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Benefits of free language choice in bilingual individuals with aphasia

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ABSTRACT

Background: Forced switching between languages poses demands on control abilities, which may be difficult to meet for bilinguals with aphasia. Freely choosing languages has been shown to increase naming efficiency in healthy bilinguals, and lexical accessibility was found to be a predictor for language choice. The overlap between bilingual language switching and other types of switching is yet unclear.

Aims: This study aimed to examine the benefits of free language choice for bilinguals with aphasia and to investigate the overlap of between- and within-language switching abilities.

Methods & Procedures: Seventeen bilinguals with aphasia completed a questionnaire and four web-based picture naming tasks: single-language naming in the first and second language separately; voluntary switching between languages; cued and predictable switching between languages; cued and predictable switching between phrase types in the first language. Accuracy and naming latencies were analysed using (generalised) linear mixed-effects models.

Outcomes & Results: The results showed higher accuracy and faster naming for the voluntary switching condition compared to single-language naming and cued switching. Both voluntary and cued language switching yielded switch costs, and voluntary switch costs were larger. Ease of lexical access was a reliable predictor for voluntary language choice. We obtained no statistical evidence for differences or associations between switch costs in between- and within-language switching.

Conclusions: Several results point to benefits of voluntary language switching for bilinguals with aphasia. Freely mixing languages improved naming accuracy and speed, and ease of lexical access affected language choice. There was no statistical evidence for overlap of between- and within-language switching abilities. This study highlights the benefits of free language choice for bilinguals with aphasia.

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Introduction

Despite a long history of research, it is still unclear whether knowing two languages may help individuals with aphasia. In his epoch-making article, Lichtheim (1885) reported on a person with aphasia who "spoke German and French fluently before the injury; but German rather the better of the two. As the aphasia diminished, German words returned before French" (p. 448). The individual experienced word-finding difficulties in both languages. In French, mostly he finds "the French equivalents of the words he can say in German" (p. 449). When words in the two languages are instead differently available, free language choice should improve naming. A bilingual speaker with aphasia may then choose the word that is most readily accessible from either language, and knowledge of two languages could thereby provide a way to bypass lexical retrieval difficulties.

At the same time, managing two languages presents a range of cognitive control demands to bilingual individuals. These demands could be difficult to meet for bilingual persons with aphasia when they have co-occurring impairments in language control. The aim of the present study was to investigate the efforts and benefits involved in bilingual language choice for bilinguals with aphasia.

To determine whether free language choice is beneficial for bilingual individuals with aphasia, we examined their picture naming abilities in conditions requiring a single language, and in conditions where language choice was free or externally cued. We also compared switching between and within languages. In the free condition, we assessed whether ease of lexical access in the languages affected language choice. In what follows, we first briefly review the extant evidence on cued and free language switching in healthy bilingual speakers and individuals with aphasia. Next, we report our new study.

Previous research has shown that language switching in a cued switching paradigm is effortful: healthy bilinguals perform worse on trials in which they have switched languages compared to trials in which the language is repeated (*switch cost*), and in blocks where they mix languages compared to single-language blocks (*mixing costs*; e.g., Branzi et al., 2016; Calabria et al., 2012; Christoffels et al., 2007; Klecha, 2013; Meuter & Allport, 1999; Verhoef et al., 2009). Switch costs are operationalised as the reaction time (RT) or accuracy difference between naming pictures in switch and repeat trials, whereas mixing costs refer to the difference between language switching conditions and "pure" language conditions (Figure 1).

The switch costs and mixing costs imply that bilinguals need top-down *control* abilities to switch between their languages. Bilinguals with aphasia (BWA) may encounter challenges in meeting these control demands if they have impairments in control abilities. Several studies have demonstrated reduced performance on language control tasks (e.g., Dash & Kar, 2014; Gray, 2020; Gray & Kiran, 2016, 2019; see Mooijman et al., 2022, for a review), but studies focusing on cued language switching abilities of BWA yielded mixed results (Calabria et al., 2019, 2021, 2014). When language switching by bilinguals with aphasia is investigated with verbal fluency tasks, it appears that BWA perform worse than neurologically healthy control participants when executive control demands are higher (Carpenter et al., 2021, 2020; Patra et al., 2020).

Further evidence for the presence of control impairments comes from reports of *pathological* code-switching (Abutalebi et al., 2000; Ansaldo et al., 2010; Calabria et al.,

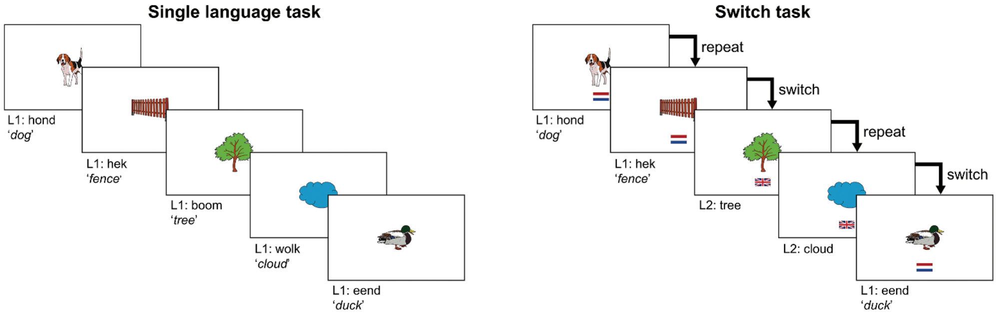

Figure 1. An illustration of a "pure" language condition (left panel) and a typical language switching paradigm using alternating runs (right panel).

2014; Fabbro, 2000; Kong et al., 2014; Leemann et al., 2007; Mariën et al., 2017). Language switching is considered "pathological" when it occurs in pragmatically inappropriate contexts (Ansaldo et al., 2008). In these cases, BWA may switch to a language not shared with their interlocutor, or to a language in which they are not proficient.

Pathological language switching has been found to co-occur with impaired non-linguistic control abilities (Calabria et al., 2014; Kong et al., 2014; Leemann et al., 2007; Mariën et al., 2017). Various studies therefore propose that a breakdown in the domain-general control system, particularly in *inhibition* abilities, may be responsible for involuntary code-switching (Abutalebi & Green, 2007; Green & Abutalebi, 2008; Kohnert, 2004). However, empirical studies that investigated whether language control impairments of BWA overlap with non-linguistic executive control impairments returned inconsistent results, as there is evidence for dissociations (Dash & Kar, 2014; Gray & Kiran, 2016, 2019; Green et al., 2011), but also for (partial) overlap (Calabria et al., 2019; Green et al., 2010; Van der Linden, Dricot et al., 2018; Van der Linden, Verreyt et al., 2018; Verreyt et al., 2013).

The conflicting findings may be due to methodological dissimilarities (Declerck et al., 2017), and examining switching abilities within the linguistic domain could reduce these differences. Previous research has shown considerable overlap in switching between and within languages in healthy bilinguals (Declerck et al., 2020), although discrepancies between the two domains have also been found (Mooijman et al., 2023). Whether BWA show overlap in within- and between-language switching, is not yet established.

Despite the aforementioned challenges, being bilingual also has benefits. Knowledge of two languages allows a bilingual to choose the most accessible language when the context allows for the use of both languages. As such, *voluntary* language switching has been found to reduce mixing costs in healthy bilinguals (Gollan & Ferreira, 2009). Indeed, several studies have demonstrated that when healthy bilinguals are free to switch between languages, they may even show mixing *benefits*: they make fewer errors and are overall faster than when they have to stay in one language (De Bruin et al., 2018; Jevtović et al., 2019). Crucially however, voluntary switching still appears to generate switch costs, although these may be diminished.

Additionally, previous research has suggested that ease of lexical access is related to voluntary switching (De Bruin et al., 2018), such that bilinguals choose the language that is easiest to access at a particular point in time. Considering that persons with aphasia have lexical retrieval problems (e.g., Goodglass & Wingfield, 1997), language switching could function as a compensatory approach for word-finding difficulties (Riccardi, 2012).

Recent studies have investigated the potential benefits of language mixing for BWA more directly. Goral et al. (2019) and Lerman et al. (2019) examined language mixing in multilinguals with aphasia, and observed more frequent mixing in more demanding contexts (with regard to aphasia severity, language proficiency levels, type of target word, and required language output). The authors found no evidence for inappropriate language mixing. Consequently, they argue that BWA may mix their languages to circumvent word-retrieval difficulties, which could be interpreted as a strategy to improve communication. Results of a recent case report support this view (Hameau et al., 2022), while Paplikar (2016) did not find that increased instances of language mixing led to higher communicative success for BWA.

In short, previous research has shown that cued switching between languages is challenging for healthy bilinguals. Language control deficits could thus imply that cued switching between languages is particularly difficult for BWA. Studies involving healthy bilinguals showed that freely mixing language may increase naming efficiency and that ease of lexical access may affect language choice and switching (De Bruin et al., 2018; Jevtović et al., 2019; Mooijman et al., 2023).

