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Switching cost and cognate facilitation between two signed languages

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This study investigated language switching and cognate facilitation in deaf bilinguals fluent in two signed languages—Irish Sign Language (ISL) and British Sign Language (BSL). Ten participants, who were all deaf and were educated in ISL and later exposed to BSL, completed a picture-naming task requiring them to switch between the two languages based on visual cues. The study aimed to establish whether a switching cost—typically observed in unimodal spoken language bilingualism—also exists in unimodal signed language bilingualism, and whether language dominance and cognate status mediated this effect. Results confirmed a general switching cost: participants were slower to respond on switch trials than during a baseline block with no switching. Both language dominance and cognate status affected the switching cost, such that switching costs were greater in the dominant language, and non-cognates were significantly slowed by switching but cognates were not. Accuracy rates were high and did not vary significantly by switching condition or language. As the first investigation to provide evidence of a switching cost in deaf bilinguals who use two signed languages, this study provides an important foundation for future work exploring how language modality and language ecology shape the cognitive control systems underlying language switching.

KEYWORDS

bilingualism, cognate facilitation, deafness, language mixing, language switching, signed language

1 Introduction: switching cost and cognate facilitation between two signed languages

Code-switching, the alternation between two or more languages or varieties within a conversation, is among the most studied language contact phenomena (Thomason, 2001). Bilinguals engage various executive functions in order to manage language switching, and are surprisingly skilled at using the target language without interruptions of the non-target language. They can also switch languages to adapt to their interlocutors, switch according to the communicative situation, or alternate languages at liberty when interacting with other bilinguals. In other words, the range of bilingual language usage patterns is diverse. While bilinguals show considerable expertise in switching between languages under varying conditions, the factors that shape bilingual language control are still under debate.

Numerous experimental studies of bilingual switching between two spoken languages have investigated language control through implementation of a picture naming task. In a typical experiment, participants are asked to name pictures or digits in one or the other language depending on a color cue. For example, they may be asked to name all pictures presented in red in their first language (L1) and all pictures presented in blue in their second language (L2) in a blocked or mixed order. A general finding of these studies is that subjects show a *switching cost*, namely they are slower to name pictures or digits on trials when they have to switch from one language to the other (*switch trials*) than on trials when they use the same language as the previous trial (*stay trials*). While this paradigm is not an ecological test of one specific type of naturalistic bilingual discourse setting, the evidence from this paradigm for switching costs is robust, coming from studies of balanced and unbalanced bilinguals, second language learners and heritage speakers (Costa and Santesteban, 2004; Hernandez Santacruz et al., 2025; Meuter and Allport, 1999), but it comes almost entirely from bilinguals who use spoken languages.

Language dominance may play a role in the size of switch costs. Meuter and Allport (1999) identify an *asymmetrical switch cost*, such that bilinguals are slowed more when switching from the weaker L2 to the stronger L1 than the reverse. Although bilinguals are typically faster in L1, Meuter and Allport argue that greater inhibition of the dominant language during L2 use leads to asymmetrical switch costs. In the context of a switch from L2, L1 inhibition spills over into a subsequent L1 trial. Likewise, Costa and Santesteban (2004) found asymmetrical switch costs in both Spanish-Catalan and Korean-Spanish bilinguals but concluded that the asymmetry is more reliable in unbalanced than balanced bilinguals. Kleinman and Gollan (2016, p. 11) investigated whether switch costs could be eliminated by telling bilinguals to "use whichever language comes to mind first." This resulted in the elimination of switching costs. Similarly, Ma et al. (2016) demonstrated that unbalanced bilinguals can reduce their reliance on reactive control processes by engaging proactive control processes to reduce the size of the switch cost when more time is available between the language cue and the stimulus onset. In a recent meta-analysis, Gade et al. (2021) investigated why switch costs are variable across different populations and tasks. Although switch costs are consistent across cued picture naming performance, they were not able to single out any factors that reliably predicted whether those costs would be symmetric or asymmetric.

