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Do Accent and Input Modality Modulate Processing of Language Switches in Bilingual Language Comprehension?

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We examined how bilinguals process language switches between their first (L1) and second language (L2). Language switching costs (slower responses to language switch than nonswitch trials) appear to arise more systematically in production than in comprehension, possibly because the latter context might sometimes elicit less language coactivation (Declerck et al., 2019). This might reduce language competition and in turn the need for bilinguals to apply language control when processing language switches. Yet even in comprehension, language coactivation may vary depending on variables such as the accent of the speaker (e.g., whether the L2 words are pronounced with an L1 or L2 accent) and input modality (spoken or written). In three experiments conducted during 2021–2022, we tested how unbalanced Mandarin–English bilinguals processed language switches during comprehension and the potential influence of a speaker's accent and input modality. Overall, across settings, participants experienced significant language switching costs. In some conditions, switching costs were larger to L1-Mandarin than to L2-English, an asymmetry consistent with the participants' dominance in L1-Mandarin and the application of language control. However, manipulating accent and input modality did not influence language switches, suggesting they did not impact language coactivation sufficiently to modulate language control.

Public Significance Statement

This study investigates how bilinguals process language switches between their first and their second language. The results suggest that, across a variety of experimental settings, Mandarin–English bilinguals experience language switching costs when comprehending words. That is, being exposed to language switches induces a processing cost and increases the time needed to process incoming language input. However, processing of language switches did not seem to be modulated by variation in speaker accent (i.e., whether the words the bilinguals heard were pronounced by a native or nonnative speaker of the target language) and input modality (i.e., whether the bilinguals heard or read the words).

Keywords: bilingualism, language switching, language processing, comprehension

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Citation diversity statement: In this article, we proactively sought to include references to studies examining bilinguals with a wide variety of linguistic profiles (e.g., Mandarin–English, French–English, and Dutch–English bilinguals). Though English appears in most language combinations, this represents the literature well as English has the largest number of L2 speakers globally. As such, the literature we review provides a global representation of bilingual language processing. The reference list includes an equal distribution of first authors with different genders.

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When producing and comprehending words, bilingual speakers have access to two languages. These languages are coactivated and compete with each other. Evidence for this coactivation has been found across linguistic levels (see, e.g., Dijkstra et al., 2000; Spivey & Marian, 1999), including with dissimilar languages differing in script (e.g., Degani et al., 2018). This competition might be strongest when two languages are used interchangeably in dual-language contexts, such as when a bilingual is switching between languages (Green & Abutalebi, 2013). At the lexical level, language-switching tasks are one of the most commonly used experimental paradigms to investigate this competition and the control bilinguals might apply to manage it. In production-based switching tasks, bilinguals alternate between naming pictures in their first (L1) and in their second language (L2). In comprehension-based switching tasks, bilinguals are asked to process words alternating between the L1 and the L2. Switch trials (where the current word is not in the same language as the word preceding it) are often compared to nonswitch trials (where the current word is in the same language as the preceding word) to examine the costs associated with language switching. While a wealth of production studies report significant switching costs across languages and different types of bilinguals (i.e., bilinguals responding more slowly when switching between languages; e.g., de Bruin et al., 2018; Meuter & Allport, 1999), these costs seem to occur less consistently in comprehension studies (e.g., Declerck et al., 2019). This could suggest that less language coactivation and competition might sometimes arise during comprehension (Declerck et al., 2019) and, consequently, that less control might (sometimes) be needed to process two languages and the switches between them.

Importantly, this language coactivation and competition might vary across bilinguals and language contexts, which, in turn, could explain why (comprehension) switching costs are observed less consistently across different studies. The amount of language coactivation could depend on various factors related to both the language users themselves as well as to the overall context they are communicating in. In this study, we therefore investigated how bilinguals process language switches across three comprehension experiments that varied in factors that could modulate this language coactivation. We first examined whether Mandarin–English bilinguals experienced significant switching costs in an auditory comprehension language switching task (Experiment 1). Next, we examined whether coactivation and competition in comprehension is modulated by speaker accent (English words pronounced by an L1-Mandarin or an L1-English speaker; Experiment 2) and input modality (spoken or written words; Experiment 3). Together, these experiments aim to assess the way bilinguals manage language competition, and potentially use language control, to process language switches in different circumstances.

Production of Language Switches

Although our study focuses on processing of language switches during comprehension, the substantial psycholinguistic literature on language switching during production has influenced theoretical frameworks on bilingual language competition and control during switching. We therefore first provide a brief review of the production literature and the theoretical frameworks that have been proposed to explain switching costs. Production-based studies typically ask bilinguals to name pictures or digits, often in response to a cue indicating which language they should use. Across tasks, contexts, and different types of bilinguals, production studies have shown that bilinguals experience switching costs (e.g., Costa & Santesteban, 2004; de Bruin et al., 2018; Jevtović et al., 2020; Meuter & Allport, 1999; see Gade et al., 2021 for a meta-analysis).

To produce the intended word while switching between languages, bilinguals are argued to manage language interference by using language control (see Declerck & Philipp, 2015; Goldrick & Gollan, 2023 for reviews). In addition to selecting a target language (e.g., the language indicated by a visual cue), inhibition-related accounts postulate that bilinguals inhibit the nontarget language (e.g., Green, 1998). As bilinguals switch from language A to language B, they not only activate language B but might also inhibit the previously used language A. When returning to Language A on the following switch trial, this previously applied inhibition needs to be released to produce a word in Language A. According to these frameworks, switching costs can thus arise as a combination of activating the target language, inhibiting the nontarget language, and overcoming previously applied inhibition.

Inhibition-related accounts are also often used to explain the asymmetrical switching patterns that have been observed in unbalanced bilinguals with different proficiency levels and different levels of language use and exposure in their two languages. Although not in all studies, these bilinguals have been found to show larger L1 switching costs (i.e., costs induced when switching from their L2 to their L1) than in the other direction (e.g., Jin et al., 2014; Li & Gollan, 2021; Macizo et al., 2012; Meuter & Allport, 1999; Peeters et al., 2014; Philipp et al., 2007; but see Bobb & Wodniecka, 2013; Gade et al., 2021). Inhibition-related accounts (e.g., Green, 1998) explain this asymmetry by postulating that the amount of inhibition over the nontarget language is proportional to its level of activation. Due to stronger baseline activation of the dominant language, unbalanced bilinguals might need to apply stronger inhibition over their L1 than their L2. When switching back to the L1, more time could then be needed to release the previously applied inhibition, resulting in larger switching costs. Although researchers often use inhibition-related accounts to explain these types of asymmetries in switching costs (see, e.g., Gade et al., 2021; Goldrick & Gollan, 2023), other explanations have been offered too. Activation-related accounts (e.g., Declerck, Koch, & Philipp, 2015; Philipp et al., 2007) explain this pattern of asymmetry through overactivation of the L2. When producing words in the L2, that language may be activated (too) strongly to facilitate production in dual-language contexts. This (over)activation may persist in time in the form of residual activation, which might interfere when switching back to the L1 and consequently increase L1 switching costs. Although various mechanisms have thus been proposed (which are not necessarily mutually exclusive), a close relationship between switching costs and language competition and control is a key component of most theories (see Goldrick & Gollan, 2023, for a review of other effects evidencing language control during production, including an evaluation of why other accounts minimizing the role of control, e.g., BlancoElorrieta & Caramazza, 2021, cannot easily and fully explain those findings).

Comprehension of Language Switches

However, the need for language control—and the influence of language coactivation and competition more generally—has been challenged in recent research on language switching during comprehension (i.e., when a bilingual is reading or listening to words that alternate between languages). Declerck et al. (2019) reported that French–English and French–Spanish bilinguals did not experience any significant switching costs across a range of comprehension tasks, although their participants did experience significant switching costs in a production-based condition (their Experiment 4). Switching costs during comprehension were absent across a range of tasks (including, e.g., a parity task, a magnitude task, and an animacy judgment task). These findings suggest that switching costs may be less likely to occur in comprehension than in production tasks.

Similar to production, nonselective access (i.e., lexical candidates in multiple languages being activated and competing for recognition or selection) is a core component of bilingual models of word recognition and comprehension (e.g., the Bilingual Interactive Activation [BIA] model, Grainger & Dijkstra, 1992; van Heuven et al., 1998; the BIA+ model, Dijkstra & van Heuven, 2002; the BIA-d model, Grainger et al., 2010; the MultiLink model, Dijkstra et al., 2019). However, when it comes to processing language switches, Declerck et al. (2019) argue that, depending for instance on the linguistic context, the comprehension of two languages might sometimes trigger less parallel language activation (see also de Bruin & Xu, 2023), thus reducing interference of the nontarget language and resulting in less (need for) language control. Therefore, language coactivation might perhaps not always be strong enough during comprehension to cause noticeable interference that results in (measurable) switching costs. During word comprehension, the word itself (in most cases) specifies the target language, with orthographic and/or phonological information activating words in that target language, which may reduce activation of words in the other language. In contrast, during production, bilinguals start with a concept, which activates corresponding words in multiple languages and might result in more language competition (e.g., Declerck, Koch, & Philipp, 2015; Green, 1998).

Across the literature, switching costs appear less robust in comprehension than in production studies (see also, e.g., Declerck et al., 2019; Struys et al., 2019; see also Ahn et al., 2020; BlancoElorrieta & Pylkkänen, 2016; Mosca & de Bot, 2017 for a discussion on whether production and comprehension switching rely on separate language control mechanisms) and patterns of switching costs vary across the comprehension research field. Some studies have found switching costs in both languages. For instance, in a visual world paradigm, Olson (2017) exposed Spanish–English bilinguals to auditorily-presented sentences containing switched or nonswitched target groups of words while they were looking at a display containing pictures associated with the target words and three competitor images. Participants were slower to look to the correct image on switch than on nonswitch trials, showing a switching cost. Likewise, using a visual lexical decision task, Aparicio and Lavaur (2014; Experiment 1) showed slower switch than nonswitch reaction times (RTs) in French–English bilinguals.