In the current study, we aimed to investigate whether voluntarily mixing languages is beneficial for BWA, leading to mixing benefits and providing a way to circumvent word-retrieval difficulties. To this end, we compared performance on three picture naming tasks: (1) naming pictures in a single language, (2) voluntarily switching between languages, and (3) cued switching between languages. These naming tasks were expected to place varying demands on control abilities. The adaptive control hypothesis of Green and Abutalebi (2013) states that the level of control necessary for bilingual language production depends on the context. In this view, the single-language naming task requires goal maintenance and interference control, and places moderate demands on control. In voluntary switching, languages can be in a cooperative relationship and this task therefore could require lesscontrol (De Bruin et al., 2018). The cued switching tasks mirror Green and Abutalebi's (2013) dual-language context, and are assumed to evoke the highest control demands. In addition to comparing these three tasks, we sought to examine whether between-language switching abilities of BWA overlap with noun-phrase switching within one language, in order to contribute to the debate regarding the degree of overlap between various language control demands. Our research objectives were:

(1) Investigate the potential benefits of language mixing, by:

(a) Analysing voluntary and cued language *mixing* costs,
(b) Comparing voluntary and cued language *switching* costs,
(c) Examining the relationship between ease of lexical retrieval and voluntary language choice.

(2) Examine how cued between-language switching costs relate to switching abilities within a language.

Methods

Participants

Nineteen BWA initially participated in the study. Two participants were excluded because the experiment was too challenging. The remaining participants (*N*= 17) were native speakers of Dutch (L1) with English or German as their second language (L2). Some participants spoke a third or fourth language (Appendix A). All participants indicated to have used or still use their L2 frequently and that they had acquired their L2 up to good-excellent levels of proficiency. However, their language history differed regarding age of acquisition and self-rated pre- and post-morbid proficiency and use.

Participants had aphasia caused by acquired brain damage due to haemorrhagic stroke (*N*= 10), ischemic stroke (*N*= 5), or traumatic brain injury (*N*= 2). Their aphasia was confirmed by their (former) speech-language therapist. The participants were all in the chronic stage of recovery (≥ 6 months, *range* 9–144 months). Six participants had motor speech impairments (apraxia of speech and/or dysarthria) in addition to aphasia, but their speech was sufficiently intelligible to participate in the study.

To get an indication of the aphasia severity and characteristics, two authors (MR and SM) qualitatively analysed the semi-spontaneous speech collected with an adapted version (Ruiter et al., 2023) of the Amsterdam-Nijmegen Everyday Language Test (ANELT; Blomert et al., 1995) using the spontaneous speech assessment scale of the Dutch Aachen Aphasia Test (Graetz et al., 1992). The latter includes multiple language-processing levels (communicative behaviour; articulation and prosody; automatised language; semantic structure; phonemic structure; syntactic structure), each scored on a six-level scale. Demographic and clinical characteristics are presented in Table 1.

Prior to participation, all participants received information about the study and gave their informed consent. The institutional ethics committee approved of the study (2019–5035).

Materials

An adapted version of the TeleTaalTest-NL (Satoer et al., 2020) was used to screen whether the verbal comprehension and word-finding difficulties were not too severe (cut-off scores <4/5 and <5/6, respectively) to hinder participation in the study. Next, participants completed a web-based questionnaire on the Qualtrics platform (Qualtrics, 2005), including questions about demographic information, handedness, clinical variables, language background, and (perceived) language and executive control abilities. Handedness was established using the Edinburgh Handedness Inventory (Oldfield, 1971).

The language background questions were based on the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian et al., 2007) and the Language History Questionnaire (LHQ 2.0; Li et al., 2014), adapted to ensure appropriateness for individuals with aphasia. Age and context of acquisition, and pre- and post-morbid self-rated language proficiency and frequency of use of all languages spoken by the participant were addressed, although we only report scores of the relevant L1 and L2. Afterwards, the average pre- and post-morbid self-rated proficiency in the L1 and L2 was calculated as the

Table 1. Individual demographic and clinical characteristics.

PWA	Age	Sex	Education[a]	Aetiology	TPO[b]	ANELT Effectiveness[c]	ANELT Efficiency[d]	Fluent	Motor speech impairments	Total score classification[e]
P01	37.6	Male	6	Haemorrhagic CVA	89	81%	15.2	Yes	No	27
P02	47.8	Male	5	Ischemic CVA (*recurrent*)	23	71%	21.7	Yes	No	28
P03	53.7	Female	6	Ischemic CVA	18	50%	8.2	No	Yes	22
P04	41.0	Female	7	Haemorrhagic CVA	35	81%	11.4	No	Yes	25
P05	54.0	Male	5	Haemorrhagic CVA	65	67%	11.3	No	No	26
P06	36.4	Male	5	Traumatic Brain Injury	65	52%	4.5	No	No	23
P07	54.2	Male	7	Haemorrhagic CVA	35	78%	10.2	No	Yes	24
P08	64.5	Male	5	Ischemic CVA	129	60%	10.7	No	No	22
P09	55.7	Female	6	Haemorrhagic CVA	26	75%	10.8	No	No	26
P10	54.6	Female	5	Ischemic CVA	120	30%	4.5	No	No	17
P11	56.4	Female	6	Haemorrhagic CVA	22	71%	16.6	No	Yes	20
P12	61.6	Female	7	Haemorrhagic CVA	74	79%	10.3	Yes	No	28
P13	55.8	Male	7	Haemorrhagic CVA	9	59%	15	No	Yes	25
P14	48.8	Male	7	Ischemic CVA (*recurrent*)	89	54%	13.9	No	No	22
P15	29.2	Male	6	Haemorrhagic CVA	30	63%	10	No	No	24
P16	22.4	Male	7	Traumatic Brain Injury	27	57%	4.7	No	Yes	19
P17	63.3	Male	5	Haemorrhagic CVA	144	56%	7.2	Yes	No	24

Note. [a] *Education based on Verhage (1964) on scale 1–7;* [b] *TPO: time post-onset in months;* [c] *ANELT effectiveness: percentage essential information conveyed;* [d] *ANELT efficiency: average number of essential information units produced per minute;* [e] *Total score classification: based on Aachen Aphasia Test classification of spontaneous speech on scale 0–30.*

mean score for comprehension and production. Writing and reading were omitted because it was not the focus of the present study. The final part of the questionnaire consisted of questions targeting self-rated language control and executive control abilities on a scale of 1–100. The language control questions were newly created and the executive control questions were adapted from Derryberry and Reed (2002). The items from the questionnaire are available upon request.

We made efforts to make completion of the questionnaire feasible for persons with aphasia (e.g., Herbert et al., 2019). We used visual support to help interpret the instructions and questions: pictograms from an open-source database (Sclera vwz, 2019) were added to the EHI and colour coding was used to illustrate levels of proficiency. The language was adapted such that only short and simple sentences were used, and we included audio recordings of the questions and instructions. Participants could take as many breaks as needed.

We administered an adapted version (Ruiter et al., 2023) of Version-I of the ANELT (Blomert et al., 1995), which includes two practice items and ten test items that require the participant to verbally respond to an everyday scenario. We used the scoring proposed by Ruiter et al. (2011), in which *verbal effectiveness* is quantified by counting produced content units related to the preamble and request of each scenario. Afterwards, the proportion of produced content units over required content units was calculated. In addition, *verbal efficiency* was operationalised as the average number of content units produced per minute (Ruiter et al., 2011). Timing started at the offset of the scenario and ended when participants finished their answer.

We designed four picture-naming tasks that closely resemble those reported in Mooijman et al. (2023). All naming tasks included the same thirty 8 × 8 cm coloured line drawings from the MultiPic database (Duñabeitia et al., 2018). Pictures had to be named in Dutch (L1) and English or German (L2), depending on the language background of the participant. The target words were frequent, early acquired, prevalent, and concrete non-cognate words (see Appendix B). Word variables were based on various databases (Birchenough et al., 2017; Brysbaert et al., 2011, 2019; Brysbaert & New, 2009; Brysbaert et al., 2014; Keuleers et al., 2010, 2015; Kuperman et al., 2012; Schröder et al., 2012).

Design and procedure

Due to the COVID-pandemic, in-person testing was not possible and the procedure took place remotely, using telephone and web-based tools. To ensure reliable measurements, we conducted the experiment using a live connection with participants, mimicking an in-person testing situation and minimising distraction. In addition, we manually annotated the answers, allowing for an evaluation of each data point before including it in the analysis. Any remaining glitches were expected to be random and not systematically impact the results. Finally, we controlled for differences in internet connection speed by including random intercepts for participants in the statistical analysis.

Participants were recruited through online communities, aphasia centres, speech-language therapists, or (if granted permission) previous studies belonging to the same research project. A screening was administered to assess feasibility of participation. Eligible participants filled in the informed consent form and the questionnaire in Qualtrics. Thereafter, the experimental tasks were administered in a peer-to-peer video call in Zoom (Zoom video Communications Inc, 2012), using a secure connection via the institution's license. The experimental materials were shown using PowerPoint via screen sharing. The experimental sessions were recorded in Zoom, stored locally, and the audio recordings were used in the analysis.

The experimental procedure started with a familiarisation task in which participants were shown each picture. They were asked to read aloud the two printed target words in their L1 and L2 or to repeat the target words after an auditory prompt. After familiarisation, four picture-naming tasks were administered in a fixed order: single-language picture naming in separate L1 and L2 blocks, voluntary language switching between L1 and L2, cued language switching between L1 and L2, and cued switching between phrase types within the L1. Our motivation to choose for this particular fixed order was as follows. The single-language task was presented first to obtain a measure of naming performance in each language separately. Voluntary switching was administered before cued switching to avoid priming language switching. The within-language switch task came last because of its relative novelty. We found that completion of the four naming tasks took approximately 30 minutes including familiarisation but excluding breaks and instructions.

