTE 2]. This model failed to converge. As there was no theoretical motivation to include by-subject random slopes for some fixed effects but not others, the random effect structure was reduced to a simple by-subject random intercept. Finally, the Bayesian inclusion factors for the three experimental factors, as well as any of their interactions, were assessed. We expected to find an LPC and perhaps an N400-type response to incongruent gender trials (*la*.FEM *mois*.MASC; *le*.MASC *maison*.FEM) compared to congruent DPs (*la*.FEM *maison*.FEM; *le*.MASC *mois*.MASC); this effect is indeed largely reported in the gender-related ERP literature (e.g., Hagoort and Brown, 1999).

2.5.2. Switching cost analysis

To answer our main research objectives, the second analysis was conducted on sentences which contained a congruent gender-relation between the critical determiner and the critical noun (in Table 2, conditions 1, 3, 5 and 6). The other conditions were excluded from this analysis, as we wanted to ensure that any ERP effects generated by switching could not be attributed to a gender congruency effect. Thus, the mixed effects model contained the fixed factors of Group (between-subject: habitual = −1, non-habitual code-switchers = 1), Context (within-subject: switched = −1, unilingual =1), Language of Determiner (within-subject: French = −1, English = 1), the topographic factors of Anteriority (frontal =0/1, central =1/0, or parietal = −1) and Laterality (left =1/0, medial =0/1, or right = −1), as well as all interactions. The (continuous) dependent variable was the participants' mean EEG response in each condition, averaged within individual ROIs. During model specification, we first tested a maximal random structure with by-subject intercepts and slopes [NOTE 2]. As this model failed to converge, and there was no theoretical motivation to include by-subject random slopes for some fixed effects but not others, the model

was simplified until it included only a by-subject random intercept. To support the frequentist statistics, the Bayesian inclusion factors for the three experimental factors, as well as any of their interactions, were assessed.

2.5.3. Correlation analyses

Since the frequency of code-switching habits is treated as categorical in the mixed models, a one-tailed Pearson correlation matrix was also computed across groups. The mean ERP value elicited by switched DPs for each participant (rather than the switching effect)3 was correlated with their overall code-switching score (obtained by averaging participants' self-reported responses to the switching questionnaire). As all participants are included, these analyses allow us to gauge whether there is a relationship between switching-related processing costs and individual code-switching habits, instead of simply investigating whether there are differences between habitual and non-habitual code-switchers.

3. RESULTS

3.1. Comprehension questions

On average, participants answered 93.5% of the questions correctly (≈33/35). Based on a divergence of 2 standard deviations from the mean (*SD* =1.56), no outliers were found; all participants were deemed to have actively attended to the experiment and none were excluded.

3.2. ERP results

3.2.1. Validity analysis: unilingual DPs

The results from this analysis are presented in Table 3 and depicted visually in Fig. 3.

3.2.1.1. 200-300 ms

In the first time-window, incongruent DPs generated significantly more negative responses than congruent DPs (main effect of Congruency: p =.022). This effect also interacted with the Gender of the Noun (p <.001). Pairwise comparisons indicated that DPs with feminine nouns exhibited mismatch effects (t(1435) =4.166, p<.001), but those with masculine nouns did not (t(1435) =-0.931, p=.788). There was a marginal but non-significant interaction between Group, Congruency, Gender (p=.071); this effect was not supported by the Bayes inclusion factor (BF_{incl} =0.542). The effects/interactions of interest did not vary according to topography (p >.18).

3.2.1.2. 300-500 ms

In the second time-window, incongruent DPs continued to generate significantly more negative responses (main effect of Congruency: p< .001). The interaction between Congruency and Gender of the noun was marginal (p=.067); a significance was observed once the between subject factor of Group was included (Group*Congruency*Gender: p< .001). Pairwise comparisons indicated that incongruent feminine DPs elicited significantly more negative responses for non-habitual code-switchers (t(1435) =5.913, p< .001), but not habitual code-switchers (t(1435) =1.087, p=.960). There was no variation according to topography (p >.15).