However, many studies only report comprehension switching costs under specific circumstances. For instance, comprehension switching costs sometimes arise only in certain types of bilinguals, for instance, depending on their code-switching habits (e.g., Gosselin & Sabourin, 2021; Valdés Kroff et al., 2018; see also Kaan et al., 2020). Furthermore, the pattern of (a)symmetry in switching costs differs across the comprehension literature, with some studies only finding switching costs in one language (e.g., Bultena et al., 2015; Gullifer & Titone, 2019; Jackson et al., 2004; Mosca & de Bot, 2017; Olson, 2017) and others finding a symmetrical cost (e.g., Declerck & Grainger, 2017, Experiment 2; Hirsch et al., 2015; Jylkkä et al., 2018; Orfanidou & Sumner, 2005; Struys et al., 2019). When the cost varies between the L1 and the L2, some studies find a larger L1 cost while others report a larger L2 cost (i.e., larger cost induced when switching from the L1 to the L2). In line with many production studies, Litcofsky and Van Hell (2017, Experiment 1) observed larger switching costs when Spanish–English bilinguals switched into their L1 than into their L2 in a self-paced reading task (see also Declerck & Grainger, 2017; Olson, 2017; Philipp & Huestegge, 2015). This type of asymmetry, which is similar to asymmetries observed in the production literature, has been explained through inhibition-related accounts (Green, 1998). However, other comprehension studies have found the opposite pattern, with larger costs when switching to the L2 than to the L1, and this pattern appears more common than larger L1 costs (e.g., Aparicio & Lavaur, 2014; Bultena et al., 2015; Grainger & Beauvillain, 1987; Liu et al., 2020; Proverbio et al., 2004; Struck & Jiang, 2022). This asymmetry with larger L2 costs has been explained through relative activation of the two languages, without a clear need or role for top-down language control. With the L2's baseline activation being lower than that of L1 words, switching to an L2 might require more time to reach activation thresholds for recognition (e.g., Bultena et al., 2015), thus resulting in larger L2 than L1 costs.[1]

Theoretical Implications of Switching Costs During Comprehension

Thus, comprehension switching costs are mixed with respect to when they occur and which language they are strongest in. Currently, it is difficult to observe a consistent pattern in the literature with respect to which type of bilinguals, tasks, or stimuli are most likely to elicit comprehension switching costs. Two core questions therefore remain open. The first question concerns the role of language coactivation during the processing of language switches. Based on Declerck et al. (2019)'s argument, sufficient language coactivation might be necessary for switching costs to emerge during comprehension. Prominent models of multilingual processing (e.g., MultiLink, Dijkstra et al., 2019; BIA, Dijkstra & van Heuven, 1998; BIA+, Dijkstra & van Heuven, 2002) would predict switching costs to occur when processing language switches but would also allow for switching to be modulated by language coactivation. Language activation in these models can be modulated by various factors such as proficiency, amount of use, and frequency, which in turn could influence the amount of language competition bilinguals experience when processing language switches.

The second open question concerns the role of (top-down) language control during the processing of language switches. Some studies have attributed switching costs to inhibition or top-down language control (e.g., Litcofsky & Van Hell, 2017). Control to manage interference during switching (through overactivation and/or inhibition resulting in larger L1 than L2 costs) can also be accounted for in models of bilingual processing. For instance, the BIA (Grainger & Dijkstra, 1992; van Heuven et al., 1998) and BIA-d (Grainger et al., 2010) models include language nodes that receive bottom-up input from the target stimuli as well as information based on, for

[1] Some production studies (e.g., Declerck, Stephan, et al., 2015; Zheng et al., 2020) also report larger L2 than L1 switching costs, but those tend to be accompanied by faster L2 responses. In comprehension studies, larger L2 costs are typically observed together with slower L2 processing, suggesting the L2 is indeed relatively less active and requires more time to be recognised.

example, the language context. These language nodes can in turn, in a top-down manner, inhibit words in the nontarget language. This inhibition could slow down processing when switching to a previously suppressed language. In the BIA+ model (Dijkstra & van Heuven, 2002), control and top-down inhibition are not part of the word recognition system itself, although language control could be implemented to operate externally through a task/decision subsystem adjusting the recognition thresholds (i.e., lowering threshold for words in the expected target language and increasing it for nontarget language words).

In the current study, we aimed to address both the role of language coactivation and the potential role of language control. We did not aim to arbitrate between the different models of bilingual processing as reviewed above. However, our studies did aim to understand the role of language control, to better understand if and how top-down language control mechanisms might be needed to explain processing of language switches. We ran three experiments varying in language- and task-related variables that might influence language coactivation and, as a result, the processing of language switches in bilinguals. We tested unbalanced Mandarin–English bilinguals, who were more proficient in L1-Mandarin than in L2-English. In Experiment 1, we first tested whether these bilinguals experience switching costs in an auditory comprehension experiment. We then examined the potential role of two specific factors that could influence language coactivation and, potentially as a consequence, control. In Experiment 2, we examined the accent with which the L2 words are produced (L2 words spoken by a L1 or L2 speaker). In Experiment 3, we examined the modality of word presentation (spoken or written). We chose accent and modality in particular as previous research suggests that both phonological and orthographic information may influence the degree of language coactivation (e.g., Lagrou et al., 2011, 2013; Lewendon, 2020; Orfanidou & Sumner, 2005).

Experiment 1—Comprehension Switching in the Auditory Modality

Introduction

Processing of Language Switches in the Auditory Modality

Most comprehension-based language switching studies have been conducted in the visual modality as stated by Olson (2017) and Van Hell (2023), even though bilinguals are most likely to experience language switching in the oral modality (e.g., when speaking to a bilingual interlocutor; Van Hell., 2023). Bilinguals experience language coactivation both when processing visual and auditory stimuli (Dijkstra & van Heuven, 1998; Ju & Luce, 2004; Lagrou et al., 2011; Spivey & Marian, 1999; Van Assche et al., 2009). Models of bilingual language processing also suggest that switching costs should be expected both in the visual and in the auditory domains as the proposed mechanisms are not domain-specific (see, e.g., the BIA+; Dijkstra & van Heuven, 2002). Thus, switching costs should be expected to arise during auditory comprehension too.

In line with visual or reading tasks, however, studies using the auditory modality have shown mixed patterns of switching costs too. Shen et al.'s (2020) eye-tracking study reported significant switching costs when Mandarin–English bilinguals heard sentences with a switched final word and were asked to press a button if they saw the target object mentioned in the sentence. In contrast, Declerck et al. (2019; Experiment 3) found no significant language switching costs with French–English bilinguals performing a parity task involving both auditory and visual stimuli. Regarding asymmetries, Olson (2017) reported that bilinguals only showed (or showed larger) switching costs to the L1 but no (or smaller) costs to the L2, while Liao and Chan (2016) showed larger L2 than L1 costs. Given this mixed pattern of results, and the limited literature on processing of switches in spoken language, our first study examined switching costs in Mandarin–English bilinguals in a comprehension-based auditory task.

Present Study

Unbalanced Mandarin–English bilinguals completed an auditory comprehension-based language switching task. They were presented with Mandarin and English spoken words and asked to perform an animacy judgment task. We focused on bilinguals' processing of individual words to exclude potential influences of sentential syntax and semantics on the lexical level (Libben & Titone, 2009) as well as the potential role of sentence context, which can influence language coactivation and competition (Lauro & Schwartz, 2017). Furthermore, the presence of switching costs during comprehension has mostly been challenged in studies using individual words without context (Declerck et al., 2019). Given the preceding mixed literature regarding the occurrence of switching costs in comprehension-based switching tasks in general (Declerck et al., 2019) and in the auditory modality in particular (e.g., Declerck et al., 2019; Liao & Chan, 2016; Olson, 2017), we examined whether participants experienced significant switching costs in an auditory language switching task. If so, we also examined whether the switching costs were asymmetric across languages and in this case, whether this asymmetry was more compatible with language control explanations (larger L1 costs than L2, e.g., Mosca & de Bot, 2017; Olson, 2017) or relative-activation based accounts without requiring top-down control (larger L2 than L1 costs; Liao & Chan, 2016).

Methodology

Transparency and Openness

The data set and analysis script are available on the Open Science Framework (https://osf.io/zh7bx/). The stimuli are provided in the online supplemental materials. Experiment 1 was part of a larger longitudinal project. While Experiment 1 only includes data from the first wave of data collection and was not preregistered separately, the preregistration of this larger project, as well as its data sets and preprint, can be found at https://osf.io/a24xv/.

Participants

The final data set included 57 Mandarin–English bilinguals (52 female, $M_{\text{age}} = 23.47$, $SD_{\text{age}} = 2.28$) who were tested between September and October 2021. We did not run a power analysis for this experiment as the analysis included the number of participants that had been tested in the first part (academic year) of the longitudinal project (i.e., before the start of Experiments 2 and 3). However, our sample size and number of trials per condition were above the 40 participants and 40 trials per condition recommended by Brysbaert and Stevens (2018) for a properly powered RTs experiment using mixed-effects analyses. At the moment of testing, 26 participants had just arrived in the United Kingdom from China (as part of the longitudinal project) and 31 were living in China (functioning as a control group for the longitudinal project).[2] To ensure that participants had the same testing conditions in both groups, both groups completed the same battery of tests led by Mandarin–English bilinguals who were given training and detailed instructions on how to run the experiment. Participants furthermore always received the same instructions on the screen in both languages. All participants had normal or corrected-to-normal vision and no known neurological, reading, or hearing impairments and they all scored at least 70% accuracy on the animacy judgment task. The study was approved by the Ethics Committee of the Department of Psychology at the University of York. Participants provided written informed consent at the start of the study.

We used multiple questionnaires to assess the linguistic background of the participants, including objective and subjective measurements of language proficiency (de Bruin et al., 2017). In Table 1, we only report the measures that were also included in Experiments 2 and 3. Participants completed the English LexTALE (Lemhöfer & Broersma, 2012), a short lexical decision task in which participants were presented with 40 words and 20 nonwords and asked to indicate whether they exist in English or not. The participants also provided self-ratings of their Mandarin and English proficiency levels on scales from 1 to 10 in terms of speaking, listening, reading, and writing skills. These measures confirmed that the participants were more proficient in Mandarin (Table 1). The participants also completed a language-background questionnaire based on Anderson et al. (2018). Given that participants were either living in China or had only just arrived in the United Kingdom, they were and had been mostly using Mandarin during their life ($M = 3.97$, $SD = 1.47$; ratings provided on a 1–5 scale with higher values indicating more Mandarin use; see Table S1 in the online supplemental materials). All participants reported that Mandarin was their native language and they had started learning English at 8.48 years old on average ($SD =$ 1.94, range 5–13). Finally, the participants reported (1 = *never*, 5 = *all the time*) how often they switched between languages on a daily basis ($M = 2.77$, $SD = 0.93$), in a conversation ($M = 2.46$, $SD =$ 0.80), and within sentences ($M = 2.16$, $SD = 0.77$).

There was a significant difference between Mandarin and English on all measurements (see Section 1 in the online supplemental materials).

Materials

Participants completed an animacy judgement task in which we asked them to indicate whether the words presented to them referred to living or nonliving entities. We selected 120 words using the Multipic database (Duñabeitia et al., 2018); Mandarin translations were provided separately by a Mandarin native speaker. Items were matched in frequency across languages (see Table 2 Sa–2Sf in the online supplemental materials for all stimuli). The Mandarin words included no more than three characters and the English words no more than three syllables. Forty-two words referred to living entities, and 78 to nonliving entities. This imbalance was due to a practical issue: Within the larger set of stimuli needed for the longitudinal project, there were not enough living entities that met the other criteria we established for stimuli selection (e.g., stimuli had to be easy-to-name words and depictable). This imbalance was not expected to influence the analyses of interest as the living and nonliving stimuli were equally distributed across trial types. We asked one female Mandarin native speaker to record both the Mandarin and the English words. The speaker had a neutral Mandarin accent, which could easily be understood by speakers from China. She produced the L2-English words with an accent that was representative of L1-Mandarin speakers of L2-English but in a way that could be easily understood. The mean duration of the recordings was 828 ms ($SD = 151$) for Mandarin words and 795 ms ($SD = 146$) for English words—no significant difference: $t(238) = 1.746$, $p = .082$. Using Praat, the recordings were matched for intensity and cut so that each audio file contained 50 ms silence before and after the target word.