Participants were given written and (pre-recorded) verbal instructions in the target language of the block that followed: L1, L2, or a mix of both languages. The instructions emphasised speed and accuracy of naming. Participants saw four practice items before single-language naming and voluntary switching, and ten (or more, if requested by the participant) practice items before the two cued switching tasks. Each task consisted of 60 trials, with short breaks between the tasks. The target pictures were presented twice in each task, and order of the items was randomised using Mix (Van Casteren & Davis, 2006), with the constraint that the repetition of items was at least 10 trials apart. We created two versions of the experiment, each with a different starting language in the single-language naming task and a different randomisation of the trials.

In the single-language naming task, participants named pictures in two blocks of trials for each language. In the voluntary switching task, participants were instructed to name pictures in whichever language first came to mind, completing two blocks. The two cued switching tasks also consisted of two blocks and had the same design: cued and predictable switching between languages or noun phrases in a *switch-repeat-switch-repeat* order. This order required participants to switch based on alternating runs, in an *AABBAA* pattern (e.g., L1-L1-L2-L2-L1-L1). A cue was presented preceding and simultaneous with each item. In the cued between-language switching task, participants named pictures in their L1 or L2 depending on a visually presented country flag. The pictures were separated across the two versions of the experiment, such that participants named an item in L1 or L2, not both, to avoid interference.

The cued within-language switching was inspired by Sikora, Roelofs, Hermans et al. (2016, 2016, 2019) and Sikora and Roelofs (2018) and involved switching between naming colour or size properties of the depicted object in the L1. All line drawings were edited such that they were red or blue, and big (14 × 14 cm) or small (6 × 6 cm). If the participants saw a colour bar, they were required to name the colour of the depicted object (e.g., *red dog* or *blue dog*). When a ruler was presented as a cue, participants named the size of the depicted object (e.g., *small dog* or *big dog*). As with the between-language switching task, participants switched in alternating runs (i.e., *size-size-colour-colour-size-size*, etc.).

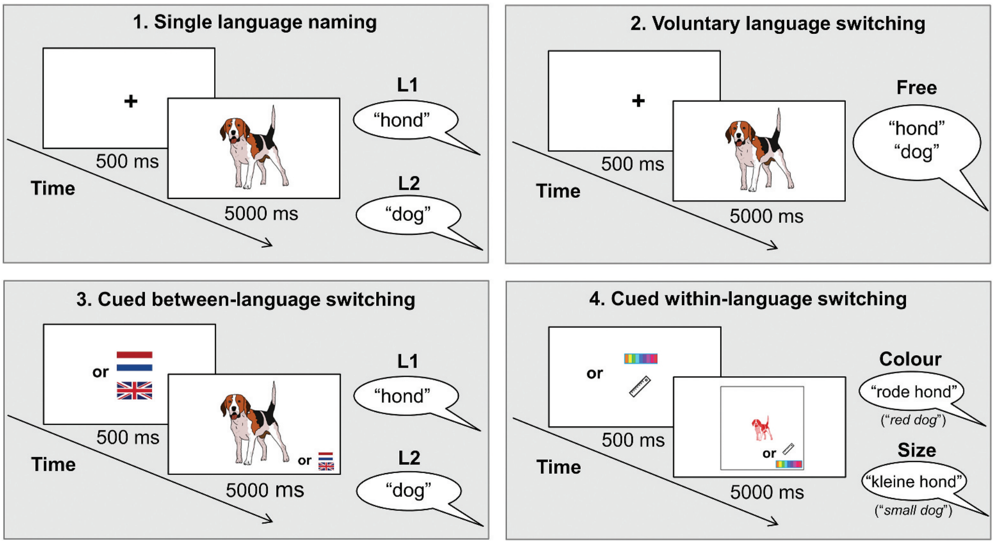

Figure 2. Experimental set-up of the four picture naming tasks in Dutch and English.

The trial structure of each task is illustrated in Figure 2. Pictures were shown for maximally 5000 ms, or shorter if the participant named the item before the end of the trial. If the participant had not completed the response before the trial ended, a blank screen was shown such that the response could be finished. The experimenter manually started the next trial, to reduce time pressure for participants and potential spill-over effects of errors or long naming latencies. A click sound was presented at the onset of each picture to enable annotation of the audio files and extraction of the response latencies. The trials were preceded by a fixation cross (single language and voluntary switching tasks) or by the visual cue (cued switching tasks), which was always shown for 500 ms.

Analysis

Error categorisation

The audio recordings of the experiments were annotated manually in Praat (Boersma & Weenink, 2022). The error categorisation was based on the classification of De Bruin et al. (2018), adapted to make it suitable for the analysis of aphasic spoken language by including categories for phonemic, semantic, and unrelated errors. Additionally, categories for specific errors made in the within-language switch task were added (i.e., between- and within-dimensional selection errors). Appendix C presents the full classification scheme. The first author coded the errors, and any unclear cases were discussed with the co-authors until consensus was reached.

Reaction times

To get a complete picture of the participants' naming abilities, we also assessed naming latencies (Evans et al., 2020). RTs were extracted in Praat (Boersma & Weenink, 2022) and operationalised as the time between the onset of the click sound and onset of the participant's response. Inaccurate answers were not included in the RT analysis. Correct answers were included if they were started within 5000 ms, also if they were preceded by filled pauses (the naming latency included the filled pause and ended at the start of the target word) or hesitations (the naming latency ended at the start of the hesitation). For within-language switching, correct answers that were realised with long breaks (≥ 250 ms) between the target adjective and noun were coded as such, qualified as correct but not included in the RT analysis.

Statistical analysis

The statistical analyses were carried out in R (R Core Team, 2022) using RStudio (RStudio Team, 2023), with packages "lme4", "lmerTest", "emmeans", "tidyverse", "ggplot2", "corpcor", "GPArotation", and "psych" (Bates et al., 2015; Bernaards & Jennrich, 2005; Lenth, 2022; Revelle, 2022; Schafer et al., 2021; Wickham, 2016; Wickham et al., 2019). In the accuracy analysis, we excluded trials with technical glitches (*N*= 3), errors that made it impossible to judge the language choice of that item (*N*= 15), and the first trials of a task or after a break (*N*= 78). In total, we excluded 96 data points (2.5%) from the accuracy analysis.

In the RT analysis, we discarded the incorrectly answered items (*N*= 834) and answers with latencies of <500 ms (*N*= 7) and >5000 ms (*N*= 208). We removed trials with technical glitches that rendered measuring naming latencies impossible or unreliable (*N*= 84). Finally, the first trials of a task or block were excluded (*N*= 61). This led to the exclusion of 1194 data points (31.3%) in the RT analysis.

Seven participant-related variables needed to be included in the statistical models: age, education level, both ANELT effectiveness and efficiency, spontaneous speech classification, self-rated L1 and L2 proficiency. To reduce the number of variables and decrease the risk of multicollinearity, a principal components analysis (PCA) was conducted on these predictors (see Appendix D for details). The PCA showed that the five language (dis)ability scores meaningfully contributed to one principal component. We calculated a factor score of this component ("aphasia factor") and included this score in the analyses. The remaining variables (i.e., age, educational level, and self-rated L2 proficiency) were included separately.

We ran multiple (generalised) linear mixed-effects regression models to answer our research questions (an overview of the models and their parameter estimates are given in Appendix E). In addition to the participant-related predictors, relevant task-related variables were included in each model. These predictors were: *task* (single-language naming, voluntary switching, cued between-language switching, and cued within-language switching), *language* (L1 and L2), and *sequence* (switch and repeat trials).

The variable *sequence* reflects the switch costs, because accuracy and RT differences on switch and repeat trials were compared. For cued switching, switch and repeat trials were predetermined by the trial order. For voluntary switching, switch and repeat trials were determined based on the participants' language choice. When they chose to name an item in the same language as the preceding trial, it was coded as a repeat trial. When language choice was different from the preceding item, the trial was coded as a switch. Consequently, the number of switch and repeat trials in the voluntary task differed between participants.

All models were fit with the maximal theoretically-informed random structure that was possible without convergence issues (Barr et al., 2013). Continuous predictors were standardised, and categorical predictors were sum-coded (−1 or +1). The interpretation of three-level predictors was facilitated by an omnibus test and post-hoc pairwise comparisons with a correction for multiple comparisons of the *p*-values. RTs were (natural) log-transformed to reduce skewness. The model assumptions of heterogeneity of variance, residual distribution and multicollinearity were checked.

Results

Questionnaire

Pre- and post-morbid self-rated language proficiency

Table 2 provides a summary of the language background questions. The included participants had differing levels of self-rated L2 proficiency. Pre-morbidly, ten participants considered their L1 and L2 proficiency to be balanced, whereas seven participants estimated their L1 skills to be higher. All participants rated their L1 and L2 proficiency higher pre-morbidly compared to post-morbidly (Figure 3). Overall, participants judged their proficiency decline to be larger in their L2 (mean difference = −1.4) than their L1 (mean difference = −1.2).

Table 2. Summary of the bilingual variables.