3.2.1.3. 500-900 ms

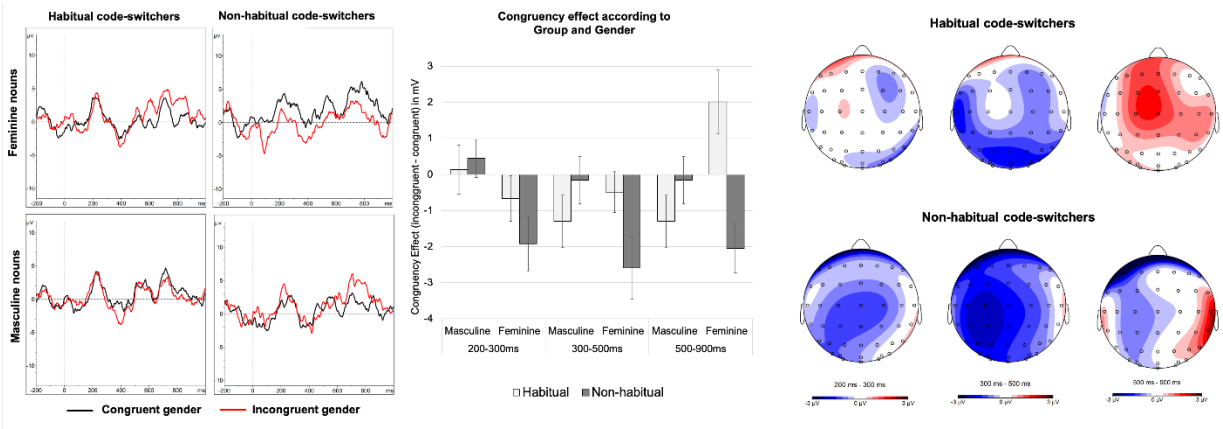
In the final time-window, a highly significant main effect involving the Gender of the noun was observed (p<.001): DPs with feminine nouns elicited more positive EEG responses. While there was no main effect of Congruency (p=.11), this factor did interact with Group (p=.001). Pairwise comparisons revealed an increased negativity in response to incongruent DPs for the

non-habitual group (t(1435) =3.436, p=.003), but not the habitual group (t(1435) =-1.092, p=.695). A three-way interaction between Group, Congruency and Gender (p<.001) indicated that incongruent DPs with feminine nouns generated increased positivities for both groups (ps<.001), but those with masculine nouns generated marginal negativities for the habitual group only (t(1435) =2.792, p=.098). None of the effects or interactions of interest varied according to topography (p >.12).

Table 3. Frequentist and Bayesian results for the Validity analysis in each time-window (TW). Significant (or substantial in the case of BFs) effects and interactions are bolded (p<.05*; p<.01**; p<.001***). There were no interactions involving the topographic factors; they are thus not included in the table.

TW	Predictors	Estimates	95% CI	*t*-value	BF_{incl}
200-300 ms	Intercept	2.32	1.61 – 3.03	**6.379*** **	—
	Group	-0.26	-0.98 – 0.45	-0.729	0.231
	Congruency	0.25	0.04 – 0.46	**2.315***	0.801
	Gender of the noun	-0.15	-0.36 – 0.07	-1.350	0.143
	Group * Congruency	0.12	-0.10 – 0.33	1.077	0.132
	Group * Gender of the noun	-0.09	-0.30 – 0.12	-0.817	0.127
	Congruency * Gender of the noun	0.40	0.18 – 0.61	**3.648*** **	**64.968**
	Group * Congruency * Gender	0.20	-0.02 – 0.41	1.809	0.542
300-500 ms	Intercept	-0.83	-1.52 – -0.15	**-2.374***	—
	Group	0.4	-0.29 – 1.08	0.829	0.304
	Congruency	0.57	0.35 – 0.78	**5.191*** **	**3.307e+4**
	Gender of the noun	0.09	-0.12 – 0.30	1.133	0.082
	Group * Congruency	0.12	-0.09 – 0.33	1.100	0.145
	Group * Gender of the noun	0.05	-0.16 – 0.27	0.491	0.095
	Congruency * Gender of the noun	0.2	-0.01 – 0.42	1.864	0.489
	Group * Congruency * Gender	0.41	0.19 – 0.62	**3.722*** **	**82.399**
500-900 ms	Intercept	0.56	-0.19 – 1.30	1.458	—
	Group	0.35	-0.40 – 1.09	0.908	0.272
	Congruency	0.19	-0.04 – 0.41	1.643	0.223
	Gender of the noun	1.48	1.26 – 1.70	**13.077*** **	**8.466e +32**
	Group * Congruency	0.37	0.14 – 0.59	**3.227****	13.841
	Group * Gender of the noun	0	-0.22 – 0.22	0.023	0.076
	Congruency * Gender of the noun	-0.18	-0.40 – 0.05	-1.560	0.200
	Group * Congruency * Gender	0.65	0.43 – 0.87	**5.750*** **	**7.234e+5**

Figure 3. Left: Neural responses (averaged across all ROIs) to both congruent and incongruent gender within the critical DP for feminine and masculine nouns. Middle: Congruency effect (i.e., incongruent trials – congruent trials). Error bars indicate standard error (SE). Right: Topographic distribution of the gender congruency effect (i.e., incongruent trials – congruent trials) in each time-window, collapsed across feminine and masculine nouns. For coloured figures, please visit the digital version. [2-column fitting image]



3.2.2. Switching cost

The results from this analysis are presented in Table 4 and depicted visually in Fig. 4.

3.2.2.1. 200-300 ms

In the first time-window, switched DPs elicited significantly more negative responses (main effect of Context: $p<.001$). This switching effect was modulated by code-switching habits (Group*Context interaction: $p<.001$). Pairwise comparisons indicated that switched DPs elicited an increased negativity for non-habitual code-switchers ($t(1435) = 5.839$, $p< .001$), but not for habitual code-switchers ($t(1435) = 0.864$, $p= .824$). Finally, an interaction was observed between Group and Determiner language ($p=.023$). Though comparisons revealed an increased negativity for DPs with French determiners among non-habitual code-switchers ($t(1435) =2.684$, $p=.037$;

all other *p*s >.85), this interaction is not supported by the Bayesian inclusion factor (BF_{incl}=1.080). The effects/interactions of interest did not vary according to topography (*p* >.36).