Additional insights into the nature and locus of language control comes from a set of studies that have incorporated cognates and non-cognates into the experimental design (Christoffels et al., 2007; Verhoef et al., 2009). If bilinguals inhibit the non-target language during language switching, then participants should not exhibit a cognate facilitation effect. However, these studies report a cognate facilitation effect in both stay and switch trials, suggesting that bilinguals do not rely on sustained inhibition of the non-target language as a whole, but instead use more transient control processes following non-selective activation of possible responses in both languages.

The study of mixed language use in signing bilinguals can elucidate what aspects of code-switching and mixing are modality-dependent. Bilingual signers may be considered bilingual because they use a signed and a spoken language, often called bimodal bilinguals, or they can be bilingual (or multilingual) by virtue of using multiple signed languages. Most signed languages are minority languages surrounded by spoken majority languages. Extensive contact between signed and spoken languages has resulted in varieties of signing that combine grammatical elements of both languages. Lucas and Valli (1992) argue that in signed-spoken language contact, a distinct "third system" emerges, blending features of both ASL and English—enabled by the use of different articulators—making it unhelpful to categorize such discourse strictly as one language or the other. The spontaneous mixing of elements of signed and spoken languages has been described by Emmorey et al. (2005), who propose the term *code-blending* because elements of spoken and signed languages are sometimes produced simultaneously, unlike mixing elements of spoken languages that require switching between the two languages in alternation. Code-blending, like code-switching, is not a phenomenon driven by a lack of proficiency in either a spoken or a signed language, but is a behavior characteristic of signing bilinguals.

How does using two modalities affect language control compared to switching within a single modality? Blanco-Elorrieta et al. (2018) were able to distinguish the cost of disengaging a previously used language from the cost of engaging a new language by studying hearing bimodal bilinguals. Using a picture naming task, participants were asked to name the picture in ASL, in English, or in both languages simultaneously. By comparing the three conditions, the investigators could distinguish the effects of engaging a language (ASL trial or English trial to ASL-English codeblending trial) vs. disengaging a language (ASL-English codeblending trial to ASL trial or English trial). MEG data revealed much more neural activity when participants were required to inhibit a language in use than when they were required to engage a language not in use. The investigators argue that for bimodal bilinguals, it is relatively effortless to produce lexical items in two languages. Similarly, Emmorey et al. (2020) found that switching out of an ASL-English code blend into ASL or English only imposes a switch cost in response time, but switching into an ASL-English code blend from either ASL or English alone does not, reinforcing the idea that inhibition is more cognitively costly than simultaneous activation of lexical items in two languages.

Kaufmann et al. (2018) explored the idea that inhibitory processes are not as essential for bimodal bilinguals due to the modality difference between their languages. They asked a group of hearing bimodal trilinguals to carry out two picture naming tasks, switching between German and English in one condition, and between German and German Sign Language in another. Comparing the German responses in each condition allowed the investigators to avoid complications related to articulatory differences in naming times in spoken vs. signed languages. Similar to classic language switching studies with spoken language bilinguals, participants exhibited a switch cost when switching between German and English. By contrast, they found no switch cost in the bimodal condition. These findings suggest that hearing bilingual signers may not engage inhibitory processing to the same degree as hearing bilingual speakers.

No studies to date have investigated language control in deaf bilingual signers. This population is rare due to the low incidence of deafness in combination with the fact that signing bilinguals are more likely to acquire a spoken language, possibly in its written form, rather than a signed language, as the second language. Deaf bilinguals who use two signed languages differ from hearing bilinguals along several dimensions. First, unlike bimodal bilinguals, these bilinguals use two languages in the same modality, but the modality is visual/manual instead of auditory/spoken. Like unimodal spoken language bilinguals, we predict that unimodal signed language bilinguals will show switch costs since they must inhibit signs in one language in order to produce signs in the other language. However, another effect of language modality is that production times are slower in sign than in speech.