Second language (L2)	**N**	**%**
English	12	71%
German	5	29%
Age of acquisition	***N***	**%**
Early	4	24%
Late	13	76%

	Pre-morbidly				**Post-morbidly**				
	Mean	SD	Min	Max	Mean	SD	Min	Max	Average difference
Self-rated L1 proficiency									
Comprehension	4.9	0.3	4	5	4.2	0.8	2	5	−0.7
Production	4.9	0.2	4	5	3.5	0.9	2	5	−1.4
Reading	4.9	0.3	4	5	3.8	0.9	2	5	−1.1
Writing	4.7	0.8	2	5	3.1	1.0	2	5	−1.6
Self-rated L2 proficiency									
Comprehension	4.5	0.5	4	5	3.6	0.6	3	5	−0.9
Production	4.4	0.7	3	5	2.6	1.2	1	4	−1.8
Reading	4.5	0.5	4	5	3.4	0.8	2	5	−1.1
Writing	4.2	1.0	2	5	2.3	1.2	1	5	−1.9
Self-rated L1 frequency of use									
Home	4.8	0.8	2	5	5	0	5	5	0.2
Family	4.6	0.8	2	5	4.8	0.4	4	5	0.2
Friends	4.7	0.6	3	5	4.6	0.8	2	5	−0.1
Work	4.9	0.3	4	5	4.5	1.1	2	5	−0.4
Self-rated L2 frequency of use									
Home	3.4	1.4	1	5	2.8	1.3	1	5	−0.6
Family	2.9	1.1	1	5	2.6	1.3	1	5	−0.3
Friends	3.2	1.5	1	5	2.6	1.3	1	5	−0.6
Work	3.7	1.4	1	5	2.1	1.0	1	4	−1.5

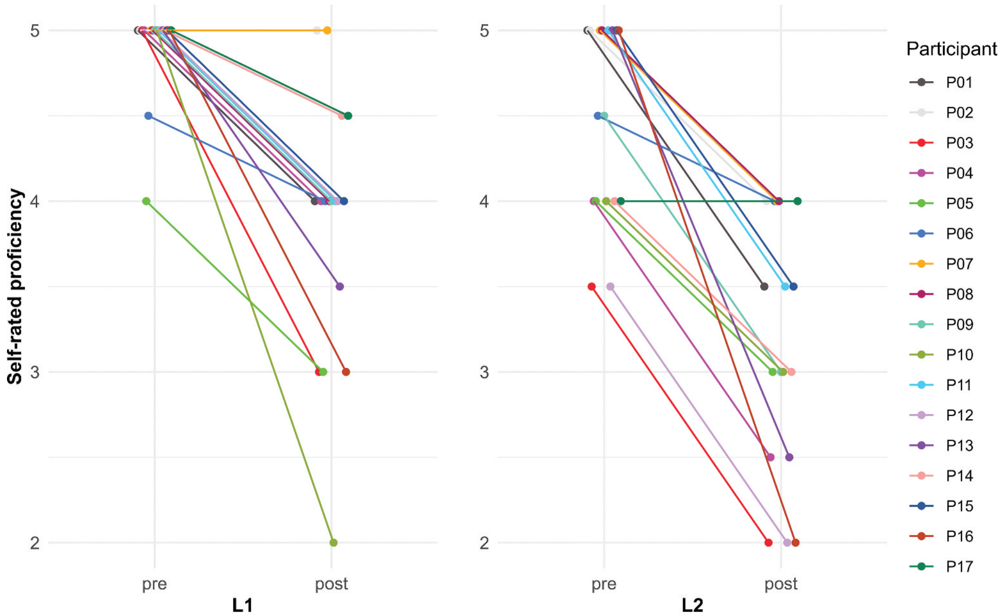

Figure 3. Self-rated pre- and post-morbid proficiency in the L1 and L2.

Language and executive control questionnaire

We highlight the main results of the language and executive control questionnaire. The average score on the question whether participants use their knowledge of another language to circumvent word-retrieval difficulties was 62.5/100 (*SD* = 29.8, *range* 9–100). The average self-rated code-switching frequency within a conversation was 37.1/100 (*SD* = 28.0, *range* 0–98). The lowest average score on the language-control questions was given for *language inhibition* ("It is easy to suppress one language when I am speaking in the other".), averaging at 40.4/100 (*SD* = 27.9, *range* 5–100). *Switching awareness* ("I notice myself switching between my languages".) received the highest average score of 79.6/100 (*SD* = 21.6, *range* 32–100). Regarding the executive-control questions, participants rated their *divided attention* lowest ("I have no trouble following two conversations at the same time".), averaging at 39.4/100 (*SD* = 29.1, *range* 0–100). Participants scored highest on their *task-switching* abilities ("I can easily switch between two different tasks".), with an average score of 65.6/100 (*SD* = 27.8, range 25–100), closely followed by *refocusing* ("After being distracted, I can easily refocus my attention on what I was doing".), averaging at 65.3/100 (*SD* = 31.3, *range* 10–100).

Experimental tasks

Task-related error patterns

The distributions of error types are visualised in Figure 4. The bars represent participant responses, and the colours illustrate the proportion of answers in each category. Participants provided correct answers (in green colours) most frequently in the voluntary switching task (including *correct, hesitations, pauses*: 88%) and least frequently in the within-language switch task (64%). In the single-language condition, 74% of answers was

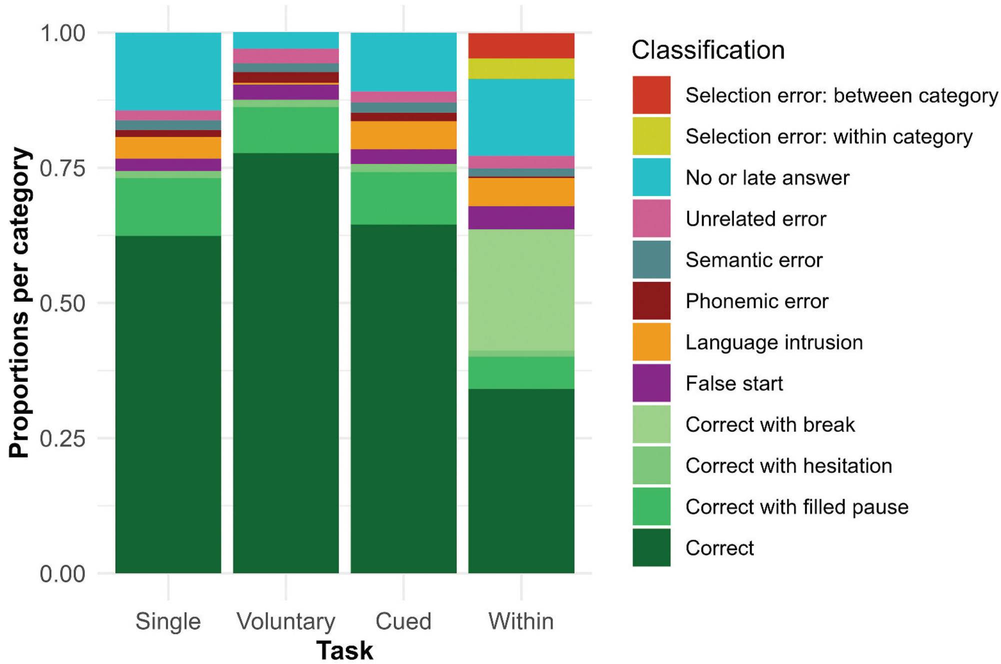

Figure 4. Classification of all observed answers divided over task. Correct answers in green colours, various errors in the other colours. Classification scheme adapted from De Bruin et al. (2018).

correct, compared to 76% in the cued switching condition. Task-specific effects contributed to some of the differences in the error distributions. The small number of *language intrusions* in voluntary switching can be attributed to the fact that both languages were considered correct in this condition. The *selection* errors, concerning the choice of the target property of the adjective, could only occur in the within-language switching condition. Besides the task-specific demands, the distribution of errors in the single-language and cued switching condition are rather similar, although participants made more language intrusions in the switching task. Notably, there were markedly fewer instances of no or late answers in the voluntary switching task as compared to the other conditions.

Costs and benefits of language mixing

In this part of the analysis, we investigated the costs and benefits of cued and voluntary language mixing by comparing the single-language task to the repeat trials in the voluntary and cued switching tasks. We were interested in the effect of task, potentially modulated by language, while controlling for aphasia factor, L2 proficiency, age, and education level. The results are visualised in Figure 5 and the model outputs are presented in Appendix E1 and E2.

Accuracy. There was a significant effect of task ($\chi^2(2)$ = 24.8, p < .001) and post-hoc pairwise comparisons showed that participants had higher accuracy in the voluntary condition compared to single-language naming (OR = 3.29, SE = 0.67, p_{adj} <.001) and

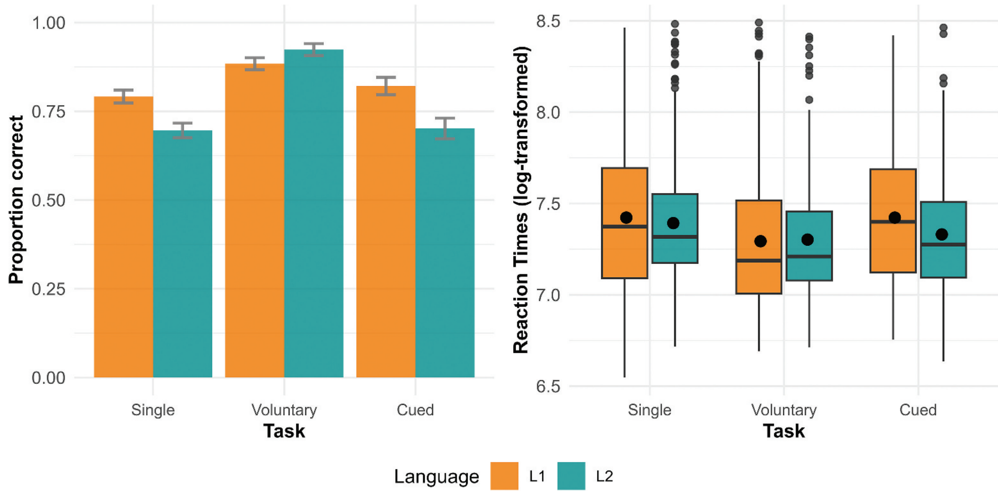

Figure 5. Accuracy and response times single-language naming, voluntary switching, and cued switching tasks. Black dots represent mean RT.

cued switching (*OR* = 0.32, *SE* = 0.07, p_{adj} <.001). There was no significant difference between single-language naming and cued switching (*OR* = 1.04, *SE* = 0.16, p_{adj} = .967). Furthermore, participants made more errors in their L2 than their L1 (*OR* = 1.27, *SE* = 0.14, *p*= .035).