3.2.2.2. 300-500 ms

In the second time-window, switched DPs continued to generate significantly more negative responses (main effect of Context: *p*=.001). In this case, the switching effect was modulated both by the determiner language (Context*Determiner Language interaction: *p*<.001), code-switching habits (Group*Context interaction *p*<.001), and both of these factors (3-way interaction: *p*=.006). Pairwise comparisons showed that an increased negativity was observed for switched DPs with French determiners among the non-habitual code-switchers (*t*(1435) =7.272, *p*< .001). The switching effect was not significant in any other comparison (*p*s >.92). Once again, there was no variation according to topography (*p*>.27).

3.2.2.3. 500-900 ms

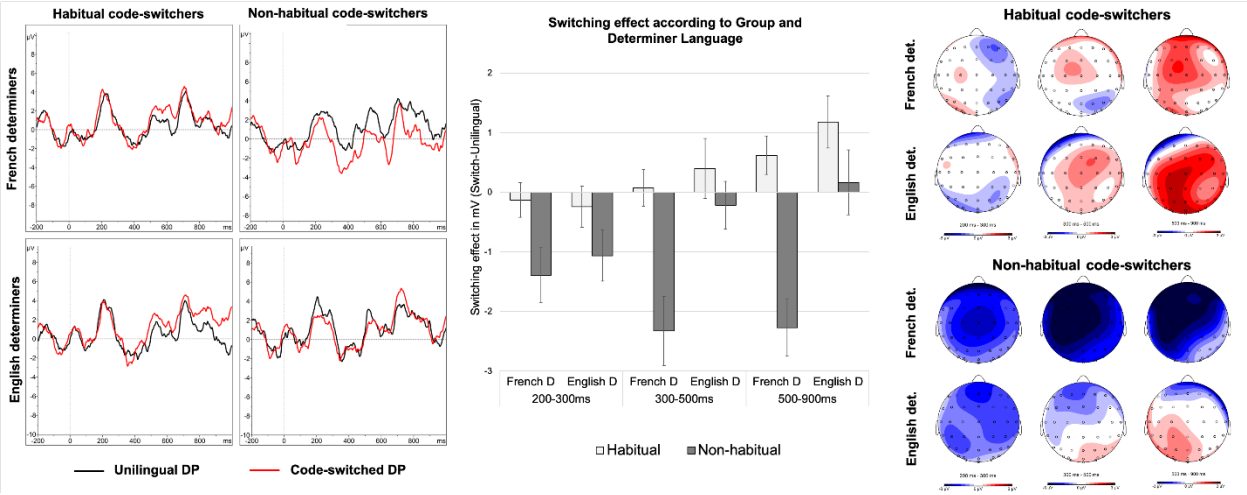
In the final time-window, DPs with French determiners elicited significantly more negative responses than those with English determiners (main effect of Determiner language: *p*=.019). While there was no main effect of Context, an interaction between Context and Group (*p*< .001) indicated that switching costs were modulated by code-switching habits. Indeed, while switched DPs generated an increased negativity among the non-habitual group (*t*(1435) = 4.647, *p*< .001), habitual code-switchers exhibited an increased positivity towards switched DPs (*t*(1435) =-3.886, *p*<.001). Finally, the switching cost was also impacted by the Determiner language (Context*Determiner language interaction: *p*< .001), and both the Determiner language and Group (3-way interaction: *p*=.004). Pairwise comparisons indicate that non-habitual code-

switchers exhibited an increased negativity towards switched DPs with French determiners (t(1435) =7.088, p< .001), but not those with English determiners (t(1435) =-0.516, p=1.000). On the other hand, habitual code-switchers showed an increased positivity towards switched DPs with English determiners (t(1435) =-3.601, p=.008), but not those with French determiners (t(1435) =-1.895, p=.554). Finally, none of the effects or interactions of interest varied according to topography (p>.16).

Table 4. Frequentist and Bayesian results for the Switching Cost analysis in each time-window (TW). Significant (or substantial in the case of BFs) effects and interactions are bolded (p<.05*; p<.01**; p<.001***). There were no interactions involving the topographic factors; they are thus not included in the table.