Procedure

The participants completed the study in the lab, within one session that included a battery of production and comprehension tasks in different conditions. The comprehension task itself lasted approximately 15 min. It was presented in PsychoPy (Peirce et al., 2019) and led in person by a Mandarin–English bilingual. The participants first completed a familiarization phase where they were presented with the spoken English and Mandarin words, accompanied by the written form to make sure participants understood the words correctly. The participants were instructed to just listen to the word and look at the written form. They then completed practice phases in English and in Mandarin, which were each immediately followed by a single language experimental block in the same language. Participants had to make an animacy judgement for each word and always indicated their responses by pressing "L" (living) or "A" (nonliving), respectively. They were asked to respond as quickly and accurately as possible. We did not counterbalance the button-press side of the living versus nonliving responses because the categories assigned to each button press were not of interest for this study (i.e., we did not aim to compare living and nonliving responses). However, living and nonliving responses (i.e., pressing "L" or "A") were distributed equally across the different conditions to avoid right- or left-hand responses influencing the trial types of interest. The order of the English and the Mandarin practice phases and single-language blocks was counterbalanced between participants. Participants also completed another set of single-language blocks after the dual-language part to compute mixing effects. However, for this study, we were purely interested in the reactive control associated with switching in the dual-language part. The mixing effects of the complete longitudinal study are analyzed and discussed in the article associated with that project.

In the dual-language part, words were presented either in Mandarin or in English. Participants first completed four practice trials. The main experimental phase then included 240 trials. Participants were randomly assigned to one of six lists of 240 experimental trials each. Each list contained 13 unique nonliving entities and seven unique living entities, with each word repeated 12 times. In each list, half of the trials were in English and the other half in Mandarin; 33% of the trials were language switch trials, and these trials were distributed equally across languages. The switching frequency was chosen to match the switching frequency in the production tasks included in the same session, which included a voluntary

[2] For this experiment, we were not interested in examining potential differences between groups, but further analyses showed that switching costs did not differ between the two groups (participants in the United Kingdom or China) at this first testing point (mean switching effects per group: participants in the United Kingdom: $M = 1$, $SD = 38$; participants in China: $M =$ 10, $SD = 43$; $p = .323$).

Table 1
Summary of Objective and Subjective Measurements of Language Proficiency in Mandarin (Left) and English (Right) for the Participants of Experiment 1

	Mandarin			English		
Language proficiency measure	Mean	*SD*	Range	Mean	*SD*	Range
LexTALE (0%–100%)	—	—	—	67.02	10.62	45–87.5
Self-rated proficiency (0–10)						
Speaking	9.23	1.05	6–10	6.02	1.04	4–8
Understanding	9.40	0.92	7–10	6.68	1.21	2–9
Writing	8.09	1.66	4–10	6.04	1.28	3–9
Reading	8.88	1.18	6–10	7.07	1.19	3–9

Note. We computed the participants' LexTALE score with the formula provided by Lemhöfer and Broersma (2012): [(number of words correct/40 × 100) + (number of nonwords correct/20 × 100)]/2. LexTALE data are missing for three participants.

switching task with an expected switching frequency of around 30%. Within each list, each word was presented an equal number of times in each condition. Between 56% and 63% of the trials were category switches (i.e., trials where participants needed to switch between a "living" and a "nonliving" response). The category switches (i.e., living vs. nonliving items) were distributed equally across trial types and language. The trials were pseudorandomized with no more than four trials of the same type (language switch or nonswitch), language, or animacy category in a row. The words were also presented pseudorandomly so that the participants would not hear the same word twice in a row. A trial consisted of a 500-ms fixation cross followed by the presentation of the target word until a response was given or for 2,500 ms if no response was given.

Data Analysis

We analyzed the RT data with mixed-effect models in R (3.6.1.) using the packages lme4 Version 1.1.21 (Bates et al., 2015) and lmerTest Version 3.1.3 (Kuznetsova et al., 2017). We did not analyze accuracy data as these data mostly represented wrong animacy category judgments. We started the analysis with a maximal model (Barr et al., 2013) that included random intercepts for subjects and items, and all within-subject/-item predictors. In the case of nonconvergence, we removed the correlations between random slopes and random intercepts. We then reduced the random effect structure by removing the random slopes explaining the least variance until reaching convergence. The final random-effects structure of the models can be found in the tables. We coded the two-level within-subject categorical predictors as follows: language (Mandarin [−0.5], English [+0.5]), and trial type (nonswitch [−0.5], switch [+0.5]).

We log-transformed the RTs to improve normality of the distribution in the analysis. We report the means of the untransformed RTs in the text and tables for ease of comprehension. Overall, participants scored 94.12% accuracy on the animacy judgment task. Prior to analysis, we excluded inaccurate trials on the animacy judgment tasks (i.e., errors in identifying words as representing living or nonliving entities) and 2.23% of correct trials as RT outliers (2.5 *SD* above/below mean per participant and condition, plus trials faster than 300 ms; Grange, 2015). Note that, contrary to production studies, all stimuli were played in the intended language, even when a participant pressed a wrong button. Therefore all trials, even those preceded by a mistake in animacy judgment, could still be identified as language switch or nonswitch trials. We did exclude trials occurring after a break as these trials were neither switch nor nonswitch trials.

Results

The RT analysis showed a main effect of language (see Tables 2 and 3 and Figure 1), with slower responses in L2-English ($M = 1{,}136$, $SD = 143$) than in L1-Mandarin ($M = 1{,}052$, $SD = 148$). The main effect of trial type was not significant but there was a significant two-way interaction between trial type and language. We examined the switching cost by language to further understand the interaction. The models included by-subject and by-item intercepts and the by-item slope for trial type. This analysis showed a significant cost when switching from L2-English to L1-Mandarin ($M = 21$, $SD = 57$, $\beta = .016$, $SE = .005$, $t = 3.235$, $p = .002$). In contrast, there was no significant switching cost when switching from L1-Mandarin to L2-English ($M = -10$, $SD = 45$, $\beta = -.009$, $SE = .005$, $t = -1.704$, $p = .091$; see Table 3).

Discussion of Experiment 1

Experiment 1 firstly showed a main effect of language, such that our unbalanced bilingual participants responded faster to L1-Mandarin than L2-English words. The Mandarin–English bilinguals also experienced significant switching costs (to Mandarin), showing that switching costs can be observed in an auditory comprehension switching task (see also, e.g., Olson, 2017; Shen et al., 2020), as opposed to previous research finding no switching costs at all (e.g., Declerck et al., 2019). This suggests that, at least in these circumstances, language coactivation was sufficient to elicit switching costs (in one of the languages) during comprehension. Our results also show that significant switching costs can be observed through behavioral measures (despite arguments that more sensitive measures such as unctional magnetic resonance

Table 2
Outcome of the Linear Mixed Effect Models for Experiment 1

Fixed effects	Estimate	*SE*	*t*-value	*p*-value
Intercept	6.972	.017	410.094	**<.001**
Trial type	0.003	.004	0.818	.417
Language	0.076	.009	8.258	**<.001**
Trial Type × Language	−0.025	.007	−3.350	**.001**

Note. The final model included by-subject random intercepts and random slopes for trial type and language and by-item random intercepts and random slopes for trial type, language, and their two-way interaction. *p* values in bold reflect significant effects.

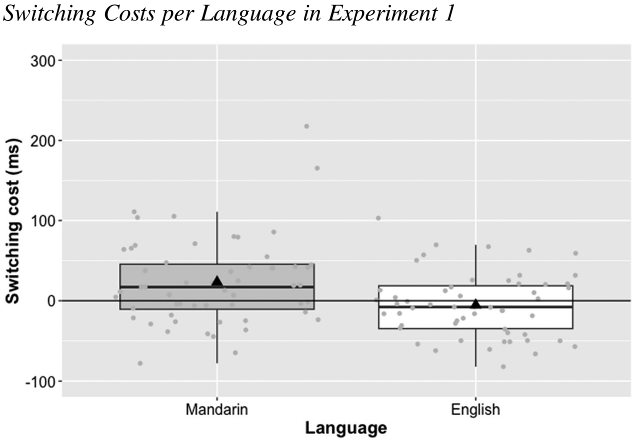
Table 3
Reaction Times and Switching Costs (Milliseconds) in Experiment 1

Trial type	Mandarin	English
Switching trials	1,066 (164)	1,129 (146)
Nonswitching trials	1,045 (143)	1,139 (143)
Switching cost	21 (57)	−10 (45)

imaging, lectroencephalography, or eye-tracking might be needed; Ahn et al., 2020) and when words are presented without context. However, we only observed significant switching costs when the bilinguals switched from L2-English to L1-Mandarin, but not from L1-Mandarin to L2-English.

When bilinguals show switching costs in comprehension, the language-specific effects vary across the literature. Our findings are at odds with the frequent observation that comprehension switching costs are larger when switching to the L2 (e.g., Aparicio & Lavaur, 2014; Bultena et al., 2015; Grainger & Beauvillain, 1987; Liu et al., 2020; Proverbio et al., 2004; Struck & Jiang, 2022). However, our results do align with other comprehension studies showing larger costs to the L1 (Declerck & Grainger, 2017; Litcofsky & Van Hell, 2017; Olson, 2017; Philipp & Huestegge, 2015) and with the more typically observed direction of asymmetries in the production literature (e.g., Meuter & Allport, 1999). This pattern of asymmetry suggests, and is often interpreted to imply (e.g., Declerck & Grainger, 2017; Olson, 2017), that the bilinguals relied on some form of top-down language control to manage access to and interference between their two languages. The opposite pattern of asymmetry, larger L2 switching costs, could be explained without this top-down control, as more time might be needed for the L2 to reach its activation threshold due to relatively lower resting activation levels. However, larger L1 switching costs (as observed here) are more typically explained through the involvement of top-down language control, either in the form of L2 overactivation (e.g., Philipp et al., 2007) or through L1 inhibition (e.g., Green, 1998; Litcofsky & Van Hell, 2017). L2 overactivation accounts would explain this asymmetry through bilinguals proactively overactivating the L2 to allow for easier L2 processing in dual-language contexts, which in turn can interfere with the L1 when switching to the L1. L1 inhibition accounts would explain the asymmetry through bilinguals inhibiting their L1 during L2 processing, resulting in longer switch times back to the L1 to overcome this inhibition.

Figure 1
Switching Costs per Language in Experiment 1



Note. Triangles represent mean switching costs; the black lines in the box plots represent the medians; the whiskers represent the lower and the upper quartiles; grey dots represent individual data points.

To make sure that the asymmetry in switching costs between languages was specifically related to the switch trials (and not due to differences on the nonswitch trials), we compared the language difference on switch and nonswitch trials with the single-language trials participants completed too. If the asymmetry in switching cost is driven by the switch trials, the language difference on the switch trials should be different from the nonswitch and single-language trials, with no language-effect difference between the nonswitch and single-language trials. We therefore computed the language difference per trial type per participant and computed an additional analysis of variance (ANOVA; given that we were now working with means per participant rather than trial-level data). This showed that the language effect (faster L1 than L2 responses) differed across trial types (main effect $p = .005$; see Section 3 and Table S3 in the online supplemental materials), with the language difference being similar for single-language and nonswitch trials (Holm-adjusted post hoc tests: $p = .237$) but differing significantly for the switch trials relative to the nonswitch ($p = .033$) and blocked trials ($p = .001$). This shows that the asymmetrical switching cost observed here (larger L1 than L2 cost) was specifically driven by the switch trials showing slower L1 responses.