There was a main effect of L2 proficiency (*OR* = 1.83, *SE* = 0.46, *p*= .015), and an interaction with task and language indicated that higher L2 proficiency positively influenced the naming accuracy of the L2 items in single-language naming and cued switching. There was a significant interaction between task and education level (*OR* = 0.66, *SE* = 0.13, *p*= .033), as accuracy differences between tasks were particularly large for participants with lower levels of education.

Reaction times. The RT results mirrored the accuracy outcomes. There was a significant effect of task ($\chi^2(2) = 18.5$, $p < .001$), as participants were faster on voluntary switching compared to single-language naming (*β* = –0.10, *SE* = 0.02, p_{adj} <.001) and cued switching (*β* = 0.07, *SE* = 0.02, p_{adj} = .013). The latter two did not differ significantly (*β* = –0.04, *SE* = 0.02, p_{adj} = .225). There were no other relevant main effects, although task was involved in three-way interactions with language and L2 proficiency, age, education, and aphasia factor. These interaction effects did not alter the interpretation of the main effect of interest (see Appendix E2).

Costs of voluntary and cued language switching

Here, we aimed to determine whether switch costs can be reduced when switching is voluntary. We were thus interested in the effect of sequence in voluntary and cued switching, potentially modulated by language of the items. We controlled for aphasia factor, L2 proficiency, age, and education level. The results are visualised in Figure 6 and the model output is given in Appendix E3 and E4.

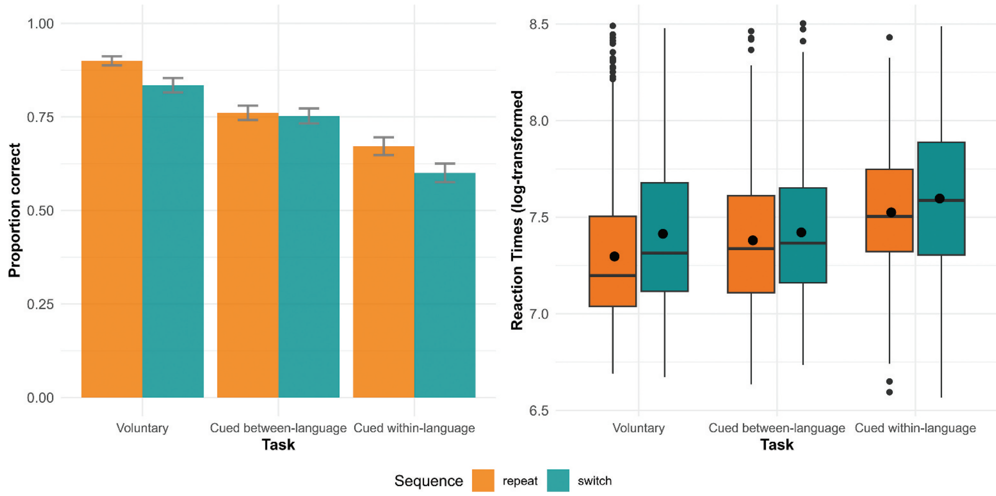

Figure 6. Switch costs (accuracy and RT difference) on tasks voluntary, cued between-language switching, and cued within-language switching. Black dots represent mean RT.

Accuracy. The accuracy analyses revealed a significant effect of sequence, indicative of a switch cost (OR = 1.18, SE = 0.09, p= .028), and showed that participants made more errors in cued than voluntary switching (OR = 0.66, SE = 0.05, p< .001). Moreover, these factors significantly interacted (OR = 0.85, SE = 0.06, p= .034), indicating that the switch costs were larger in voluntary than cued switching. Post-hoc pairwise comparisons showed that there were significant voluntary switch costs (OR = 1.93, SE = 0.48, p_{adj} = .016), in contrast to cued switching, where we did not observe a significant difference between switch and repeat trials (OR = 1.02, SE = 0.18, p_{adj} = .994).

Reaction times. The RT analysis demonstrated that participants were slower on switch than repeat trials (β = 0.03, SE = 0.01, p< .001), and on cued switching compared to voluntary switching (β = 0.03, SE = 0.01, p< .001). There was no significant interaction effect between sequence and task (β = 0.01, SE = 0.01, p= .230).

Correlations. Next, we carried out a correlation analysis to investigate whether voluntary and cued switching were related (Figure 7). The results showed that the switch costs of the two tasks were not significantly correlated (r= –.17, p= .544), whereas the mean overall RT on these tasks were strongly positively correlated (r= .93, p < .001).

Lexical accessibility and language choice

In the following part, we investigated whether ease of lexical retrieval could predict language choice in the voluntary task. Ease of lexical access was operationalised in two ways: (1) *accuracy difference*, by subtracting item-level accuracy in the L2 from the L1 based on the items of the single-language naming task (–1 for items that were named correctly only in the L2, 0 for equal scores in both languages, +1 for items that were named correctly only in the L1), and (2) *RT difference*, by subtracting item-level RTs in the L1 from the L2, again including only items of the single-language naming task (negative

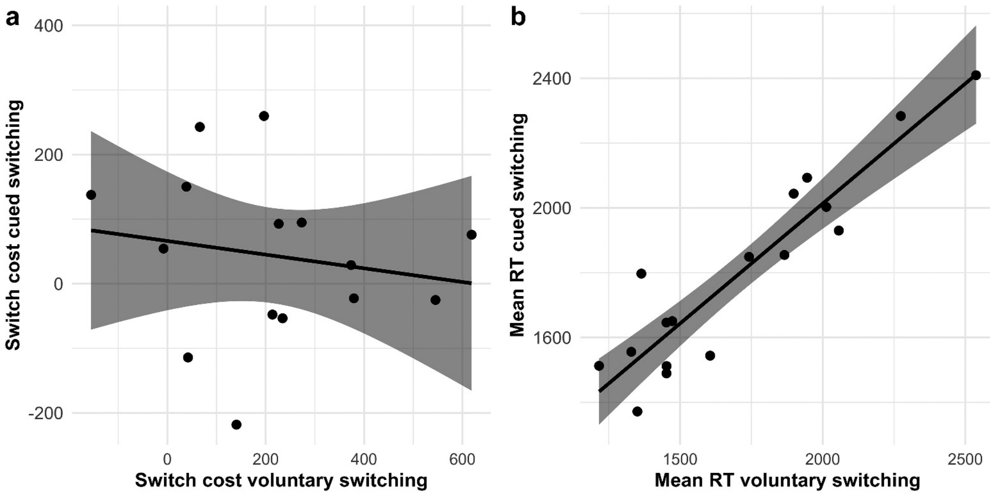

Figure 7. Correlation plots of voluntary and cued language switching.

values indicate a retrieval advantage for the L2, positive values an advantage for the L1). The RT difference score could therefore only be calculated for items that were correctly named in both languages. We used these difference scores in two models with language choice as binary outcome, while controlling for aphasia factor, L2 proficiency, age, and education level (Appendices E5 and E6 present the models).

The voluntary switching data show that participants switched on average in 36% of the trials (*range* 0% – 53%) and that they used their L2 on 44% of the trials (*range* 0% – 90%). The outcomes of the first model reveal that language choice in the voluntary task was significantly related to ease of lexical access operationalised as accuracy difference (OR = 0.30, SE = 0.06, p< .001). This suggests that items that were more often accurately named in the L1 than the L2 in the single-language condition, were also more likely to be named in the L1 in the voluntary switching condition, and vice versa (Figure 8A). This effect was obtained regardless of whether it concerned switch or repeat trials (OR = 1.19, SE = 0.23, p= .356).

Our second model demonstrated that ease of lexical access as measured with RT difference was also significantly related to language choice in the voluntary task (OR = 0.68, SE = 0.10, p= .006). Importantly, lexical access interacted with switching (OR = 0.72, SE = 0.10, p= .014), suggesting that participants were more inclined to stay in, but not switch to, a language in which the word was easier to retrieve (Figure 8B). Aphasia factor, age, and education level also affected voluntary language choice, but these effects were independent of ease of lexical access.

To assess whether the language of the final block of the single-language task impacted performance in the subsequent voluntary switching task, we conducted a post-hoc analysis examining the effect of experiment *version* on voluntary switching behaviour. We observed no significant effect of this variable on overall language choice (OR = 0.75, SE = 0.36, p= .537), indicating that the language in which the participants finished the single-language task, did not significantly affect their voluntary language choice. Similarly, there was no significant effect of version on the likelihood of switching in the voluntary task (OR = 0.94, SE = 0.32, p= .847).