Although equally fluent, signers are slower in picture naming because hand movement to sign onset takes longer. Emmorey et al. (2012) found this transition time to be 460 ms on average in a study of ASL-English bimodal bilinguals. This difference in the timing of language production could mitigate switching costs in the same way that Ma et al. (2016) were able to eliminate switching costs by increasing the time between the language cue and the stimulus onset. Additionally, the language ecology of deaf signing bilinguals differs from that of most hearing bilinguals. Deaf signing bilinguals are constantly accommodating the hearing people around them whether they know a signed language or not. The constant pressure to adapt to the needs of hearing people may lead deaf signing bilinguals to strategically employ a greater amount of proactive rather than reactive control processes. Deaf bilinguals also experience more communication breakdowns than hearing bilinguals and must be ready to repair misunderstandings possibly by engaging reactive control processes. These differences could dampen switch costs in deaf signing bilinguals. Finally, it is not uncommon for signed languages to have many cognates, which creates an opportunity to assess whether inhibition is engaged prior to or following lexical selection.

The present study is based on a portion of the first author's doctoral dissertation at University College London (Adam, 2016). The study was designed to assess whether bilingual signers exhibit switch costs, and if so, whether Meuter and Allport's (1999) finding of asymmetric costs of switching could be replicated with two signed languages, and finally, whether a cognate facilitation effect would mitigate the cost of switching. The method used was picture naming in a language switch task, based on the methodology used by Costa and Santesteban (2004). We predict that:

(a) There will be a switch cost due to the unimodal nature of switching between two signed languages,
(b) The switch cost will be asymmetric reflecting the language dominance of the signers, and
(c) There will be a cognate facilitation effect in both stay and switch trials.

2 Method

2.1 Participants

Twelve participants were recruited, all natives of Ireland (either the Republic of Ireland or Northern Ireland). They were all deaf bilinguals who had been educated in Irish Sign Language (ISL) as an L1 in Dublin and who had acquired British Sign Language (BSL) as an L2. Of the 12 participants, two were eliminated from the analysis (see Results). The remaining 10 participants (7 male; 3 female, age range 26-53) were educated in schools for deaf children in Cabra, Ireland (St Joseph's boys' school or St Mary's girls' school). Recruitment and testing was carried out in three locations: London (2 participants), Belfast (4 participants), and Dublin (4 participants). The London participants were both Irish Deaf people who had migrated to the UK for employment or training opportunities (Leeson, 2005; Stone, 2010). Participants were recruited through Deaf community networks: usually one participant known to the first author invited other Deaf people in the same location to take part. An additional bilingual deaf participant (a 59 year old man who lived in Belfast) was recruited to pilot the experiment. All participants had normal or corrected vision. One participant acquired ISL in the home from his Deaf parents, and one used ISL at home with a Deaf sibling. All others learned ISL at school.

2.2 Materials

The materials comprised 18 pictures, selected to elicit specific signs in both ISL and BSL (Figures 1, 2). The signs for nine of the pictures were categorized as cognates in the two languages; the signs for the remaining nine were categorized as non-cognates. Signs were considered to be cognates if they shared two or more of the three major articulatory parameters (handshape, location, movement) but there were no identical cognates in the stiumuli.

Target sign pairs did not differ in orientation, whether cognate or non-cognate. For example, the ISL and BSL signs for KISS differ in only one parameter (handshape) and so were classified as cognates. Additional cognate signs in ISL and BSL elicited by the pictures were: BABY, BOOK, BREAD, HOUSE, TOILET, WINDOW, WOMAN, WORLD. Non-cognate target signs in ISL and BSL were: ADDRESS, BUS, WATER, TRAIN, MAN, MILK, PEOPLE, PRIEST, TEA. However, following the study, it became clear that most participants used different signs in ISL and BSL for WINDOW and WOMAN. As a result, the responses for WINDOW and WOMAN were re-classified in the non-cognate group, resulting in 7 cognates and 11 non-cognates.

2.3 Procedure

The experiment comprised 186 trials. The first 36 trials included a block of all 18 pictures presented twice in random order in a single color, eliciting either ISL or BSL. This was the *block* condition, during which no language switching was required. Subsequently, participants completed three blocks of 50 trials, with equal numbers of ISL and BSL trials, in which the target language was signaled by the color of the image, red or blue. Seventy eight stay trials and 72 switch trials were ordered such that sequences of one, two, three, or four stay trials in one language occurred before a switch to the other language.