Overall, our findings thus suggest that bilinguals experienced language competition during auditory processing and that this competition was sufficient to elicit switching costs. Furthermore, the pattern of costs (only present when switching to the L1 but not to the L2) suggests that they not only experienced language competition during switching but that they also applied language control to manage this. This competition and control could be applied at different levels, including at the lexical and the phonological levels. The latter component might be especially relevant in this study considering the differences in phonology between Mandarin and English (cf., Declerck & Philipp, 2015, for a review of the different levels affected by language switching). We discuss language control during language switching further in the General Discussion section.

Importantly, because we wanted all participants (including those living in China) to be familiar with the accent the words were pronounced with, all words, including the English ones, were pronounced by an L1-Mandarin speaker. There is evidence that phonological information can influence the degree of language coactivation (e.g., Lagrou et al., 2011, 2013; Lewendon, 2020). It is possible that the L1-Mandarin accent used on the L2-English words boosted the activation of L1-Mandarin throughout the task. Thus, Mandarin might have been the more dominant language in the task not just because of participants' earlier age of acquisition of and higher proficiency level in that language, but also because of the Mandarin accent potentially coactivating Mandarin words more strongly during L2 word processing. This might have further increased the amount of control (potentially inhibition) the bilinguals needed to apply toward L1-Mandarin, and as a result, increased the switching costs into L1-Mandarin.

Thus, based on the results of Experiment 1, it could be hypothesized that accents modulate language coactivation and competition, and potentially the need for language control when processing language switches. We probed this further in Experiment 2 to investigate the potential influence of accents on language control and switching costs. To do so, we manipulated whether the L2-English words were pronounced by an L1-Mandarin speaker or by an L1-English speaker to assess the role of accent when processing language switches.

Experiment 2—The Role of Accent

Introduction

Phonological Information and Language Coactivation

Studies investigating the effect of accent on L2 processing have mainly tried to understand whether hearing the L2 with an L1 accent makes comprehending the L2 easier or more difficult, with mixed results. Lagrou et al. (2011, 2013) found that participants exposed to L1 or L2 words pronounced by a native or nonnative speaker of that language responded faster to words pronounced with their congruent accent (i.e., produced by a native speaker of the language). This may be because this corresponded to how participants had stored the lexical representations of the target words. In contrast, Major et al. (2002) and Munro et al. (2006) found that L1 accented speech could facilitate L2 comprehension in some circumstances.

Very few studies, however, have examined whether accents modulate language activation (Lewendon, 2020), although some research suggests that phonological cues can influence the degree to which a bilingual's two languages are coactivated during language comprehension. For example, Ju and Luce (2004) found that including L2-English voice onset times at the beginning of L1-Spanish words (e.g., "playa") increased bilinguals' likelihood to look at pictures of cross-language English competitors (e.g., "pliers") during a Spanish visual world task. Likewise, in a study with Welsh–English bilinguals, Lewendon (2020) exposed participants to pairs of semantically unrelated L2-English words pronounced with an L1-Welsh accent (e.g., prime word: "interview" and target word: "warm"), whose L1-Welsh translation-equivalents overlapped phonologically (e.g., in Welsh "interview" and "warm" translate as "cyfweliad" and "cynnes," respectively). Although the words did not overlap phonologically in English, participants experienced implicit phonological priming when the Welsh equivalents did. Crucially, this phonological priming did not occur when the L2-English words were pronounced with their corresponding English accent, which suggests that the L1-Welsh accent boosted coactivation of the nontarget language. Similarly, Lagrou et al. (2011) assessed how Dutch–English bilinguals processed interlingual homophones (e.g., "lief" [sweet in Dutch]—"leaf" in English) embedded in low- or high-constraint L2-English sentences pronounced by an English or a Dutch L1 speaker. The bilinguals showed significant homophone effects (i.e., slower RTs on interlingual homophones) during the auditory lexical decision task both with L2 English-accented and L1 Dutch-accented sentences, but they were faster with L2 English-accented sentences. There are two potential explanations for these results: The English accent may have reduced coactivation of Dutch, or the Dutch accent may have increased coactivation of Dutch while processing the homophones.

Together, this set of studies suggests that phonological information such as a speaker's accent may modulate coactivation of the nontarget language and language interference in the listener (e.g., Lewendon, 2020). In our Experiment 1, the fact that all words were produced by an L1-Mandarin speaker could have increased the activation of the nontarget L1-Mandarin language while processing the L2-English words, and in turn might have boosted the need for language control and increase or result in switching costs. Thus, in Experiment 2, we manipulated whether the English words were pronounced by an L1-Mandarin or an L2-English speaker to assess the effect of accent on processing of language switches and the potential influence of language coactivation on control during comprehension.

Present Study

To examine how accent influences processing of language switches in bilinguals, in Experiment 2, we manipulated whether the L2-English words were pronounced by L1-Mandarin speakers as in Experiment 1 (henceforth referred to as the "one-accent task," with all words pronounced by L1-Mandarin speakers) or by an L1-English speaker (the "two-accent task" henceforth, with L2-English words pronounced by L1-English speakers and L1-Mandarin words by L1-Mandarin speakers). Importantly, two speakers were used to record the stimuli per language, so that there would be speaker switches in each language in both tasks.

Predictions

Based on the results of Experiment 1 and previous research, we formulated two sets of questions and hypotheses:

1. As a first (although not main) research question, we examined how accent influenced overall processing of words (regardless of language switches). If accent has an influence, we expected RTs on L2-English words to differ between the one-accent and the two-accent tasks. Given that L1-Mandarin words are always produced by an L1-Mandarin speaker, this effect would emerge as an interaction between language (Mandarin vs. English) and accent (one-accent vs. two-accent task). Specifically, if the L1-Mandarin accent (i.e., the Mandarin accent that the Mandarin–English bilinguals are familiar with) makes it easier to process the L2-English words (Major et al., 2002; Munro et al., 2006), we expected bilinguals to process the L2-English words faster when produced by a L1-Mandarin speaker (in the one-accent task) than by an L1-English speaker (two-accent task). If, on the contrary, the L1-Mandarin accent makes it more difficult to process the L2-English and/or words are recognized faster in the congruent accent (Lagrou et al., 2011, 2013), we expected the bilinguals to process the L2-English words faster when produced in a L1-English accent (two-accent task).
2. Given the results of Experiment 1, we expected to observe significant switching costs, in particular when participants switched to the L1-Mandarin. We also had the following sets of predictions, which went in two different directions, with the second prediction being related to language coactivation and control specifically:
   a. If switching between different accents (L1-Mandarin vs. L1-English accents) increases processing time at the phonological level, we expected a significant interaction between trial type (language switch vs. nonswitch) and accent, with a larger switching cost in the two-accent task than in the one-accent task. This type of pattern

could purely reflect increased demands at the phonological level, without requiring changes in language coactivation or competition as such.

b. If language-specific phonological information reduces activation of the nontarget language (e.g., Lagrou et al., 2013) at the lexical and/or phonological level, we expected the two-accent task (L2-English words with an L1-English accent) to reduce L1-Mandarin coactivation relative to the one-accent task that was similar to Experiment 1 (where L2-English words with a L1-Mandarin accent might boost L1-Mandarin coactivation). In this case, we expected a smaller switching cost in the two-accent task than in the one-accent task. If this decrease in L1 activation specifically affects language control (e.g., the release of L1 inhibition when switching to the L1), we expected a three-way interaction between trial type, language and accent reflecting a larger switching cost asymmetry in the one-accent task (with smaller L1 costs in the two-accent task).

Methodology

Transparency and Openness

The preregistration of the study (https://osf.io/r9d2c) and its complete data set and analyses script (https://osf.io/zh7bx/) are available on the Open Science Framework. The stimuli are provided in the online supplemental materials.

Participants

The final data set included 97 Mandarin–English bilinguals (65 female, $M_{age} = 27.93$, $SD_{age} = 7.96$) who were tested between July and December 2022. These participants completed the two tasks of Experiment 2 and the task of Experiment 3 within one single online session. The target number of participants was determined with a power analysis based on a series of simulations ran with mixed-effect models using the faux package (DeBruine et al., 2023). Using the Mandarin trials of Experiment 1 (to focus on the significant L2–L1 costs observed in this experiment), we found that, with a sample size of 90 participants, we could detect an L2–L1 switching cost with an effect size of .013 with 72% power. Using the data of de Bruin and Xu (2023), a comprehension-based language switching study with visual stimuli, we found that, with a sample size of 90 participants, we could detect a switching cost in a visual context (as in Experiment 3) with an effect size of .021 with 91% power. Based on this, we estimated that a sample size of 96 would give sufficient power to detect small-to-medium switching costs. Unfortunately, we could not run simulations with accent and modality as factors, as no previous study had targeted these variables in a set up similar to our study. Note that although we originally planned to collect data from 96 participants only, we received data from 97 eligible participants. Ninety-four participants were living in the United Kingdom, while the remaining three were not living in the United Kingdom but confirmed they had all previously lived there, which was important as the participants listened to British speakers during the experiment. All participants had normal or corrected-to-normal vision and no known neurological, reading, or hearing impairments. Although we tested 102 eligible participants in total, five participants were excluded from the final data set because they scored less than 70% accuracy on the animacy judgment task on one of the three tasks (four participants) or because they completed only one of the tasks (one participant). The study was approved by the Ethics Committee of the Department of Psychology at the University of York. Informed consent was provided at the start of the online study.

Participants completed the English LexTALE (Lemhöfer & Broersma, 2012; see Experiment 1) as well as a Mandarin version of the LexTALE (Wen et al., 2023). They provided the same self-reported assessments of their Mandarin and English proficiency levels and language use as in Experiment 1. These confirmed that Mandarin was the most proficient language of the participants (Table 4). The participants reported that they had started learning Mandarin at 0.48 years old on average ($SD = 1.39$, range 0–7) and English at 5.85 years old on average ($SD = 3.37$, range 0–14). The participants' responses suggested that they used English and Mandarin to a similar extent in their current interactions ($M = 2.84$, $SD = 0.96$; ratings provided on a 1–5 scale with higher values indicating more Mandarin use; see Table S4 in the online supplemental materials). The participants also reported on 1–7 scales (1 = *never*, 7 = *all the time*) how often they switched between languages on a daily basis ($M = 5.60$, $SD = 1.44$), in a conversation ($M = 4.54$, $SD = 1.85$) and within sentences ($M = 4.23$, $SD = 1.92$).

Design

This study included three within-participants variables: language (English vs. Mandarin), trial type (nonswitch vs. switch trials), and accent (two-accent task with L1-Mandarin words produced by L1-Mandarin speakers and L2-English words by L1-English speakers vs. one-accent task with all words produced by L1-Mandarin speakers).

Materials

As in Experiment 1, the participants completed an animacy judgment task. We selected 60 words from the Multipic database (Duñabeitia et al., 2018); 30 represented living entities, while 30 referred to nonliving entities. These words were a subset of the words used in Experiment 1. The English and Mandarin versions of these words had a maximum of three syllables or three characters, respectively. The words' frequencies were matched across languages (see Table S5a–S5c in the online supplemental materials).