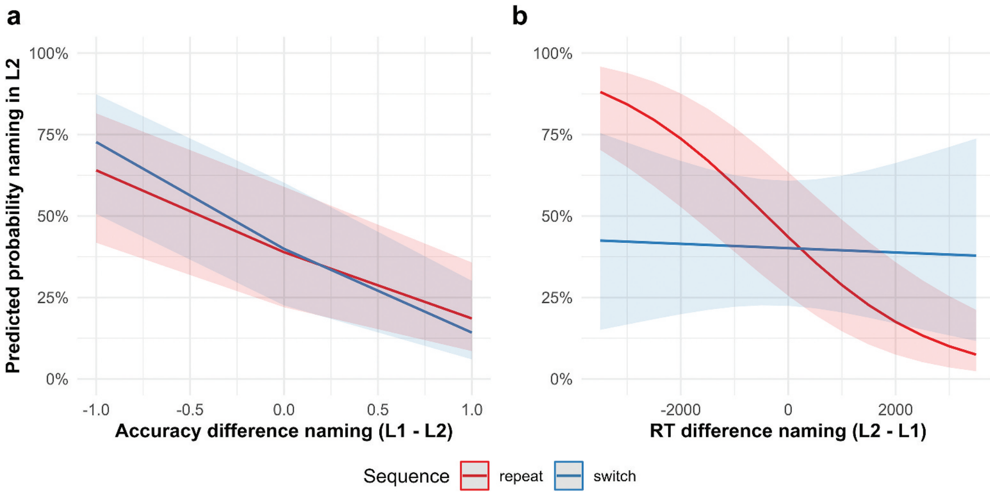

Figure 8. The model plots of the probability of naming an item in the L2 in the voluntary switching task, predicted by the accuracy difference (A) and RT difference (B) in naming items in the L1 and L2.

Relationship cued between- and within-language switching

Finally, we explored the differences and commonalities between cued between-language and within-language between adjectival phrase switching. Our main interest was the interaction between task and switch costs, while controlling for aphasia factor, age, and education level (see Appendix E7 and E8 for the models). The accuracy and RT results are visualised in Figure 6.

Accuracy. The accuracy analyses revealed that participants made significantly more errors in the within-language switching task compared to the between-language switching task (*OR* = 1.57, *SE* = 0.10, *p*< .001). Task interacted with aphasia factor (*OR* = 0.63, *SE* = 0.05, *p*< .001), as aphasia severity negatively impacted accuracy on the within-language, but not the between-language switch task. An interaction between task and L2 proficiency indicates that L2 proficiency only impacted accuracy on the between-language switch task (*OR* = 1.37, *SE* = 0.11, *p*< .001). Finally, it appears that higher education level negatively affected accuracy in the within-language switch task, but not in the between-language switch task (*OR* = 1.42, *SE* = 0.12, *p*< .001). Despite a trend visible in Figure 6, the accuracy difference between switch and repeat trials across tasks was not significant (*OR* = 1.09, *SE* = 0.06, *p*= .128), nor was the interaction between switching and task (*OR* = 0.93, *SE* = 0.05, *p*= .189).

Reaction times. In correspondence with the accuracy results, participants were slower to respond to items in the within-language switch task as compared to the between-language switch task (β = 0.10, *SE* = 0.01, *p*< .001). Here, we observed a significant switch cost across tasks (β = 0.03, *SE* = 0.01, *p*= .007), although there was no statistical evidence that these costs differed between tasks (β = 0.01, *SE* = 0.01, *p*= . 474).

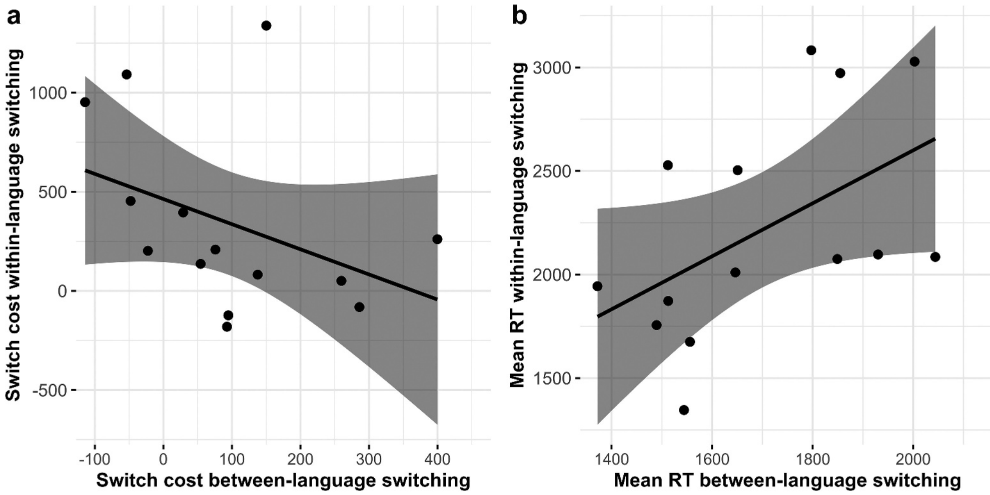

Figure 9. Correlation plots of cued between-language and within-language switching.

Correlations. A correlation analysis (Figure 9) showed that there was no significant correlation between the switch costs in cued between-language and within-language switching ($r= -.39$, $p = .170$), and that the moderate positive correlation of the overall RTs between the tasks also did not reach significance ($r= .51$, $p = .062$).

Discussion

The aim of this study was to investigate whether voluntary language mixing can be helpful for bilingual individuals with aphasia. We investigated this by focusing on mixing and switching costs associated with voluntary and cued language switching and by examining the influence of lexical accessibility on voluntary language choice. Additionally, we explored whether the costs associated with bilingual language switching coincide with switching between noun phrases in the first language.

Benefits of voluntary language mixing

Several results point to benefits associated with voluntarily mixing languages. Our analyses revealed that voluntary switching was easier than single-language naming in the L1 and L2, and cued language switching between both languages. Participants made fewer errors and were faster to name items in the voluntary task compared to the other conditions. These results corroborate voluntary mixing benefits observed for healthy bilinguals (De Bruin et al., 2018, 2020; De Bruin & Xu, 2023; Gollan & Ferreira, 2009; Jevtović et al., 2019) and BWA (Carpenter et al., 2020), but contrast the results of Grunden et al. (2020), who did not observe any mixing effects for BWA.

Our results are consistent with Carpenter et al. (2020), who found that BWA performed better on a verbal fluency task when they were free to switch between their languages. The authors argue that this result can be explained by the low control demands associated with this condition, or because BWA can benefit from their knowledge of multiple languages when the language constraints are not predetermined by the context. Following up on this question, we propose that several of our findings highlight a greater influence of bottom-up lexical retrieval processes over top-down control mechanisms in voluntary language switching by BWA.

The errors patterns specifically showed that the BWA in our study provided fewer "no or late" responses in the voluntary switching task as compared to the other tasks. This suggests that when it is difficult to access an item in one language, the other language is recruited. The results of the questionnaire confirmed that most participants reported that their knowledge of multiple languages was useful when encountering a word-retrieval problem. These results are in line with research suggesting that language mixing may function as a compensation for anomia (Goral et al., 2019; Hameau et al., 2022; Lerman et al., 2019; Riccardi, 2012). More evidence for compensation came from our observation that relative ease of lexical access in the L1 and the L2 was a reliable predictor for language choice in voluntary switching. These results correspond with studies involving early and late healthy bilinguals (De Bruin et al., 2018; Mooijman et al., 2023).

Importantly, lexical accessibility and switching interacted in predicting language choice. When ease of lexical access was operationalised as the *accuracy* difference between naming items in the L1 and L2, it predicted voluntary language choice in both switch and repeat trials. This suggests that participants were inclined to choose the item in the more accessible language, also if that meant having to make a switch. However, when lexical accessibility was investigated with the *RT* difference, we observed that it predicted language choice of only the repeat trials. In other words, items that surfaced more quickly in one language, were more likely to be named in that language, except when that implied having to make a switch. This divergence could be indicative of an (unconscious) cost-benefit analysis: The accuracy difference implies that participants were *unable* to name an item in one of the languages, whereas the RT difference merely signifies that one of the languages was *faster* to retrieve. In the latter case, participants accepted a longer retrieval time to avoid having to switch, suggesting a "threshold" for switching.

A potential reason that participants avoided switching is that it was found to be costly, even when made voluntarily. The observed voluntary and cued switch costs corroborate research involving healthy bilinguals (De Bruin et al., 2018, 2020; De Bruin & Xu, 2023; Gollan & Ferreira, 2009; Gollan et al., 2014; Jevtović et al., 2019) and the BWA in Grunden et al. (2020). However, contrary to our predictions, we observed *smaller* switch costs in cued compared to voluntary switching. We tentatively explain these effects as follows. In voluntary switching, BWA may decide to switch languages upon encountering a word-finding failure. This failed word-retrieval process is time consuming and therefore, the associated voluntary switch costs also reflect lexical retrieval time in the other language. Cued switching, on the other hand, is prompted by a predictable and external cue, and is thereby governed more prominently by top-down control (Green & Abutalebi, 2013). Similar results were found in a study involving healthy bilinguals (Mooijman et al., 2023). This explanation aligns with the results of the correlation analysis of voluntary and cued switching, which showed that overall RTs on these tasks were strongly correlated, indicative of an overlap in the abilities required to perform these tasks. However, the switch costs were not correlated, adding to our suggestion that the voluntary switch costs may specifically reflect bottom-up lexical access processes more strongly than top-down control processes.