The stimuli were presented using Microsoft PowerPoint on an Apple MacBook laptop with a 13-inch screen. Each stimulus was displayed for 2,000 ms without an interstimulus

FIGURE 1
ISL and BSL signs for BREAD (COGNATE).

FIGURE 2
ISL and BSL signs for MAN (NON-COGNATE).

interval, pausing only after each block of 50 pictures. Participants were instructed to respond as quickly as possible—in ISL when the picture was blue, and in BSL when the picture was red, or vice versa as the colors were counterbalanced across participants.

Following the procedure used by Orfanidou et al. (2009), a DV video camera was set up so that it was possible to see both the stimulus on the screen and the signed response from the participant. The experiment was video-recorded and then analyzed in ELAN (Crasborn and Sloetjes, 2008).

3 Coding

Signed responses were coded for (1) response latency, and (2) accuracy, and this coding was checked by a second coder who did not know of the experimental aims. In the absence of latency measurement software comparable to a voice activation key, response latency was coded in ELAN from the time between stimulus onset and *sign onset time*.

Sign onset time was operationalized as the point at which (a), (b), or (c) was the case:

(a) The handshape(s) were fully formed

  (i) Internal movements in formation were completed (e.g., index finger and thumb in 'F' handshape make contact)
  (ii) Orientation matches that of the sign (e.g. orientation in BREAD (BSL) was that of the point of contact although the hand had not yet made contact with the chin, see Figure 1b)
  (iii) Before the hands made contact for a sign

(b) For a two-handed sign with contact between the hands, when the hands were at their highest or most extreme location, or
(c) For a two-handed sign where the hands do not make contact, when the handshape was fully formed, and the elbow movement ended, indicating that the sign was about to start its movement.

Trials in which participants produced a response in the wrong language or produced an incorrect sign were considered errors. There were no mixed responses in the data, in which participants responded in two languages, or self-corrected a response by producing a response from the other language.

4 Results

Two participants were excluded from analyses: one participant who after performing the task reported having BSL as L1 and ISL as L2; and a second participant who only completed the first two blocks. Across the remaining 10 participants, there were a total of 1,778 (96%) correct responses and 79 (4%) errors. The mean response time and accuracy according to switching condition, language and cognate status is available in Supplementary Table 1.

4.1 RT analysis

RT data were analyzed in R (version 2025.05.1+513) using a linear mixed effects model with the lme4 package (Bates et al., 2015; R Core Team, 2022; see https://osf.io/nm2yh/ for data and R code). Fixed effects were Switching condition (Block, Stay, Switch), Language (BSL, ISL) and Cognate status (Cognate, Noncognate) and all interactions. Random intercepts of participant and item were included in the model as follows:

$$lmer\ (RT \sim Switching\ Condition \times Language \times Cognate\ Status + (1|Participant) + (1|\ Item)$$

A significant main effect of switching indicated that participants were slower on switch trials (1,229 ms) than block trials (973 ms, $\beta = 108.47$, SE = 54.22, $t = 2.00$, $p < 0.05$). Stay trials (1,129 ms) were slower than block trials, and faster than switch trials, but there was not a significant difference between block and stay trials, typically used to index the effect of language mixing, nor between stay and switch trials, typically used to index the effect of language switching. Participants also responded significantly faster in their first language, ISL (1,048 ms), than their second language, BSL (1,172 ms, $\beta = 200.80$, SE = 74.02, $t = 2.71$, $p < 0.01$). The interaction between switching condition and language exhibited a trend for participants to show a larger switch cost in their first than in their second language ($\beta = 137.42$, SE = 72.76, $t = 1.89$, $p = 0.06$). A significant interaction of switching condition with cognate status indicated no effect of switching condition on cognates, whereas non-cognates were significantly slower in the switch condition relative to the block condition (see Figure 3, $\beta = 133.86$, SE = 67.74, $t = 1.98$, $p < 0.05$). In other words, cognate status mitigated the impact of language switching, facilitating response time for cognates as task demands increased. The model output is reported in Supplementary Table 2.