We asked two female L1-Mandarin speakers to record the Mandarin and English words, while two female L1-English speakers recorded the English words for the two-accent task. We recorded two speakers per language to ensure that we could include speaker switches even in the case of two consecutive trials in the same language and even in the one-accent task (as the two-accent task necessarily included speaker switches). This way, there were speaker switches between each trial, also on trials that did not include a language switch. The L1-Mandarin speakers had a Chinese accent that could be easily understood by speakers from China. The L1-English speakers had a British accent, similar to the kind of accent the bilinguals included in this study would have been exposed to as they learned English and used English in the United Kingdom (where most participants were living). Using Praat, the recordings were matched for intensity and cut for each audio file to include 50 ms

Table 4

Summary of Objective and Subjective Measurements of Language Proficiency in Mandarin (Left) and English (Right) for the Participants of Experiments 2 and 3

	Mandarin			English		
Language proficiency measure	Mean	*SD*	Range	Mean	*SD*	Range
LexTALE (0%–100%)	91.83	10.16	57.5–100	74.28	13.06	48.75–97.5
Self-rated proficiency (0–10)						
Speaking	9.44	1.13	5–10	7.70	1.62	4–10
Understanding	9.58	0.92	5–10	8.01	1.55	3–10
Writing	8.95	1.82	2–10	7.72	1.59	4–10
Reading	9.53	0.96	5–10	8.37	1.36	5–10

Note. There was a significant difference between Mandarin and English on all measurements (see Section S2 in the online supplemental materials).

silence before and after the target word. For the one-accent task (across the two speakers), the mean duration of the recordings was 790 ms ($SD = 216$) for Mandarin words and 786 ms ($SD = 231$) for English words, $t(238) = 0.121$, $p = .904$. In the two-accent task (across the four speakers), the mean duration of Mandarin recordings ($M = 790$, $SD = 216$) was shorter than that of the English recordings ($M = 869$, $SD = 135$), $t(238) = -3.442$, $p < .001$. This might be due to differences between the speakers rather than differences due to the stimuli themselves, which were the same across tasks and matched in duration in the one-accent task (where both languages were produced by the same speakers).

Procedure

The participants completed the study online, within one session of about 30 min. The study was built in Gorilla (Anwyl-Irvine et al., 2020), and the participants were predominantly recruited via Prolific (https://www.prolific.co/) or via SONA (https://www.sona-systems.com/). The testing session comprised the three language switching comprehension tasks (the two tasks of Experiment 2 and the task of Experiment 3, see below), with the task order counterbalanced across participants. We report Experiments 2 and 3 separately as they address different research questions and were preregistered as two separate studies within the same session. The participants never saw the same set of items twice as they completed each task with a different list of 20 unique items.

Each task started with a familiarization phase in which the participants were presented with the target words auditorily (for the two tasks of Experiment 2) or visually (for the visual task of Experiment 3), accompanied by pictures. After the familiarization phase, participants were not presented with pictures but only heard (auditory tasks of Experiment 2) or saw (visual task of Experiment 3) the words. Participants then completed four practice trials in English, followed by a practice block with the 20 English items included in the main part of the study. They then completed four practice trials in Mandarin, followed by a practice block with the 20 Mandarin items included in the main part of the study. The language order for these practice phases was the same for all participants. During these practice trials, participants were asked to indicate whether the presented word referred to a living entity by pressing "L" or to a nonliving entity by pressing "A," and to respond as quickly and accurately as possible. This instruction was written on the screen in English and in Mandarin during each trial. As in Experiment 1, we did not counterbalance the side of the living versus nonliving responses. Finally, the participants completed four practice trials combining both languages.

Then the main task started. Each task contained 160 experimental trials and for each task, participants were randomly assigned to one of three possible lists of 160 trials. To create these lists, we split the selected 60 items into three sets of 20 items each, containing 10 living and 10 nonliving entities, with each item repeated 8 times per list within each task. Half of the trials were language switches and the other half nonswitches, with the languages distributed equally across these two trial types. The switching ratio differed from Experiment 1, as we wanted to generate similar numbers of trial types across conditions. Category switches (i.e., living vs. nonliving items) were also distributed equally across trial types and language combinations. In all lists, no more than four trials in the same language, of the same type of category or language switch were presented in a row. There was a speaker switch on each trial.

A trial consisted of a 500-ms fixation cross followed by the presentation of the target word. The participants were automatically presented with the next trial once they had provided a response, or after 2,500 ms if no response was given. Once the three tasks were completed, participants filled in the language proficiency, use and exposure questionnaire followed by the English and the Mandarin LexTALEs, the order of which was counterbalanced between participants. For all tasks, the instructions were presented both in Mandarin and in English.

Data Analysis

We followed the same analysis procedure as in Experiment 1. The two-level categorical predictors were coded as follows: language (Mandarin [−0.5], English [+0.5]), trial type (nonswitch [−0.5], switch [+0.5]), and accent (two-accent task [−0.5], one-accent task [+0.5]). Overall, participants scored 95.43% accuracy on the animacy judgment task. Prior to analysis, we excluded inaccurate trials on the animacy judgment task, trials preceded by a break, and 1.29% of correct trials as RT outliers.

Results

Confirmatory Analysis

There was a significant effect of trial type (Tables 5 and 6 and Figure 2). This reflected a switching cost with slower responses on switch ($M = 1{,}031$, $SD = 143$) than on nonswitch trials

Table 5
Outcome of the Linear Mixed Effect Models for Experiment 2

Fixed effects	Estimate	*SE*	*t*-value	*p*-value
Intercept	6.904	.015	474.396	**<.001**
Trial type	0.008	.004	2.155	**.036**
Language	0.057	.009	6.163	**<.001**
Accent	−0.002	.007	−0.217	.829
Trial Type × Language	−0.003	.007	−0.356	.723
Trial Type × Accent	0.001	.006	0.131	.897
Language × Accent	0.013	.008	1.569	.121
Trial Type × Accent × Language	−0.025	.011	−2.170	**.034**

Note. The final model included by-subject random intercepts and random slopes for trial type, language, accent, and the two-way interactions between trial type and language, and between language and accent. It also included by-item random intercepts and random slopes for all main effects of and interactions between trial type, language, and accent. *p* values in bold reflect significant effects.

($M = 1{,}023$, $SD = 139$). There was a main effect of language, with slower responses in L2-English ($M = 1{,}055$, $SD = 144$) than in L1-Mandarin ($M = 1{,}000$, $SD = 144$), but no significant main effect of accent (one-accent task: $M = 1{,}026$, $SD = 142$; two-accent task: $M = 1{,}028$, $SD = 147$). There were no significant two-way interactions. However, there was a significant three-way interaction between trial type, accent, and language (see Figure 2), which reflected that the asymmetry in switching costs differed between the one- and the two-accent tasks (Table 6). While switching costs were somewhat larger for L1-Mandarin in the one-accent condition, the pattern was the opposite for the two-accent condition.

To follow-up on this interaction, we examined the one- and two-accent tasks separately. In the one-accent task, in line with Experiment 1, switching costs were numerically larger into L1-Mandarin ($M = 17$, $SD = 54$) than into L2-English ($M = 2$, $SD = 53$, see Table 6), although this did not reach significance ($p = .103$, see Table S6 in the online supplemental materials). In the two-accent task, we observed the reverse pattern, with switching costs being somewhat numerically larger into L2-English ($M = 12$, $SD = 51$) than into L1-Mandarin ($M = 3$, $SD = 58$), although this was not significant ($p = .321$, see Table S7 in the online supplemental materials). Examining the interaction by language showed different trial type by accent directions in L2-English and L1-Mandarin. For L1-Mandarin, the switching cost was numerically larger in the one-accent task (see Table 6), although this did not reach significance ($p = .111$, see Table S8 in the online supplemental materials). For L2-English, the opposite pattern was present, with a numerically larger switching cost in the two-accent task (although not significant: $p = .144$, see Table S9 in the online supplemental materials). However, the different directions of patterns observed (supported by the significant three-way interaction) appeared mostly driven by the nonswitch (rather than switch) trials (see Table 6).

Table 6
Reaction Times and Switching Costs (Milliseconds) in Experiment 2

Trial type	One-accent task		Two-accent task	
	Mandarin	English	Mandarin	English
Switching trials	1,005 (154)	1,059 (147)	1,006 (154)	1,059 (157)
Nonswitching trials	988 (149)	1,057 (147)	1,002 (151)	1,046 (152)
Switching cost	17 (54)	2 (53)	3 (58)	12 (51)

Exploratory Analysis

Both in Experiments 1 and 2, the bilinguals showed (numerically) larger switching costs when switching from L2-English to L1-Mandarin when all words were produced by L1-Mandarin speakers (one-accent tasks). This asymmetry was significant in Experiment 1 but did not reach significance in Experiment 2. The two tasks were similar in many ways: They both tested unbalanced Mandarin–English bilinguals with a higher proficiency in Mandarin than English, they included the same animacy judgment tasks, and the stimuli of Experiments 2 were a subset of the stimuli of Experiment 1. However, they also differed in a few other ways, including the switching rate and the study being in-person or online. Although the overall language profile was comparable, bilinguals in Experiment 2 also were somewhat more balanced in their daily-life use of English and Mandarin. Moreover, the familiarization phase of Experiment 2 used pictures while it used written words in Experiment 1. We therefore wanted to examine if the switching costs, and the asymmetrical pattern, differed between the one-accent tasks in Experiments 1 and 2. This allowed us to examine whether the significance of the asymmetry in one experiment but not in the other reflected a true difference between Experiments or, instead, whether this pattern was consistent across experiments. Furthermore, we used this combined data set to assess the potential influence of response type switching. Language switching costs in this type of task have also been suggested to depend on the semantic judgement that needs to be made, in particular whether a participant needs to respond to the same category as on previous trial or not (Von Studnitz & Green, 2002). To ensure the language switching cost was not driven or modulated by response-type switching costs, this analysis included response switching (switch between animacy judgement relative to previous trial).

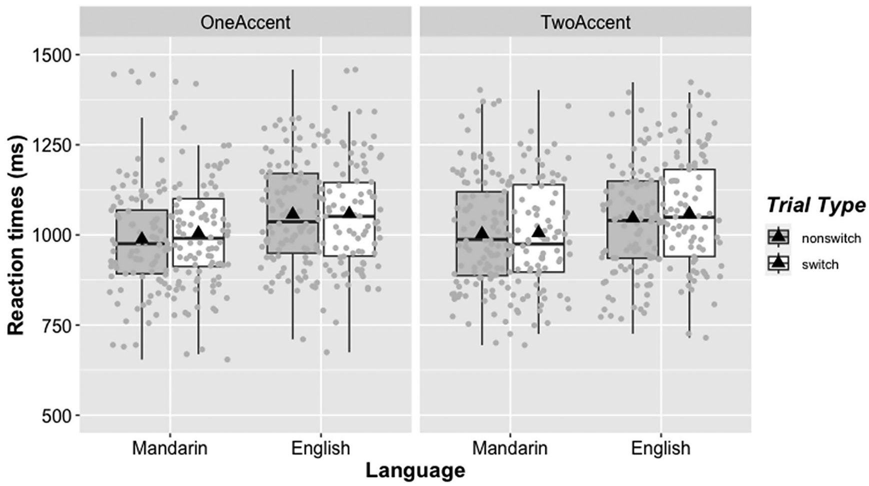
The analysis revealed a significant two-way interaction between trial type and language ($p < .001$) across Experiments 1 and 2 (Table S10 in the online supplemental materials): There was a significant switching cost only when switching to L1-Mandarin but not to L2-English (Tables S11 and S12 in the online supplemental materials). As in the individual studies, a main effect of language showed that the participants responded more slowly in L2-English than in L1-Mandarin. There was a main effect of experiment, reflecting that RTs were overall shorter in Experiment 2 ($M = 1{,}026$, $SD = 142$) than in Experiment 1 ($M = 1{,}093$, $SD = 141$). However, Experiment did not interact with Trial Type, or Language × Trial Type, showing that the asymmetry in switching costs in the one-accent task did not differ between Experiments. Switching between response categories increased processing times, especially for English trials and in Experiment 2 (Tables S11–S14 in the online supplemental materials). Importantly, response switching did not interact with, or explain, the language switching cost. These results confirm that bilinguals experienced larger L1 than L2 switching costs across the one-accent tasks of Experiment 1 and 2, without a significant modulation of experiment, and that this was not due to additional switching costs associated with switches in the response type.