The findings discussed thus far revealed that voluntary language mixing leads to more accurate and faster naming, that ease of lexical access is related to language choice, and that voluntarily mixing languages comes at relatively high switch costs that may originate from retrieval difficulties. These results agree with the literature on the potential benefits of bilingualism for persons with aphasia. Several studies found that BWA mixed their languages more frequently in more demanding contexts (Goral et al., 2019; Lerman et al., 2019), indicative of a compensatory reason to code-switch. Similarly, Muñoz et al. (1999) report that differences in code-switching patterns between healthy bilinguals and BWA were quantitative rather than qualitative. Considering that BWA likely encounter more word-retrieval difficulties than healthy bilinguals, increased code-switching rates could be the result of a strategy to access the word in either language (Muñoz et al., 1999). Our results provide additional evidence that subtle differences in ease of lexical access may be a motivation to choose a particular language, and thus add to the growing evidence that language switching can be recruited as a strategy to improve verbal functional effectiveness in persons with aphasia (Goral et al., 2019; Hameau et al., 2022; Lerman et al., 2019; Muñoz et al., 1999; Riccardi, 2012).

Promoting language switching as a strategy to manage lexical retrieval difficulties could serve as a starting point for clinical practice. The effectiveness of encouraging language switching may depend on the pragmatic context: If a bilingual individual frequently interacts in contexts where both languages are understood by interlocutors, code-switching may be a more effective strategy than when someone mostly operates in monolingual settings. At the same time, we agree with Hameau et al.'s (2022) proposal that code-switching could be useful even in situations where not all languages are shared, as this could nevertheless provide a way to self-cue and retrieve a word in the target language. This proposal is in line with the notion of "translanguaging", which is used to refer to the idea that bilinguals fluidly use all their linguistic resources to communicate (e.g., Wei & García, 2014). The value of promoting flexible use of the entire linguistic repertoire and explicitly training language switching to increase communicative effectiveness for individuals with aphasia needs to be tested in future studies.

Contrary to our expectations, we did not obtain statistical evidence for cued mixing costs. We propose two, not mutually exclusive, accounts for the absence of significant differences between single-language naming and cued language switching. Firstly, item repetition may have facilitated naming performance in the cued switching task, thereby eliminating the effects of the increased demands evoked by having to switch languages based on a cue. Secondly, cross-language interference effects, caused by the familiarisation and alternating language blocks, may have already negatively impacted naming performance in single-language naming. Future studies should further examine the effects of item repetition and task order for bilingual individuals with aphasia.

Domain specificity of bilingual language switching

We also examined the generalisability of cued between-language switching abilities of BWA. Because previous research on this topic has been inconclusive, we limited the comparison to the language domain. We evaluated performance on a cued between-language switching task (between the L1 and L2) to a within-language switching task (between naming colour and size). While the within-language switching task appeared to be more demanding than between-language switching, as demonstrated by lower accuracy and longer RTs, we did not find statistical evidence for differences in switch costs between the tasks. At the same time, our correlation analyses did not show a significant relationship between the switch costs or overall reaction times on the tasks. An absence of significant correlations between switching tasks has been observed previously in the literature on healthy bilinguals (Branzi et al., 2016; Calabria et al., 2015, 2012; Klecha, 2013; Segal et al., 2019; Timmer et al., 2018; Weissberger et al., 2012).

In one view, this could be interpreted as indicative of a domain-specific ability involved in switching between two languages. However, it is problematic to interpret null findings, especially since trends were visible and our sample size was small. We also recognise that despite our efforts to match the tasks as closely as possible (the same pictures were used, both tasks required a verbal response and used an alternating-runs design and a comparable cue presentation), they inevitably differed in some ways. The response alternatives between the two tasks differed and the within-language switch task required a more complex response (a correctly inflected adjective and the target noun) than the between-language switch task (the target noun). Perhaps as a result, participants experienced more difficulties in the within-language switching task. These differences could also explain the absence of significant correlations between the switching tasks.

The performance in between- and within-language switching was differentially influenced by participant-related factors. The aphasia factor, measured in the L1, had a greater impact on the within-language switch task, which required complex noun-phrase production in the L1, than on the between-language switch task, which required producing bare nouns. This was expected because aphasia severity is likely to negatively impact the production of more complex phrases. Conversely, L2 proficiency had a stronger effect in the between-language switching task, which involved naming in both languages.

Limitations

Our study has several limitations. Firstly, we observed that individual differences between the participants in our sample impacted performance on the picture naming tasks. Individuals with aphasia vary in lesion characteristics (size, aetiology, localisation) and aphasia characteristics (severity, type, time post-onset). Additionally, bilinguals differ in age and manner of acquisition, proficiency level, frequency and context of language use, and linguistic similarity between their languages (e.g., Marian & Hayakawa, 2021). These differences certainly affect performance on picture naming and switching experiments, as confirmed by several interaction effects observed in our analysis. However, due to our limited sample size, we cannot draw definitive conclusions regarding these interactions. Importantly, the interaction effects generally did not alter the interpretation of the main effects of interest. Future studies with larger sample sizes may explore individual differences related to bilingualism and aphasia in more detail. Furthermore, the combined effects of aphasia and bilingualism may have impacted naming performance, regarding both accuracy and latency. The extent to which these combined effects introduced additional inter-individual variance in our response measures is open for investigation.

Secondly, the order in which the tasks were administered and the repetition of items may have affected task performance. This has potential drawbacks, because picture naming may have become easier with each item repetition, although increasing interference or fatigue as the experiment progressed could have had detrimental effects on the participants' performance. Importantly, errors were never corrected by the experimenter during the experiment, and the pattern of the mixing costs (i.e., a decrease in RTs in voluntary switching and an increase in RTs in cued switching) shows that participants were sensitive to experimental manipulation despite repeating items. Another limitation regarding the design of the experiment was the difference in task complexity between the cued switching tasks. This difference was inevitable, but complicated comparing the two tasks.

A final limitation concerns the lack of equated tests in both languages of participants. The web-based setting and the characteristics of the included population made it difficult to administer elaborate tests, and we preferred a brief protocol over more detailed information of both languages. The combination of the ANELT, the assessment of the semi-spontaneous speech, and the results of the single-language naming test in both languages appears to have given a valid indication of the severity of the language disorder.

Conclusion

This study reveals that when two languages are equally appropriate, bilinguals with aphasia frequently mix their languages. Moreover, freely mixing languages leads to fewer errors and faster naming compared to single-language naming or cued switching. The finding that ease of lexical retrieval was related to language choice supports the idea that the knowledge of two languages can be recruited to increase naming efficiency. At the same time, voluntary language switching was found to be costly as demonstrated by relatively high switch costs. The voluntary switch costs are attributed to lexical retrieval difficulties, as BWA may be inclined to switch when they are unable to access a word in a language. These retrieval difficulties are time-consuming and are subsequently interpreted as high switch costs. Despite these costs, voluntarily mixing languages appears to be helpful for BWA as demonstrated by the mixing benefits. In contrast, cued language switching induced only modest switch costs, and we did not find statistical evidence of a relationship between bilingual language switching and within-language switching abilities of BWA. Overall, our findings contribute to the growing body of evidence that bilingual individuals with aphasia can harness their knowledge of two language to compensate for word-retrieval difficulties.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Abutalebi, J., & Green, D. W. (2007). Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics*, *20*(3), 242–275. https://doi.org/10.1016/j.jneuroling.2006.10.003

Abutalebi, J., Miozzo, A., & Cappa, S. F. (2000). Do subcortical structures control "language selection" in polyglots? Evidence from pathological language mixing. *Neurocase*, *6*(1), 51–56. https://doi.org/10.1093/neucas/6.1.51

Ansaldo, A. I., Marcotte, K., Scherer, L., & Raboyeau, G. (2008). Language therapy and bilingual aphasia: Clinical implications of psycholinguistic and neuroimaging research. *Journal of Neurolinguistics*, *21*(6), 539–557. https://doi.org/10.1016/j.jneuroling.2008.02.001

Ansaldo, A. I., Saidi, L. G., & Ruiz, A. (2010). Model-driven intervention in bilingual aphasia: Evidence from a case of pathological language mixing. *Aphasiology*, *24*(2), 309–324. https://doi.org/10.1080/02687030902958423

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Maechler, M., Bolker, B., & Walker, S. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01. https://doi.org/10.18637/jss.v067.i01.

Bernaards, C. A., & Jennrich, R. I. (2005). Gradient projection algorithms and software for arbitrary rotation criteria in factor analysis. *Educational and Psychological Measurement*, *65*(5), 676–696. https://doi.org/10.1177/0013164404272507

Birchenough, J. M. H., Davies, R., & Connelly, V. (2017). Rated age-of-acquisition norms for over 3,200 German words. *Behavior Research Methods*, *49*(2), 484–501. https://doi.org/10.3758/s13428-016-0718-0

Blomert, L., Koster, C., & Kean, M. L. (1995). *Amsterdam-nijmegen test voor alledaagse taalvaardigheid [amsterdam-nijmegen everyday language test]*. Swets & Zeitlinger.