TW	Predictors	Estimates	95% CI	*t*-value	BF_{incl}
200-300 ms	Intercept	2.30	1.69 – 2.90	**7.434*** **	—
	Group	0.35	0.21 – 0.50	-0.251	0.235
	Context	0.11	-0.03 – -0.26	**4.761*** **	**5.136e+3**
	Det. Lang.	-0.08	-0.68 – 0.53	1.489	0.198
	Group * Context	-0.03	-0.17 – 0.12	**3.509*** **	**31.440**
	Group * Det. Lang.	0.26	0.11 – 0.41	**2.312***	1.080
	Context * Det. Lang.	0.17	0.03 – 0.32	-0.369	0.081
	Group * Context * Det. Lang	-0.05	-0.20 – 0.09	-0.737	0.133
300-500 ms	Intercept	-0.89	-1.49 – -.028	**-2.871****	—
	Group	0.00	-0.60 – 0.61	0.012	0.214
	Context	0.26	0.10 – 0.42	**3.250****	**12.904**
	Det. Lang.	-0.06	-0.21 – 0.10	-0.707	0.078
	Group * Context	0.35	0.22 – 0.53	**4.731*** **	**4.105e+3**
	Group * Det. Lang.	0.09	-0.07 – 0.24	1.081	0.148
	Context * Det. Lang.	-0.30	-0.46 – -0.15	**-3.826*** **	**116.420**
	Group * Context * Det. Lang	-0.22	-0.38 – -0.07	**-2.793****	4.601
500-900 ms	Intercept	0.52	-0.05 – 1.09	1.792	—
	Group	0.08	-0.49 – 0.65	0.286	0.202
	Context	0.04	-0.12 – 0.19	0.474	0.068
	Det. Lang.	0.19	0.03 – 0.35	**2.390***	0.956
	Group * Context	0.49	0.33 – 0.64	**6.108*** **	**5.602e +6**
	Group * Det. Lang.	0.09	-0.06 – 0.25	1.176	0.159
	Context * Det. Lang.	-0.37	-0.53 – -0.22	**-4.682*** **	**4.566e+3**
	Group * Context * Det. Lang	-0.23	-0.39 – -0.08	**-2.934****	7.581

Figure 4. Left: Neural responses (averaged across ROIs) to unilingual and code-switched DPs, separated by the language of the determiner. Middle: Switching effect (switch trials – unilingual trials). Error bars indicate standard error (SE). Right: Topographic distribution of the code-switching effect (i.e., switched – unilingual DPs) in each time-window, separated by the language of the determiner. For coloured figures, please visit the digital version. [2-column fitting image]



3.3. Correlation analyses

Recall that Pearson correlation matrices were computed between participant's average score on the code-switching questionnaire, and their neural responses to switched trials and unilingual trials (averaged across all ROIs). As dominance has been shown to play a role in supposed code-switching costs (see Litcofsky and van Hell, 2017), the neural responses were also correlated to participant's self-reported proportion of current daily interactions in English (note that their daily interactions in French make up the remaining proportion, so both languages are not shown). The results from the correlation analysis are depicted in Table 5 and Fig. 5.

In the first time-window (200–300 ms), participants who code-switched less (r =− 0.26, p=.05) and those with more interactions in English exhibited more negative responses to switched DPs with French determiners; this latter effect was only marginal (r =− 0.24, p =.06). There were no other correlations (ps > .27). From 300 to 500 ms, switching habits were again

significantly correlated to the neural responses generated by switched DPs with French determiners ($r = -0.26$, $p = .04$). Similar to the first time-window, participants with the highest proportion of English interactions exhibited the most negative ERP waves to switched DPs with French determiners ($r = -.48$, $p < .001$). For all other DP types, the results remained null ($r < 0.20$, $p > .10$). The same results were observed in the final time-window (switching habits X switched DPs with French determiners: $r = -0.28$, $p = .04$; interaction in English x switched DPs with French determiners: $r = -0.32$, $p = .04$, all others: $p > .11$).

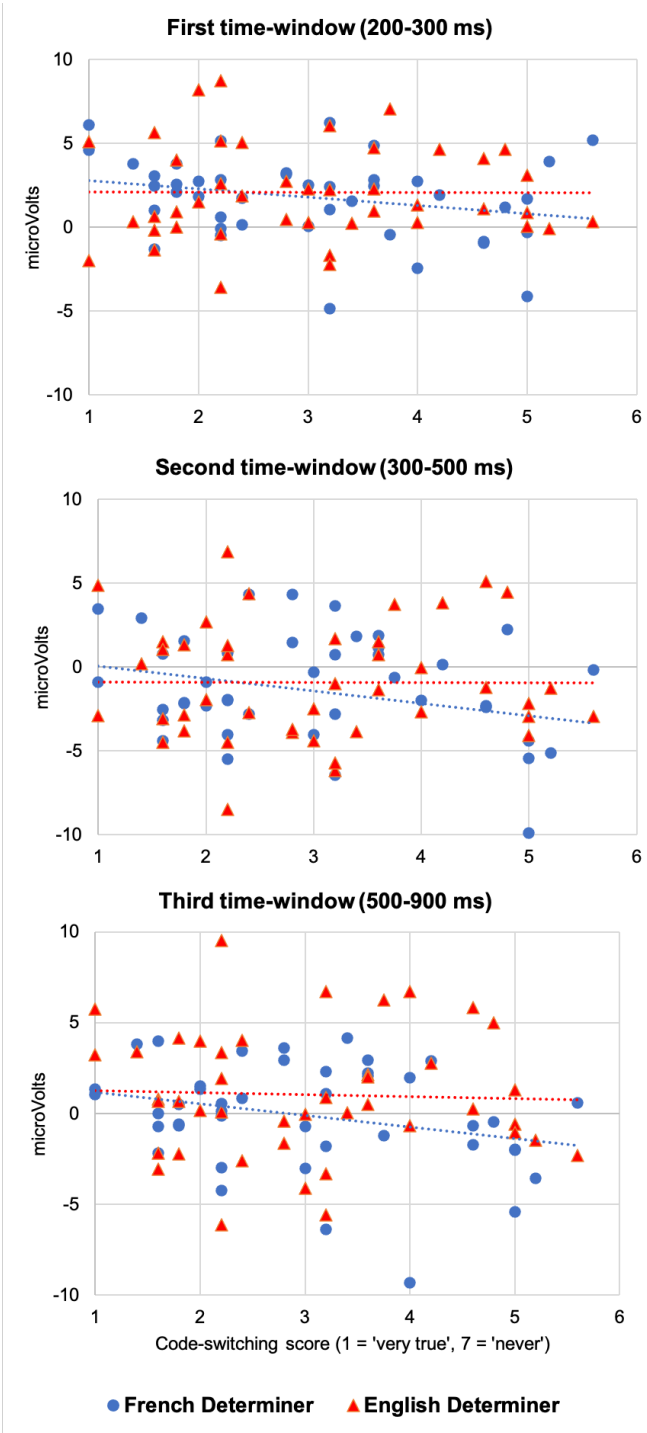
Table 5. *Participants' neural responses to the experimental conditions (i.e., code-switched or unilingual DPs with French or English determiners) correlated to i) the participants' average score to the code-switching questionnaire and ii) their proportion of interactions in English.*