Discussion of Experiment 2

Similar to Experiment 1, Experiment 2 shows that Mandarin–English bilinguals can experience switching costs in an auditory comprehension switching task (see also, e.g., Olson, 2017; Shen et al.,

Figure 2

Reaction Times per Task, Language, and Trial Type in Experiment 2



Note. Triangles represent mean reaction times; the black lines in the box plots represent the medians; the whiskers represent the lower and the upper quartiles; grey dots represent individual data points.

2020; but see Declerck et al., 2019). There was also a main effect of language which, again, showed that these unbalanced bilinguals processed the L1-Mandarin words faster than the L2-English words.

The accent with which the L2-English words were pronounced did not influence L2 response times (Hypothesis 1). This indicates that the accent manipulation did not affect the overall ease with which the bilinguals processed the L2-English words. In other words, the L1 accent on the L2-English words neither facilitated their processing nor made it more complicated (vs. Lagrou et al., 2011, 2013; Major et al., 2002; Munro et al., 2006).

The pattern of results in the one-accent task in the confirmatory analysis is very similar to the results of Experiment 1: The switching cost into L1-Mandarin is numerically larger than the switching cost into L2-English, though the corresponding two-way interaction did not reach significance in Experiment 2. The exploratory analysis suggests that the pattern of switching costs did not differ significantly across the two Experiments, with bilinguals showing larger L1 than L2 switching costs when collapsing the data across Experiment 1 and the one-accent task of Experiment 2. This may suggest that, in the one-accent task here, and as in Experiment 1, the bilinguals applied top-down language control, through L2 overactivation (e.g., Philipp et al., 2007) or through L1 inhibition (e.g., Green, 1998; Litcofsky & Van Hell, 2017) to manage activation of their L2 or interference from their L1 while processing the L2-English words. However, this should be interpreted with caution when considering Experiment 2 on its own, given that this individual analysis did not reach significance.

The significant three-way interaction between Trial type, Accent and Language suggests that the switching-cost pattern was different for the two-accents and one-accent task and that accent did modulate the (a)symmetry of switching costs in English and Mandarin. At first sight, our results seem to align with the predictions of Hypothesis 2b. The three-way interaction supports that the asymmetry pattern is significantly different for the one- and two-accent tasks, with the two-accent task showing no evidence for larger L1 than L2 switching costs (no significant asymmetry and, if anything, the cost pattern is numerically going in the opposite direction). This could suggest that the accent of the speakers could modulate the way bilinguals process language switches. However, inspection of the data reported in Table 6 reveals that the effect of accent on the switching costs and their direction seems to be driven by the nonswitch trials. The bilinguals' Mandarin and English RTs on switch trials are similar across the one-accent and the two-accent tasks. Thus, at this point, we cannot attribute the variation in the direction of switching costs between accent conditions to an influence of accent on switching (and thus on reactive language control) in particular. The effect of accent mostly concerned Mandarin nonswitch trials, which actually did not differ between the tasks as they were produced by the same speakers with L1-Mandarin accents in both the one-accent and the two-accent tasks. Given that the effect of accent on these nonswitch trials was unexpected and very small (a difference of less than 15 ms), it remains unclear whether this is a meaningful effect. Thus, Experiment 2, in line with Experiment 1, does suggest that switching costs can be observed but they do not appear to be (substantially) modulated by accent.

Importantly, it seems like this absence of an accent effect (in terms of overall RTs and switch trials) cannot be explained by whether the participants noticed the differences in accent between the two tasks or not. In a posttask questionnaire, we asked the participants if they had recognized the accent with which the English words were pronounced in the one-accent and the two-accent tasks. Although only 51.5% of the participants noticed that here was a change in accent on the L2-English words between the two tasks (and among these, 98% correctly identified that the L2-English words had an L1-English accent in the two-accent task and an L1-Mandarin accent in the one-accent task), we found that there were no significant differences in switching costs between participants noticing the accent manipulation and those not noticing it.

Our other hypothesis (2a) focused on the possibility of multiple accents increasing the overall switching costs. Potential processing costs could be added at the phonological level when having to switch between L1-Mandarin versus L1-English accents (as opposed to just listening to L1-Mandarin speakers). This was not the case in the current study. Alternating between L1-Mandarin and L1-English speakers in the two-accent task did not increase overall processing times nor switching costs relative to just alternating between L1-Mandarin speakers. This suggests that there was no additional processing time at the phonological level. However, the presence of different speakers in both accent conditions meant participants had to alternate between different speakers in all tasks, which could have masked small phonological costs associated with accent switching. Furthermore, in both Experiments 1 and 2, regardless of the speaker, Mandarin and English were used, which are two languages that differ substantially in terms of phonology. It is possible that part of the switching cost stems from the phonological level (as opposed to the lexical level) in all conditions and is not further increased by accent switches.

We therefore further investigated the role of sublexical processing in Experiment 3 by working with visual stimuli. Orthographic cues could also be expected to act as a strong modulator of language coactivation (Orfanidou & Sumner, 2005), and could potentially have more influence than accents given that Mandarin and English use completely different writing systems. While Mandarin uses characters, English uses the Latin alphabet. In Experiment 3, we therefore compared the role of accents in spoken word processing to the role of orthographic information in visual word processing. This allowed us to examine two questions. First, we examined how visual information that is closely associated with each language (Mandarin characters vs. English letters) modulates language coactivation and, thereby, potential (asymmetries in) switching costs. Second, previous research with language production has suggested that switching costs can be larger when the stimuli are presented in the written than in the spoken modality (Declerck, Stephan, et al., 2015). Therefore, Experiment 3 also allowed us to test a potential impact of modality on language processing in general and language switching specifically.

Experiment 3—The Role of Input Modality

Introduction

As reviewed in the introductory part, comprehension switching costs have been observed in the visual domain both in sentences (e.g., Gullifer & Titone, 2019; Litcofsky & Van Hell, 2017) and when participants are presented with isolated words (e.g., de Bruin & Xu, 2023), but results have been mixed (see, e.g., Aparicio & Lavaur, 2014; Bultena et al., 2015; Declerck et al., 2019; Litcofsky & Van Hell, 2017). Notably, these studies have mostly targeted bilinguals speaking language pairs that use the same writing system (e.g., Spanish–English, Dutch–English, French–English; but see de Bruin & Xu, 2023; Jylkkä et al., 2018; Liu et al., 2020; Struck & Jiang, 2022). However, languages with different writing systems might enhance effects on language switching costs, including in terms of the influence on language coactivation. In Experiment 3, we therefore compared switches in the visual versus spoken domain in two languages using different scripts (Mandarin and English).

Orthographic Information and Language Coactivation

Previous research provides some evidence that orthographic information could reduce activation of the lexical representations of the nontarget language. For example, van Heuven et al. (2011) found that script differences reduced cross-linguistic interference on a color Stroop task in trilinguals (see also Chen & Ho, 1986; Hoshino & Kroll, 2008; Lee & Chan, 2000; Smith & Kirsner, 1982). More recently, in a masked translation priming study, Casaponsa et al. (2015) asked Spanish–Basque bilinguals to perform a lexical decision task on Spanish target words preceded by their Basque translation-equivalents. The bilinguals experienced significant priming when the Basque prime word contained orthotactic patterns acceptable in both languages, but not when it contained language-specific bigram combinations. This result suggests that orthographic information can regulate lexical access between languages (see also the results of the bilingual Reicher–Wheeler task included in Casaponsa et al., 2015). Furthermore, Hoshino et al. (2021) asked Spanish–English and Japanese–English bilinguals to name pictures in L2-English while ignoring visually presented L1 distractors. While Spanish–English bilinguals showed several effects associated with the L1 distractor (e.g., semantic interference and phonological facilitation), these effects were not found for Japanese–English bilinguals. These results suggest that the bilinguals speaking languages with different writing systems could use visual information for earlier language selection and/or to reduce language coactivation during speech planning. Regarding processing of language switches, Orfanidou and Sumner (2005) compared Greek–English bilinguals' performance on a lexical decision task that involved words containing letters that either existed in both languages or only in Greek. In language-switch trials, the participants responded faster to words that contained language-specific letters. This suggested that language-specific orthographic information could reduce the interference from the lexical representations of the nontarget language. Thus, visually presented orthographic information may modulate language coactivation, and in particular, reduce activation of the nontarget language in a given task. There is also some initial evidence that this can influence switching costs. In Experiment 3, we therefore examined how visual language-specific information modulated the pattern of switching costs, and whether such information was more likely to influence processing of language switches than variation in accents.

Phonology Versus Orthography

Indeed, there is some evidence suggesting that switching costs can be different in the visual and auditory domain, in terms of naming times during production (Declerck, Stephan, et al., 2015). In their study, participants had to name words either based on a visual depiction or based on auditory information associated with it (e.g., chirping for "bird"). Switching costs were smaller in the auditory than in the visual domain. Several explanations are provided in Declerck, Stephan, et al.'s (2015) article, but these are mostly related to preparation time in relation to the design and stimuli used and the relationship between auditory input and participants' spoken responses. In contrast, Wong and Maurer (2021) found larger production switching costs in response to auditory than to visual stimuli, perhaps because auditory stimuli provided less preparation time. Thus, it remains unclear how modality can influence switching costs, in particular also when participants are not producing words themselves.

With respect to language coactivation, studies comparing modality have mostly looked at the effects of orthographic versus phonological word form overlap across languages (cognates). Across several studies (e.g., Cornut et al., 2022; Dijkstra et al., 1999; Frances et al., 2022), cognate facilitation effects appear larger when word forms across languages are comparable in orthography (as compared to phonology).

This suggests that orthography might influence language coactivation more strongly than phonological information. The focus, however, has been on overlap in orthography. In our Experiment 3, we worked with languages that are dissimilar in orthography. We therefore examined whether, when languages differ in terms of orthography and phonology, orthographic information has a larger impact on processing times and switching costs.

Present Study

In Experiment 3, we examined two questions. First, we examined whether orthographic information during visual-word processing might influence processing (in terms of overall processing times and switching costs) more than phonological information during spoken-word processing. Second, we examined whether orthographic information closely associated with (and differing between) two languages is more likely to influence language competition and control than phonological information (accents) differing between languages as in Experiment 2. In Experiment 3, we therefore compared processing of visually presented words (visual task) to the two auditory tasks of Experiment 2 (one-accent task and two-accent task).

Predictions

We list below the two sets of hypotheses we preregistered, which predicted opposite patterns of results. However, it should be kept in mind that some distinctions we had expected between the visual task versus the one-accent and the two-accent tasks might be less relevant given the absence of strong differences between the two one-accent and two-accent tasks in the results of Experiment 2.