To further investigate the possibility of an asymmetric switch cost, we calculated the switch cost in each language for each participant based on mean response time in the switch and stay conditions. For this analysis only, since we could not include random slopes, we eliminated all responses that were two standard deviations outside the mean response time calculated across all participants for each language. This resulted in elimination of 4.7% of the data. The switch cost in ISL was 104 ms whereas the switch cost in BSL was only 40 ms, a significant difference as determined by a one-tailed paired samples t-test, $t\ (9) = 1.95$, $p < 0.05$, see Figure 4.

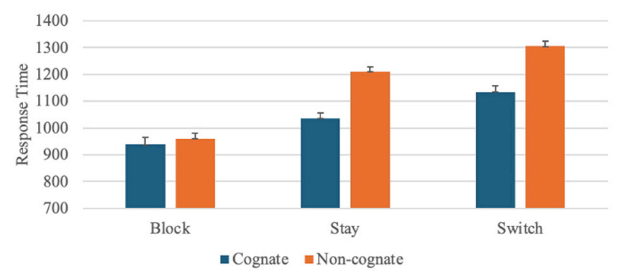

FIGURE 3
Cognate facilitation effect by switching condition. Error bars show standard error of the mean.

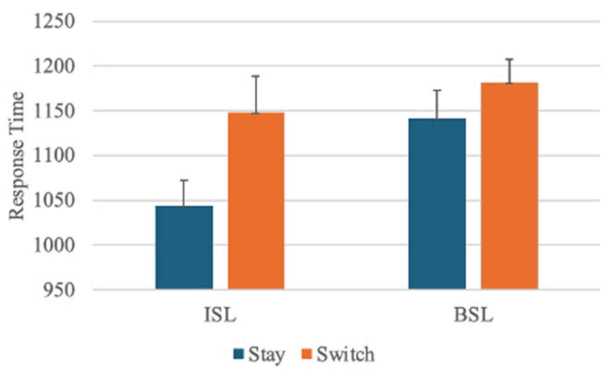

FIGURE 4
Switch cost by language. Error bars show standard error of the mean.

4.2 Accuracy analysis

Participants maintained a high level of accuracy across all conditions (see Supplementary Table 1). Participants produced two types of errors. The most common error type was to respond in the non-target language, such as producing the ISL sign for MAN instead of the BSL sign for MAN. A second error type occurred when participants took so long to respond, that the next stimulus had already been displayed. Accuracy data were analyzed in R using generalized linear mixed effects models with the lme4 package (see https://osf.io/nm2yh/ for data and R code). Fixed effects were Switching condition (Block, Stay, Switch), Language (BSL, ISL) and Cognate status (Cognate, Non-cognate). A model with all interactions and two random intercepts did not converge, so we simplified the model by removing interactions and ran separate models with random intercepts for participant and for item. No significant effects were found. The model output is reported in Supplementary Tables 3, 4.

5 Discussion

It is now well-established that bilinguals activate both languages even in monolingual settings, whether spoken (Hermans et al., 1998) or signed (Morford et al., 2011, 2019). Language production in bilinguals thus requires inhibition of the non-target language to permit fluent production in a single language. Language control processes are even more essential in contexts of language mixing, and include both reactive and proactive inhibition (Green and Abutalebi, 2013). Studies of spoken language bilinguals provide robust evidence of language switching costs when bilinguals need to switch languages in response to an external cue. To date, no studies have investigated how deaf bilinguals using two signed languages are affected by the need to switch between their languages. How might language modality and the ecology of signed language usage shape language control in signing bilinguals as opposed to speaking bilinguals?

We predicted (a) a switch cost due to the unimodal nature of switching between two signed languages, (b) an asymmetric switch cost reflecting the language dominance of the signers, and (c) a cognate facilitation effect such that cognates would mitigate switch costs relative to non-cognates. These predictions were supported, indicating that similar control processes are at work in bilinguals regardless of the modality of language use. As the first attempt to document switch costs in deaf bilinguals who use two signed languages, this study provides an important foundation for future work exploring how language modality and language experience shape the cognitive control systems underlying language switching.