	Switching habits				**% Interactions in English**			
	Code-switched DP		**Unilingual DP**		**Code-switched DP**		**Unilingual DP**	
TW (ms)	**FR det.**	**EN det.**	**FR. det**	**EN det.**	**FR det.**	**EN det.**	**FR det.**	**EN det.**
200-300	-.256*	-.004	.010	.143	-.244	.051	-.089	.222
300-500	-.264*	-.003	-.046	.120	-.483**	-.067	-.195	.055
500-900	-.277*	-.042	.029	.123	-.320*	-.139	-.188	.036

3.4. Overall summary of results

The first analysis was conducted to examine whether unilingual French trials yielded an expected gender congruency effect. Incongruent DPs generated an increased negativity in the first two time-windows; the effect appeared to be most robust for gender mismatches involving feminine nouns. From 300 to 500 ms, the congruency effect was only observed for non-habitual code-switchers. In the LPC time-window, feminine nouns were indexed by overall more positive responses. Both groups exhibited a positivity for mismatched feminine nouns.

Figure 5. Correlation between participants' switching habits (i.e., average score on the code-switching questionnaire) and their neural responses to switched DPs, according to the language of the determiner. For coloured figures, please visit the digital version. [single-column fitting image]



The main analysis examined code-switching-related processing costs. In the first two time windows, switched DPs were indexed by an increased negativity for the non-habitual code-switchers (but not habitual code-switchers); this effect was particularly robust for switched DPs with French determiners. In the final time-window, the increased negativity for switched DPs with French determiners was maintained for non-habitual code-switchers. On the other hand, habitual code-switchers exhibited an increased positivity for code-switched DPs relative to unilingual DPs, but only for those with English determiners. Finally, correlation matrices indicated that switching habits were indeed related to switching costs. The less participants reported code-switching, the more negative were their responses to code-switched DPs with French determiners. In the second and the final time-window, this type of DP was also correlated to participants' language-specific interactions: those who reported higher proportion of interactions in English exhibited the most negative ERP waves.

4. DISCUSSION

4.1. Switching-related negativity effects

Previous studies that have tested habitual code-switchers did not yield any negativity-related switching cost (Kaan et al., 2020; Litcofsky and van Hell, 2017). We obtained similar results for the habitual code-switchers in the current study. On the other hand, earlier research conducted on bilinguals who did not necessarily mix their languages suggested that code-switching *does* lead to negative ERP effects (e.g., Moreno et al., 2002; Proverbio et al., 2004; van der Meij et al., 2011). An N400-like response to switching was also exhibited by the non-habitually code-switching group in the current study. With this in mind, the differences between

the results in the literature do not appear to be coincidental; they seem to be very much linked to the participants under study.

Under this view, code-switching is not inherently effortful to process, at least at the lexicosemantic level. Rather, the cognitive costs classically attributed to switching are only present for individuals who are not used to seeing such stimuli, just like they would be for other linguistic irregularities. The production-distribution-comprehension (PDC) model (MacDonald and Thornton, 2009; Guzzardo Tamargo et al., 2016) supports this hypothesis. It posits that prior experience with a linguistic structure (and the relative frequency of this experience) modulates the comprehension costs attributed to the same structure. It is thus unsurprising that individuals who do not code-switch regularly (i.e., participant samples preceding Litcofsky and van Hell (2017); our non-habitual group) exhibit processing difficulties for switched DPs, and that this processing difficulty is reflected in the ERP waves. In our case, non-habitual code-switchers had little experience with switched DPs. When confronted with such 'unusual' linguistic data, these participants could not readily activate their representations, and a lexical-semantic processing effort ensued (an N400). Since habitual code-switchers encounter switched DPs on a regular basis, they are not privy to comprehension costs related to this type of input (as evidenced in the current study and in Kaan et al., 2020; Litcofsky and van Hell, 2017). This finding also illustrates that classic language switching costs in the behavioural literature are likely inapplicable to code-switching.