1. With respect to the first question, we examined whether visual and spoken words differ in overall processing times and in terms of switching costs. Given the strong script differences between Mandarin and English, we hypothesized that switching between different orthographies could increase processing time and switching costs relative to spoken-word processing (see discussion of de Bruin & Xu, 2023). This could reflect increased demands at the level of orthographic processing, even without a direct influence on language coactivation or competition at the lexical level. If such processing cost is larger for orthographic than phonological information, we would expect a larger switching cost in the visual (two-writing systems) task than in the phonological (two-spoken systems) task. Alternatively, if such demand is related to the form differences as such (regardless of the modality), we would expect a larger switching cost in the visual task (different forms) than in the one-accent auditory task (more similar forms). However, given that we did not see such effect in Experiment 2 when comparing the one- and two-accent tasks, this latter direction seemed less likely.
2. If language-specific visual cues can reduce language coactivation (e.g., through allowing earlier language selection, Hoshino et al., 2021, and reducing interference from the nontarget language, Orfanidou & Sumner, 2005), we expected switching costs to be smaller (potentially mostly reducing the L1 cost) in the visual task than in the one-accent task. This hypothesis is similar to Experiment 2's hypothesis (2b) regarding the comparison between the two-accents and one-accent task. Furthermore, if orthographic information influences lexical access more than phonological information (e.g., Cornut et al., 2022), the visual modality might be more likely to reduce language coactivation than the two-accent task in Experiment 2 (smaller visual than two-accent switching cost).

Methodology

Overall Description

The participants and the stimuli were the same as in Experiment 2 (see Participants section). In terms of design, this study included three within-participants variables: language (English vs. Mandarin), trial type (language nonswitch vs. switch), and modality (two-accents; one-accent; written). For the procedure, see the Procedure section.

Data Analysis

We followed the same analysis procedure as in Experiments 1 and 2. The three-level categorical modality was coded using ANOVA coding to compare the visual task (−0.333) to the one-accent auditory task (0.667; two-accent task coded as −0.333; this comparison is henceforth referred to as "Modality 1") and the visual task (−0.333) to the two-accent auditory task (0.667; one-accent coded as −0.333; henceforth "Modality 2"). Comparing the visual condition to the one-accent task allowed us to examine if visual, orthographic cues differing between the languages impact language switching relative to processing of switches that are more similar in form (when presented aurally in the same accent). Comparing the visual condition to the two-accent task allowed us to examine if effects of orthography are stronger than those of phonology, when both differ between the two languages (i.e., when different accents are used for the L1 and the L2). Overall, participants scored 95.35% accuracy on the animacy judgment task. Prior to analysis, we excluded inaccurate trials on the animacy judgment task and 0.43% of correct trials as outliers. We also excluded trials occurring after a break.

Results

There was a significant effect of trial type (see Tables 7 and 8, and Figure 3). This reflected a switching cost with slower responses on switch ($M = 912$, $SD = 128$) than nonswitch trials ($M = 903$, $SD =$

Table 7
Outcome of the Linear Mixed Effect Models for Experiment 3

Fixed effects	Estimate	*SE*	*t* value	*p* value
Intercept	6.758	.014	484.679	**<.001**
Trial type	0.011	.002	5.379	**<.001**
Language	0.050	.007	7.029	**<.001**
Modality 1	0.434	.013	33.646	**<.001**
Modality 2	0.436	.012	35.014	**<.001**
Trial Type × Language	−0.006	.006	−0.876	.385
Trial Type × Modality 1	−0.008	.005	−1.546	.122
Trial Type × Modality 2	−0.008	.005	−1.719	.086
Language × Modality 1	0.029	.009	3.203	**.002**
Language × Modality 2	0.016	.010	1.640	.107
Trial Type × Language × Modality 1	−0.005	.011	−0.432	.668
Trial Type × Language × Modality 2	0.020	.011	1.852	.069

Note. The final model included by-subject and by-item random intercepts, by-subject slopes for language and modality, and by-item slopes for Language × Modality, and Switching × Language × Modality. *p* values in bold reflect significant effects.

Table 8
Reaction Times and Switching Costs (Milliseconds) in Experiment 3 in the Written Task

Trial type	Mandarin	English
Switching trials	670 (128)	687 (122)
Nonswitching trials	654 (121)	679 (120)
Switching cost	16 (41)	7 (45)

122) across modality conditions. There was a main effect of language with slower responses in L2-English ($M = 929$, $SD = 124$) than in L1-Mandarin ($M = 887$, $SD = 128$). There were also significant effects of Modality 1 and Modality 2, with RTs being faster in the written task ($M = 672$, $SD = 119$) than in the one-accent ($M =$ 1,026, $SD = 142$) and in the two-accent task ($M =$ 1,028, $SD = 147$).

There was a significant two-way interaction between language and Modality 1. Further analyses with the data split per language showed that there were significant effects of modality in both language conditions (Tables S15 and S16 in the online supplemental materials). However, the difference in RTs between the written task and the two auditory tasks, respectively, was larger for L2-English (written task: $M = 683$, $SD = 119$; one-accent task: $M =$ 1,058, $SD = 144$; two-accent task: $M =$ 1,053, $SD = 152$) than for L1-Mandarin trials (written task: $M = 662$, $SD = 123$; one-accent task: $M = 996$, $SD =$ 149; two-accent task: $M =$ 1,004, $SD = 150$). In other words, participants needed more time to process the words in the auditory task, but more so in L2-English than in L1-Mandarin.

No further interactions were found, suggesting the switching costs did not differ between the spoken and written tasks.

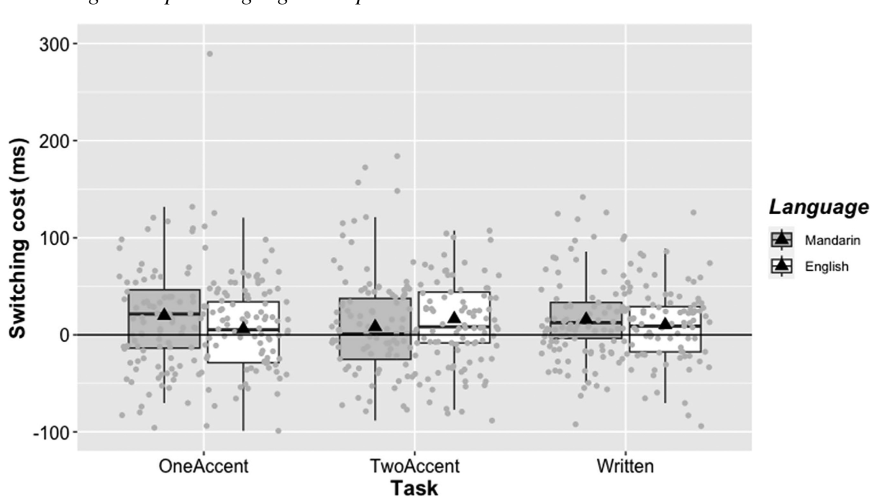
Discussion of Experiment 3

Experiment 3 shows a significant effect of trial type which indicates that there was a significant switching cost across the visual and auditory tasks. This provides further evidence that switching costs can occur in comprehension-based language switching tasks (Olson, 2017; Orfanidou & Sumner, 2005; Shen et al., 2020; but see Declerck et al., 2019). The only significant difference observed between modalities was that participants processed the written stimuli faster than the spoken stimuli. Given that written words are presented as a whole, while spoken words unfold with time, faster processing is expected for the former type of stimuli. Interestingly, this modality effect was larger for L2-English than for L1-Mandarin trials. This suggests that seeing the written words rather than hearing them might be particularly helpful when processing words from the nondominant, less proficient L2.

Modality did not significantly influence the results beyond overall processing times. Switching costs did not differ significantly between the written task and the one-accent auditory task or between the written task and the two-accent auditory task. In Hypothesis 1, we hypothesized that orthographic information (given the large differences between the English and the Mandarin writing systems) might perhaps add a larger processing cost when processing switches compared to phonological processing. However, we did not observe larger switching costs in the visual than in the auditory tasks. This suggests that switching between the Mandarin and the English orthographic systems did not increase processing times relative to switching between phonological systems. It is possible that Mandarin and English differ sufficiently in both phonology and orthography to influence processing costs when switching, without the two different scripts adding additional costs.

Hypothesis 2 focused on the potential influence of modality on language coactivation and control. Previous research on language production has found diverging results when comparing written or spoken input (Declerck, Stephan, et al., 2015; Wong & Maurer, 2021). We did not observe any significant differences between the visual and auditory tasks. If anything, contrary to our prediction, the pattern of the switching cost asymmetry was more similar to the one-accent task than to the two-accent task. However, none of the interactions with modality and switching costs reached significance,

Figure 3
Switching Costs per Language in Experiments 2 and 3



Note. Triangles represent mean switching costs; the black lines in the box plots represent the medians; the whiskers represent the lower and the upper quartiles; grey dots represent individual data points.

suggesting that there was no clear effect of modality on language switching during comprehension. This suggests that visual orthographic information did not allow for earlier language selection and reduction of coactivation than phonological information (but see Hoshino & Kroll, 2008; Hoshino et al., 2021). Given that L2 speakers are often exposed to written L2 input, even (or perhaps especially) in the early L2 learning stages and in parallel to L2 auditory input, it might also be that their L2 lexical knowledge is costructured on orthographic and phonological information (Veivo & Järvikivi, 2013). Thus, L2 speakers in general, and therefore the participants in our study, may have relied on the visual forms of the words for processing, even in the two auditory tasks (see, e.g., Veivo et al., 2016). This could have further reduced the likelihood to observed different patterns of results between the auditory and the visual tasks.

General Discussion

Across three comprehension experiments, this study examined how bilinguals process language switches. Specifically, we wanted to investigate the role of language coactivation and the potential role of top-down control in comprehension-based language switching tasks, given the mixed literature on switching costs in comprehension studies (see, e.g., Declerck et al., 2019). To do this, Mandarin–English bilinguals performed animacy judgments on alternating L1-Mandarin and L2-English words. Experiment 1 tested if the bilinguals experienced significant switching costs in an auditory comprehension task. The goal of Experiments 2 and 3 was to assess the potential influence of variation in accent and input modality on the processing of language switches. While in Experiment 1, all L2-English words were pronounced with an L1-Mandarin accent, in Experiment 2, we manipulated whether the L2-English words were pronounced by a L1-Mandarin speaker or by a L1-English speaker. In Experiment 3, we compared processing of words and language switches presented auditorily or visually.

Overall, we found that Mandarin–English bilinguals can experience significant comprehension switching costs (at least toward the L1) across various experimental setups. The patterns of asymmetries in switching costs in Experiment 1 and in the one-accent task of Experiment 2, with larger switching costs to L1 Mandarin than L2 English (significant in Experiment 1 and in the combined analysis, but not in Experiment 2 alone), are consistent with the view that bilinguals rely on language control to manage competition between their languages while processing words in dual-language contexts. Finally, Experiments 2 and 3 found no strong evidence that input modality (spoken vs. written) and accent (L1 vs. L2) differentially affect language coactivation and the way bilinguals process language switches.