Although we found evidence of a switch cost when comparing the blocked, single language condition with the language switch condition, many studies of spoken language bilinguals are also able to distinguish effects of *language mixing* (block vs. stay) from effects of language *switching* (stay vs. switch). Our data did not allow us to draw this distinction, leaving open two possible explanations for our results. One possibility is that our study is underpowered. As the first study of its kind, with a rare population, we had to select a sample size with little guidance in the literature, and take into account the burden on the Deaf community of oversampling and research burnout. Future studies with a more robust sample size will be important to address this limitation. With greater power, it is possible that the patterns revealed in this study would become more pronounced, demonstrating that deaf signing bilinguals exhibit standard reactive and proactive inhibition effects comparable to hearing bilinguals who use two spoken languages.

A second possibility is that Deaf bilinguals exhibit smaller switch costs than other populations of bilinguals due to adaptations in the control system emerging from their experience within their language ecology. Like all bilinguals, deaf signing bilinguals must choose between their two languages depending on the context of an interaction, but deaf individuals are also expected to accommodate the needs of hearing interlocutors in a variety of ways. Deaf signers accommodate spoken language influence, fingerspelled borrowings, and atypical prosody characteristic of hearing second language signers (Johnson et al., 1989; Hoffmeister and Shettle, 1983; Nicodemus, 2009), or rely on lip-reading and writing when interlocutors lack signing skills.

When hearing interlocutors do not know a signed language, deaf individuals are expected to read lips, or to use writing and texting to facilitate communication. Moreover, deaf signers accommodate signers from other language communities if they don't share a common signed language (Byun et al., 2018). Within this language ecology, deaf signing bilinguals are frequently anticipating the need to switch languages and language modality and to repair communication after a breakdown. This language ecology could lead to heightened levels of either proactive or reactive inhibitory control, or both. One outcome of these differences in experience with control processes could be less robust switching costs in bilingual signers.

In addition to a general switch cost, we found some evidence of an asymmetric switch cost indicating that deaf bilingual signers must inhibit their dominant language more than their non-dominant language. Participants named pictures more quickly in ISL than BSL in every condition, but the size of this difference decreased as the need for language control increased. Specifically, participants were more than 200 ms faster on ISL than BSL naming in the blocked trials, around 100 ms faster in the stay trials, but only 50 ms faster on average in the switch trials. Importantly, evidence for asymmetrical switch costs is much more inconsistent than for switch costs in general. As Gade et al. (2021) conclude, the size and direction of switch costs may change even within individual bilinguals as the need for control changes. For the current study, our results simply reinforce the idea that language control is a dynamic process, and that even in the case of signed languages, bilinguals may need increased or reduced levels of control depending on the exact nature of switching demands.

Finally, we found that switching cost was mediated by cognate status. Christoffels et al. (2007) also found a cognate facilitation effect in hearing bilinguals, but the effect was stronger in stay than in switch trials. We found the opposite order with cognate facilitation strongest when participants had to engage higher levels of language control. We interpret this finding as providing evidence that inhibition applies only after non-selective activation of lexical forms, but also as evidence that cognates reinforce activation of each other such that the effects of inhibition are dampened—for example the signs WORLD in ISL and BSL support activation of each other due to their phonological overlap, allowing either lexical item to surpass a threshold for production more rapidly even when response inhibition must be overcome.

In sum, our results provide the first laboratory evidence of language control mechanisms at work in bilingual signers who use two signed languages. The broad pattern of evidence is consistent with findings from hearing bilinguals who use spoken languages, indicating that language control mechanisms are universal across language modality. Further evidence from corpus, observational, and experimental studies is essential for achieving a fuller understanding of the effects of language modality and language ecology on bilingual language control.

Data availability statement

The original contributions presented in the study are publicly available. The datasets presented in this study can be found at https://osf.io/nm2yh.

Ethics statement

The studies involving humans were approved by Graduate School Ethics Committee of University College London through the Deafness Cognition and Language Research Center, and informed consent was obtained from each participant. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RA: Writing – original draft, Formal analysis, Funding acquisition, Conceptualization, Data curation, Methodology. JM: Writing – review & editing, Formal analysis.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/flang.2025.1722425/full#supplementary-material

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