Going further, switched DPs elicited an N400 for non-habitual code-switchers, even though all the sentences read during the experiment contained both French and English words. This suggests that a single experiment is not sufficient to modify an individual's linguistic expectations based on their standard interactional context (dual-language vs. dense code-

switching; Green and Abutalebi, 2013). That is, non-habitual code-switchers exhibited lexical-semantic comprehension costs for switched DPs, since code-switching was unexpected within the scope of their interactional norms (even though it was highly expected within the scope of the study itself). The results from the correlations analyses also suggest that interactional context may have played a role in the findings. That is, bilinguals who reported an overall higher proportion of daily interactions in English exhibited the most negative ERP waves for code-switched DPs with French determiners. We stipulate that individuals with more interactions in English may often find themselves in single-language interactional contexts, as the majority language of the city of Ottawa is English. This could explain why these bilinguals generated the largest negativity effects.

Interestingly, the results from the correlation analyses also tend to suggest that the lexical-semantic switching cost was modulated by the language of the determiner within the switched DP. Namely, bilinguals who reported frequent code-switching exhibited less negative neural responses for switched DPs with French determiners (e.g., '*la* house'), but not those with English determiners (e.g., 'the *maison'*). We believe that these results support the presence of a directional asymmetry for French-English code-switching (contrary to behavioural results from Burkholder, 2018). As has been demonstrated for Spanish-English (e.g., Liceras et al., 2005), code-switchers may favour using gendered determiners when they alternate between their languages at the level of the DP. Since French is the gendered-language in the pair, we presume that the habitual code-switchers from the current study possessed prior experience with '*la* house'-type switches but not with 'the *maison'*-type switches. As a result, switching habits only modulated the responses to DPs with French determiners. DPs with English determiners are

simply irregular in the linguistic community, regardless of underlying code-switching habits. This explanation also supports the role of experience in comprehension-related processing costs.

Once again, not all bilinguals are code-switchers and switching habits should thus be carefully considered. Differing processing mechanisms appear to be at play for those who frequently code-switch and those who do not habitually mix their languages (and perhaps, even within these subgroups). Namely, lexical-semantic switching costs do not reflect the reality of all bilinguals; only those who have little prior experience with code-switching.

4.2. Switching-related positivity effects

Recall that Kaan et al. (2020) reported an overall LPC for code-switching and that Litcofsky and van Hell (2017) noted a late positivity for switches in the dominant-to-weak direction. Our findings resemble those studies in that switched DPs elicited an increased positivity in the final time-window, but (in our case) only for habitual code-switchers. Litcofsky and van Hell (2017) concluded that the LPC may reflect efforts on the bilingual's behalf to inhibit their more dominant language and activate their weaker language at a code-switching juncture. This explanation is logical for bilinguals within dual-language contexts (Green and Abutalebi, 2013), since this interactional context is thought to involve a coupled controlled mode rather than an open control mode (see Green and Wei, 2014). In coupled control, a bilingual's languages may be inputted into a planning layer, a sort of "gate" which allows bilinguals to switch languages when appropriate. This gate solicits cognitive control processes, which may be indexed as LPCs in the ERP responses.

We originally conjectured that the bilinguals from our sample originated from within a dense code-switching interactional context. This context incurs the least control processes, as

individuals from this type of environment have co-operating (versus competing) languages (Green and Abutalebi, 2013) and generally operate in open control mode. In an open control mode, the planning layer "gate" is open, so little cognitive control processes are required (Green and Wei, 2014). Indeed, past research has indicated that habitual code-switchers are equipped to integrate switched speech whenever it occurs (Valdés Kroff et al., 2017). Under the assumption that our habitual code-switchers were functioning in the open control mode, cognitive mechanisms should not be necessary. Consequently, we may gather that, in the current experiment, the LPC elicited by the habitual group for switched DPs was unrelated to cognitive control (i.e., activation-inhibition) mechanisms.

However, it is also possible that the stimuli included in the present study triggered the coupled control mode for the habitual code-switchers. Some type of switches, such as alternations and insertions, are expected to utilize the planning layer, and thus, to generate greater cognitive efforts. On the other hand, congruent lexicalisation (i.e., when "a shared language structure is realised with words/morphemes from different languages", Green and Wei, 2014, p.500) involves few control processes. One may argue that the switches in our material generated LPCs since they resembled alternations: French and English remained separate and did not overlap at the morphological level (Muysken, 2000; see also Green and Wei, 2014).