Switching Costs in Comprehension

The current study shows that Mandarin–English bilinguals can experience significant (L1) switching costs in comprehension tasks, across in-person and online testing contexts, and both with spoken and written stimuli (see, e.g., Aparicio & Lavaur, 2014; Bultena et al., 2015; Litcofsky & Van Hell, 2017; Olson, 2017; but see Declerck et al., 2019; Struys et al., 2019). Though the significant switching costs we observe remain relatively small as compared in particular to costs in the production literature (see, e.g., de Bruin & Xu, 2023), they are in line with models of bilingual word recognition and comprehension postulating nonselective lexical access (e.g., the BIA model, Grainger & Dijkstra, 1992; van Heuven et al., 1998; the BIA+ model, Dijkstra & van Heuven, 2002; the BIA-d model, Grainger et al., 2010; the MultiLink model, Dijkstra et al., 2019). It also shows that significant switching costs can be observed in comprehension tasks in a behavioral paradigm (i.e., it does not require potentially more sensitive measures like eye tracking; Ahn et al., 2020), and when presenting participants with isolated words rather than in sentence contexts (see Litcofsky & Van Hell, 2017 for a discussion), which allows for the examination of lexical processes, without potential influences of sentential syntax and semantics (Libben & Titone, 2009). Although most comprehension-based language switching studies have focused on the visual modality (Olson, 2017; Van Hell, 2023), Experiments 1 and 2 show that bilinguals can experience significant switching costs in the auditory modality too (see also Olson, 2017; Shen et al., 2020; but see Declerck et al., 2019). Such findings are in line with studies indicating that a bilingual's languages are coactivated not only when processing visual input, but also when exposed to auditory stimuli (Dijkstra & van Heuven, 1998; Ju & Luce, 2004; Lagrou et al., 2011; Spivey & Marian, 1999; Van Assche et al., 2009).

Overall, our results suggest that, in the experimental setups implemented in our study, language coactivation was strong enough to result in interference, trigger language control, and in turn lead to significant switching costs. At least in the circumstances and bilinguals tested here, language competition appeared strong enough to result in significant switching costs. As a second potential explanation for no comprehension switching costs, Declerck et al. (2019) consider that processing of words in comprehension might be faster than word production, thus also speeding up language control and reducing switching costs. In our study, however, switching costs were observed both when overall processing was fast (visual task) and when it was slower than most production studies (auditory task, as participants need to wait for the spoken word to unfold). This suggests that overall processing time is less likely to explain the absence or reduction of switching costs observed in other comprehension studies.

However, an open question remains how switching costs might be influenced by specific characteristics of the bilingual's languages. In our study, the bilinguals' language pair (Mandarin–English) was very dissimilar across different linguistic levels (including vocabulary, phonology, and orthography). It is possible that the observed switching costs (at least in part) stem from additional processing time needed to switch between very different phonologies or orthographies. None of the modulations studied in our experiments provided direct evidence for this additional cost though, considering that switching costs did not differ between visual or spoken modalities and given that they were not modulated by the number of accents participants had to switch between. Furthermore, if switching to a different phonology or orthography adds processing time, we would expect this to add more time for switches to the L2 than to the L1. Retrieving phonological and orthographic information from the L2 might be more difficult and thus, take more time than retrieving such information from the L1, in unbalanced bilinguals such as the ones tested in our study. In contrast, the absence of L2 switching costs (in combination with L1 switching costs) in the one-accent task suggests that processing of (L2) phonology did not lead to switching costs. However, it is plausible that the overall distance between languages can increase switching costs. This in turn might explain why smaller or no switching costs might be more likely to be observed with bilinguals with similar language pairs (e.g., English, French, or Spanish; Declerck et al., 2019).

Crucially, however, the switching costs we observed did differ between languages in some of the experiments. In the following sections, we discuss what these asymmetries suggest regarding language control.

Asymmetries in Switching Costs

In Experiment 1 and in the combined analysis, the bilinguals experienced significantly larger L1-Mandarin than L2-English switching costs, and, numerically, we also observed a similar pattern of results in the one-accent task of Experiment 2 and in the visual task. This direction of asymmetry (larger L1 than L2 costs) contrasts with the type of asymmetry reported in several studies in the comprehension literature, that is, larger costs into the L2 (see, e.g., Aparicio & Lavaur, 2014; Bultena et al., 2015; Grainger & Beauvillain, 1987; Liu et al., 2020; Proverbio et al., 2004; Struck & Jiang, 2022). Rather, it seems to reflect the type of asymmetries most frequently observed in the production literature (e.g., Jin et al., 2014; Macizo et al., 2012; Meuter & Allport, 1999; Peeters et al., 2014; Philipp et al., 2007; see Bobb & Wodniecka, 2013; but see Gade et al., 2021) and aligns with a few other comprehension studies also reporting either larger switching costs into the L1 or switching costs into the L1 only (Declerck & Grainger, 2017; Litcofsky & Van Hell, 2017; Mosca & de Bot, 2017; Olson, 2017; Philipp & Huestegge, 2015).

In both the production and the comprehension literature, asymmetries with larger L1 costs tend to be explained through accounts involving some degree of language control. Most frequently this explanation involves inhibition (Green, 1998). The asymmetry can be driven by bilinguals applying more inhibition toward their L1 than toward their L2. As a result, it can take bilinguals more time to release L1 inhibition when switching to the L1 than to release L2 inhibition when switching to the L2, which leads to switching costs that are larger for the L1 than for the L2 (see, e.g., Litcofsky & Van Hell, 2017 for similar interpretations of comprehension results). On the other hand, according to accounts postulating an overactivation mechanism (Declerck, Koch, & Philipp, 2015; Philipp et al., 2007), L2 words, which have a lower resting activation level than L1 words, may need to be activated particularly strongly. Such (proactive) overactivation may then increase the amount of time necessary to switch back to the L1 and increase L1 switching costs relative to L2 switching costs. Distinguishing between inhibition and overactivation accounts is very difficult with bilingual speakers, although studies examining trilingual switching costs have shown evidence supporting the role of inhibition specifically (e.g., Philipp et al., 2007; see Goldrick & Gollan, 2023, for a review).

Although our results do not allow us to distinguish between these two types of accounts, the pattern of asymmetries we observed implies that the Mandarin–English bilinguals relied on some degree of language control to manage their two languages when they processed language switches. This provides support for models of bilingual word recognition that involve some language control directly affecting word recognition (e.g., the BIA model: Grainger & Dijkstra, 1992; van Heuven et al., 1998; the BIA-d model: Grainger et al., 2010; but see the BIA+ model: Dijkstra & van Heuven, 2002; the MultiLink model: Dijkstra et al., 2019). For instance, through the BIA and BIA-d models, our findings could be explained through language nodes (over-)activating words in the target language and/or inhibiting the nontarget language.

This asymmetry was most clearly present in the auditory one-accent task, but the participants also experienced numerically larger L1 than L2 costs in the visual task of Experiment 3 (though this was not significant). It thus may not be specific to auditory switching, which would align well with models of bilingual language processing according to which control mechanisms are not domain-specific (see, e.g., the BIA-d; Grainger et al., 2010). Finally, the fact that we observed asymmetries with the same direction as in the production literature could also support the idea that production and processing of language switches rely on similar control mechanisms (Peeters et al., 2014; but see Ahn et al., 2020; BlancoElorrieta & Pylkkänen, 2016; Mosca & de Bot, 2017), although this was not assessed directly in the current study.

The two-accent task was the only task not showing this asymmetry, not even in numerical patterns, and instead reflecting more symmetrical (or even somewhat larger L2) switching costs. However, even though the asymmetry in switching costs differed between the one-accent and two-accent tasks (cf., the significant three-way interaction of Experiment 2), this different pattern of asymmetries cannot be fully ascribed to an influence of the speaker's accent. The effect of accent in Experiment 2 was driven by the nonswitch trials. Furthermore, modality (Experiment 3) did not influence the switching costs either. This could indicate that accent and input modality did not affect language coactivation (enough) in our experimental setups to modulate language competition and language control. This appears at odds with previous research showing that language-specific phonological and orthographic information can modulate language coactivation (see, e.g., Casaponsa et al., 2015; Lagrou et al., 2013; Lewendon, 2020; Orfanidou & Sumner, 2005). However, it is possible that the manipulations used in our Experiments 2 and 3 did influence language coactivation, but simply not sufficiently to influence competition and language control. Furthermore, regarding the absence of a clear accent effect, it is possible that the participants in our study were very familiar with both Mandarin-accented and English-accented L2-English words, thanks to their time in the United Kingdom using English with both Mandarin-L1 and English-L1 speakers. Such familiarity may have reduced possible effects of accent manipulations on language processing in these bilinguals.

Ultimately, our results suggest that differences in language dominance were the main drivers of the (numerical) asymmetries in switching costs observed in the one-accent tasks of Experiments 1 and 2 (and to some extent in the written task). The Mandarin–English bilinguals we tested across experiments acquired Mandarin first and were more proficient in L1-Mandarin than in L2-English. It is this difference in Mandarin and English dominance and proficiency levels that likely determined the nature of the language competition and coactivation they experienced, the way they applied language control, and whether switching costs arose. Specifically, the tested bilinguals might have experienced higher levels of L1-Mandarin activation, and thus needed to apply more inhibition toward L1-Mandarin when processing L2-English words. This is in turn might have led to the (numerically) larger L1 costs we observed. However, it should again be noted that the switching costs (and asymmetries observed) are relatively small. It is therefore possible that even smaller modulations such as the way these stimuli are presented are too weak to modulate language coactivation sufficiently to impact language control and switching costs.

Constraints on Generality

Our study focuses on Mandarin–English bilinguals, who are speakers of two languages that differ greatly from each other in various aspects. Based on our current study, it is therefore unclear whether our results would extend to bilinguals with a different linguistic profile. As discussed above, it is possible that the high linguistic distance in terms of phonology and orthography between Mandarin and English influenced switching costs through additional processing time at the sublexical level. Given that previous research has not observed switching costs in similar paradigms with bilinguals speaking more similar languages (French–English and Spanish–English, Declerck et al., 2019), further research is needed to examine the role of language distance. We also note that our study tests mostly female participants, although this gender imbalance was reduced in Experiments 2 and 3.

Furthermore, the materials used could also modulate the presence or size of a switching cost. However, given that previous literature has reported switching costs in sentence contexts too (see, e.g., Olson, 2017; Shen et al., 2020), we would expect a similar group of bilinguals to experience significant comprehension switching costs in sentences as well as with individual words, as used here.

Finally, it is important to note that we obtained similar result patterns across the one-accent tasks in Experiments 1 and 2 although they differed in various aspects. For example, the tasks of the two experiments included different switching rates (see Procedure section). Furthermore, while Experiment 2 was run online with bilinguals living in the United Kingdom (who had a more balanced use of both languages than the participants in Experiment 1), we conducted Experiment 1 in the lab, with bilinguals who were living in China or had just arrived in the United Kingdom. Finding similar results across experiments in spite of these differences demonstrates the robustness of our results. Future research will need to examine, however, if and how differences in linguistic profile in terms of proficiency, language use and switching habits relate to potential differences within and between bilingual groups in language control.

Conclusion

Recent research has challenged the idea that bilinguals experience switching costs when processing words alternating between two languages in comprehension (Declerck et al., 2019). However, across three experiments, we here show that bilinguals with languages differing in phonology and orthography (Mandarin–English) do experience significant comprehension switching costs in a variety of experimental settings, including the presentation of both auditory and visual stimuli. The observed asymmetries in switching costs suggest that the tested bilinguals relied on some form of top-down language control to regulate language coactivation and potential cross-linguistic interferences. This suggests that, at least for some bilinguals, language control might be part of the processing of language switches during comprehension as well as production. However, while other processes associated with accent (L1 or L2) and stimulus modality (spoken or written) have been found to influence language coactivation in previous research, such influence did not extend to processing of language switches and language control in the current study.

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