To complicate matters, an LPC was not observed for the non-habitual code-switchers. Rather, for this group, the N400-like response was sustained in the final time-window. This is unlike previous studies that tested participants who did not necessarily code-switch regularly (Moreno et al., 2002; van der Meij et al., 2011). We stipulate two potential explanations for the absence of the LPC among non-habitual code-switchers. Firstly, it is possible that the LPC found in previous literature is a consequence of the fact that bilinguals were collapsed into a single

group. That is, authors may have been inadvertently testing both habitual and non-habitual code-switchers in their participant samples, resulting in the presence of both N400 and LPC effects for code-switched sentences. When the participant groups are separated, as in the present study, it becomes conceivable that code-switching is indexed by comprehension costs for non-habitual switchers (N400), and that the LPC implies processing mechanisms specific to habitual code-switchers.

A second explanation is that positivity effects were simply not observable for the non-habitual group as the LPC temporally overlapped with the large and long-lasting N400 effect. In order to test this hypothesis, we verified whether distant ROIs were correlated across the second and third time-windows for non-habitual code-switchers. This was indeed the case: frontal left electrodes from 300 to 500 ms were strongly correlated to parietal right electrodes from 500 to 900 ms (two-tailed Pearson r =.59, p =.004). That is, the more negative the overall switching effect in the second time-window, the less positive the effect in the last time-window. The same result was found between frontal right and parietal lefts ROIs (r =0.60, p =.003). Thus, it is very much possible that LPC effects generated by switched DPs were masked by the preceding high-amplitude negativity observed for non-habitual code-switchers.

All of this considered, the exact nature of the LPC elicited by switched DPs is puzzling. While real-life code-switching has been termed effortless and fluid, it appears that this linguistic behaviour is indeed qualified by a differential electrophysiological signature. Perhaps there is a division in the cognitive mechanisms related to the *production* of switching and those related to the *processing* of switching. It is possible that some mechanism (indexed by the LPC) is indeed elicited when bilinguals process switched sentences, but that any switching-related costs become negligible in production, since they are outweighed by the greater ease of opportunistic word

retrieval for habitually code-switching individuals. This interpretation is linked to the "switch now, pay later" principle advanced by Gollan and Ferreira (2009). Indeed, various behavioural studies have shown that, when given the choice to switch languages at their own leisure (i.e., voluntary or internally generated switches; see Gullberg et al., 2009), bilinguals continue to do so, even when it lengthens their response times (de Bruin et al., 2018; Gollan and Ferreira, 2009; Jevtović et al., 2020). The "switch now, pay later" principle theorizes that bilinguals may not recognize the potential switching cost, and therefore opt to code-switch on the basis of pragmatic factors and/or lexical accessibility (Gollan and Ferreira, 2009). This principle may explain why an LPC was observed for habitual code-switchers.

Alternatively, it is possible that the LPC effect may have been caused by the nature of the experiment (though see Koronkiewicz and Ebert, 2018 for behavioural results). During the task, participants silently read French-English code-switched sentences. Admittedly, this modality is not the most natural, as code-switchers are more likely to hear or produce code-switched utterances than to read them. In addition, some researchers (e.g., Bialystok and Ryan, 1985) have indeed argued that visual presentation (i.e., reading) puts a spotlight on linguistic structure, while auditory presentation sets the focus on meaning. These factors may partially explain why switched DPs generated a late positivity: the P600-like effect is mainly attributed to syntactic difficulties, such as structure violation or reanalysis (e.g., Hagoort and Brown, 1999). We note that this may be particularly important for the current study, as code-switching in the francophone Canadian context is often stigmatized (e.g., Poplack, 1988). Interestingly, recent research does indeed indicate that switching-related LPC effects may be impacted by extralinguistic factors (e.g., the presence of another bilingual: Kaan et al., 2020). Other studies

examining habitual code-switchers also demonstrate that the LPC is not an absolute successor to code-switched language (Beatty-Martínez and Dussias, 2017).

4.3. Asymmetrical gender congruency effect

The current study yielded an additional, unanticipated finding. We conducted an analysis on the unilingual French DPs from our stimuli to verify whether expected gender congruency effects were present. Intriguingly, the observed effect appeared to be modulated by the gender of the noun within the critical DP and the participant group.

Firstly, unilingual DPs with feminine nouns generated overall more positive responses from 500 to 900 ms. We believe that this effect was observed since feminine is the 'marked' gender in French, while masculine is the 'unmarked' default (Nelson, 2005). Past studies have indicated that marked items may require more effort to process, as indicated by longer RTs (Domínguez et al., 1999), greater reading times (Deutsch and Bentin, 2001) or larger ERP effects (Aleman Banon and Rothman, 2016; Deutsch and Bentin, 2001). Recent reviews also support the idea that there are processing differences (both behaviourally and electro-physiologically) according to grammatical gender (see Beatty-Martínez and Dussias, 2019; Beatty-Martínez, Bruni, Bajo & Dussias, 2020).

Next, both N400-like and LPC-like gender congruency effects were observed for mismatches involving feminine nouns. Interestingly, from 300 to 500 ms, this effect was only exhibited by non-habitual code-switchers. The asymmetry in the gender effect may be attributable to the idea that feminine is the more "informative" gender, given that masculine is the default in French. Indeed, in an eye-tracking study, Valdés Kroff et al. (2017) found that Spanish-English bilinguals within code-switching communities utilized feminine gender to

anticipate upcoming nouns, but not masculine gender. Strikingly, this result was observed both in single-language and code-switching contexts. While our results do not completely align with those of Valdés Kroff et al. (2017), they seem to indicate that unilingual language is not impermeable to participants' switching habits. We posit that the habitual code-switchers in our study did not exhibit a classic congruency effect as these individuals are altogether more flexible to incoming input. Given that habitual code-switchers are exposed to switched DPs (that is, DPs containing both English and French words) on a regular basis, these bilinguals do not necessarily expect French determiners *la* or *le* to precede a gender congruent French noun. For instance, they could instead be followed by an English noun devoid of grammatical gender. These hypotheses provide an interesting avenue for further research.

4.4. Limitations

As always, certain limitations must be addressed. Firstly, all of the sentences included in the present study contained both French and English words. That is, none of the stimuli, including fillers, were completely unilingual sentences. We opted for this design to imitate a dense code-switching context, and since switching points prior to the critical DP are believed to mitigate processing costs (Burkholder, 2018). An anonymous reviewer suggests that this methodology may have favoured habitual code-switchers, as these individuals are more likely to be immersed in a type of setting where all communication occurs in code-switched speech. It is possible that habitual code-switchers may exhibit increased lexical semantic processing costs when code-switches are less expected in the stimuli list. Nonetheless, our results indicate that code-switches are not inherently cognitively costly, and that processing differences exist between habitual and non-habitual code-switchers. Future studies should venture to disentangle code-

switching frequency and code-switching context, and test the processing cost of switching by varying the proportion of code-switched sentences within stimuli sets.

Relatedly, it is notable that the experiment in the current study involved externally-induced code-switches rather than internally-generated code-switches (see Gollan and Ferreira, 2009; Gullberg et al., 2009; van Hell et al., 2018), as is the case for all of the existing ERP code-switching studies, to our knowledge. Consequently, a crucial avenue for future research involves implementing tasks (Gullberg et al., 2009) which would allow researchers to verify whether internally-generated code-switches also elicit LPC-like processing costs.

Lastly, in the main analysis (Section 3.2.2), all French determiners were congruent with the gender of the noun's translation equivalent (e.g., *la* house, 'the.$_{\text{FEM}}$ house', with 'house' being feminine in French). However, some past research has reported that certain types of bilinguals may prefer to use a default masculine (e.g., *le* house, 'the.$_{\text{MASC}}$ house') when they code-switch (Liceras et al., 2008). This recurring code-switching pattern has been reported for Spanish-English. While current research in our lab accounts for these variables and will attempt to verify if such patterns hold for French-English code-switching, they have not been considered in the present results.

5. Conclusion

The current study investigated the processing costs previously associated with code-switching. We compared a group of bilinguals who reported habitual code-switching to a matched group of bilinguals who reported infrequent switching. The main results indicate that code-switching does not necessarily lead to a lexical-semantic processing effort. That is, comprehension-related costs (as indexed by the N400) are absent for individuals who engage in

switching behaviour on a regular basis. These costs do, however, take place for non-habitual code-switchers; they are relatively long-lasting and may even attenuate subsequent LPC effects. For habitual code-switchers, switching incurs an LPC. This effect may be an artifact of the modality used during the experiment (i.e., visual vs. auditory stimuli) or be linked to a stimuli-induced coupled control mode. The results from the present study substantiate the idea that most previous studies likely yield semantic switching costs as they did not test habitual code-switchers. Our findings support the importance of participant sampling within this field (and other bilingualism-related fields) of research: there is no inherent mutual entailment between being bilingual and being a code-switcher. By demonstrating that code-switching is *not* a result of linguistic inability, but rather that it is a highly natural and skillful use of a bilingual's languages, we hope to lessen the stigma that surrounds the practice within francophone communities in Canada.

Notes

[1] Indeed, when random variability is not taken into account in the current study, as in Repeated-Measures ANOVAs, many of the critical effects and interactions yielded by the linear mixed models are reduced or nullified.

[2] Note that, as we initially planned to conduct analyses of variance on the data (see Section 2.5 and footnote 1), the original EEG codes for the experiment did not allow us to implement a random effect structure for experimental items.

[3] Correlations were computed individually for code-switched DPs and unilingual DPs in order to obtain a more fine-grained understanding of the data. That is, this procedure allows us to ascertain whether participants' language use was directly related to their neural responses to code-

switches. Switching habits were not expected to be related to ERPs in the unilingual trials, but these trials could introduce variability within the correlation matrices, therefore weakening the analysis. A more conservative approach involves correlating switching effects (i.e., unilingual – switched DPs) to language use; this analysis is included in the supplementary material.

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Data availability statement. A full stimuli list, as well as the additional analyses and figures can be found in the supplementary material. Averaged data are available on Open Science Framework (https://osf.io/npg6j/?view_only=730f604068774b88894e55056fa072ef).

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