Boersma, P., & Weenink, D. (2022). *Praat: Doing phonetics by computer (6.2.10)* [Computer software]. http://www.praat.org/

Branzi, F. M., Calabria, M., Boscarino, M. L., & Costa, A. (2016). On the overlap between bilingual language control and domain-general executive control. *Acta Psychologica*, *166*, 21–30. https://doi.org/10.1016/j.actpsy.2016.03.001

Brysbaert, M., Buchmeier, M., Conrad, M., Jacobs, A. M., Bölte, J., & Böhl, A. (2011). The word frequency effect: A review of recent developments and implications for the choice of frequency estimates in German. *Experimental Psychology*, *58*(5), 412–424. https://doi.org/10.1027/1618-3169/a000123

Brysbaert, M., Mandera, P., McCormick, S. F., & Keuleers, E. (2019). Word prevalence norms for 62,000 English lemmas. *Behavior Research Methods*, *51*(2), 467–479. https://doi.org/10.3758/s13428-018-1077-9

Brysbaert, M., & New, B. 2009. Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977–990. https://org.ru.idm.oclc.org/10.3758/BRM.41.4.977. https://doi.org/10.3758/BRM.41.4.977.

Brysbaert, M., Stevens, M., De Deyne, S., Voorspoels, W., & Storms, G. (2014). Norms of age of acquisition and concreteness for 30,000 Dutch words. *Acta Psychologica*, *150*, 80–84. https://doi.org/10.1016/j.actpsy.2014.04.010

Calabria, M., Branzi, F. M., Marne, P., Hernández, M., & Costa, A. (2015). Age-related effects over bilingual language control and executive control. *Bilingualism: Language and Cognition*, *18*(1), 65–78. https://doi.org/10.1017/S1366728913000138

Calabria, M., Grunden, N., Serra, M., García-Sánchez, C., & Costa, A. (2019). Semantic processing in bilingual aphasia: Evidence of language dependency. *Frontiers in Human Neuroscience*, *13*, 205. https://doi.org/10.3389/fnhum.2019.00205

Calabria, M., Hernandez, M., Branzi, F. M., & Costa, A. (2012). Qualitative differences between bilingual language control and executive control: Evidence from task-switching. *Frontiers in Psychology*, *2*, 399. https://doi.org/10.3389/fpsyg.2011.00399

Calabria, M., Jefferies, E., Sala, I., Morenas-Rodríguez, E., Illán-Gala, I., Montal, V., Fortea, J., Lleó, A., & Costa, A. (2021). Multilingualism in semantic dementia: Language-dependent lexical retrieval from degraded conceptual representations. *Aphasiology*, *35*(2), 240–266. https://doi.org/10.1080/02687038.2019.1693025

Calabria, M., Marne, P., Romero-Pinel, L., Juncadella, M., & Costa, A. (2014). Losing control of your languages: A case study. *Cognitive Neuropsychology*, *31*(3), 266–286. https://doi.org/10.1080/02643294.2013.879443

Carpenter, E., Peñaloza, C., Rao, L., & Kiran, S. (2021). Clustering and switching in verbal fluency across varying degrees of cognitive control demands: Evidence from healthy bilinguals and bilingual patients with aphasia. *Neurobiology of Language*, *2*(4), 532–557. https://doi.org/10.1162/nol_a_00053

Carpenter, E., Rao, L., Peñaloza, C., & Kiran, S. (2020). Verbal fluency as a measure of lexical access and cognitive control in bilingual persons with aphasia. *Aphasiology*, *34*(11), 1341–1362. https://doi.org/10.1080/02687038.2020.1759774

Christoffels, I. K., Firk, C., & Schiller, N. O. (2007). Bilingual language control: An event-related brain potential study. *Brain Research*, *1147*, 192–208. https://doi.org/10.1016/j.brainres.2007.01.137

Dash, T., & Kar, B. R. (2014). Bilingual language control and general purpose cognitive control among individuals with bilingual aphasia: Evidence based on negative priming and Flanker tasks. *Behavioural Neurology*, *2014*, 679706. https://doi.org/10.1155/2014/679706

De Bruin, A., Samuel, A. G., & Duñabeitia, J. A. (2018). Voluntary language switching: When and why do bilinguals switch between their languages? *Journal of Memory and Language*, *103*, 28–43. https://doi.org/10.1016/j.jml.2018.07.005

De Bruin, A., Samuel, A. G., & Duñabeitia, J. A. (2020). Examining bilingual language switching across the lifespan in cued and voluntary switching contexts. *Journal of Experimental Psychology: Human Perception and Performance*, *46*(8), 759–788. https://doi.org/10.1037/xhp0000746

De Bruin, A., & Xu, T. (2023). Language switching in different contexts and modalities: Response-stimulus interval influences cued-naming but not voluntary-naming or comprehension language-switching costs. *Bilingualism: Language and Cognition*, *26*(2), 402–415. https://doi.org/10.1017/S1366728922000554

Declerck, M., Grainger, J., Koch, I., & Philipp, A. M. (2017). Is language control just a form of executive control? Evidence for overlapping processes in language switching and task switching. *Journal of Memory and Language*, *95*, 138–145. https://doi.org/10.1016/j.jml.2017.03.005

Declerck, M., Ivanova, I., Grainger, J., & Duñabeitia, J. A. (2020). Are similar control processes implemented during single and dual language production? Evidence from switching between speech registers and languages. *Bilingualism: Language and Cognition*, *23*(3), 694–701. https://doi.org/10.1017/S1366728919000695

Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology*, *111*(2), 225–236. https://doi.org/10.1037/0021-843X.111.2.225
Duñabeitia, J. A., Crepaldi, D., Meyer, A. S., New, B., Pliatsikas, C., Smolka, E., & Brysbaert, M. (2018). MultiPic: A standardized set of 750 drawings with norms for six European languages. *Quarterly Journal of Experimental Psychology*, *71*(4), 808–816. https://doi.org/10.1080/17470218.2017.1310261
Evans, W. S., Hula, W. D., Quique, Y., & Starns, J. J. (2020). How much time do people with aphasia need to respond during picture naming? Estimating optimal response time cutoffs using a multinomial Ex-Gaussian approach. *Journal of Speech, Language, and Hearing Research*, *63*(2), 599–614. https://doi.org/10.1044/2019_JSLHR-19-00255
Fabbro, F. (2000). Pathological switching between languages after frontal lesions in a bilingual patient. *Journal of Neurology, Neurosurgery & Psychiatry*, *68*(5), 650–652. https://doi.org/10.1136/jnnp.68.5.650
Gollan, T. H., & Ferreira, V. S. (2009). Should I stay or should I switch? A cost–benefit analysis of voluntary language switching in young and aging bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(3), 640–665. https://doi.org/10.1037/a0014981
Gollan, T. H., Kleinman, D., & Wierenga, C. E. (2014). What's easier: Doing what you want, or being told what to do? Cued versus voluntary language and task switching. *Journal of Experimental Psychology: General*, *143*(6), 2167–2195. https://doi.org/10.1037/a0038006
Goodglass, H., & Wingfield, A. (1997). *Anomia: Neuroanatomical and Cognitive Correlates*. Academic Press.
Goral, M., Norvik, M., & Jensen, B. U. (2019). Variation in language mixing in multilingual aphasia. *Clinical Linguistics & Phonetics*, *33*(10–11), 915–929. https://doi.org/10.1080/02699206.2019.1584646
Graetz, P., De Bleser, R., & Willmes, K. (1992). *Akense Afasie Test. Nederlandstalige Versie*. Swets & Zeitlinger.
Gray, T. (2020). The relationship between language control, semantic control and nonverbal control. *Behavioral Sciences*, *10*(11), 169. Article 11. https://doi.org/10.3390/bs10110169
Gray, T., & Kiran, S. (2016). The relationship between language control and cognitive control in bilingual aphasia. *Bilingualism: Language and Cognition*, *19*(3), 433–452. https://doi.org/10.1017/S1366728915000061
Gray, T., & Kiran, S. (2019). The effect of task complexity on linguistic and non-linguistic control mechanisms in bilingual aphasia. *Bilingualism: Language and Cognition*, *22*(2), 266–284. https://doi.org/10.1017/S1366728917000712
Green, D. W., & Abutalebi, J. (2008). Understanding the link between bilingual aphasia and language control. *Journal of Neurolinguistics*, *21*(6), 558–576. https://doi.org/10.1016/j.jneuroling.2008.01.002
Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology*, *25*(5), 515–530. https://doi.org/10.1080/20445911.2013.796377
Green, D. W., Grogan, A., Crinion, J., Ali, N., Sutton, C., & Price, C. J. (2010). Language control and parallel recovery of language in individuals with aphasia. *Aphasiology*, *24*(2), 188–209. https://doi.org/10.1080/02687030902958316
Green, D. W., Ruffle, L., Grogan, A., Ali, N., Ramsden, S., Schofield, T., Leff, A. P., Crinion, J., & Price, C. J. (2011). Parallel recovery in a trilingual speaker: The use of the Bilingual Aphasia Test as a diagnostic complement to the Comprehensive Aphasia Test. *Clinical Linguistics & Phonetics*, *25*(6–7), 449–512. https://doi.org/10.3109/02699206.2011.560990
Grunden, N., Piazza, G., García-Sánchez, C., & Calabria, M. (2020). Voluntary language switching in the context of bilingual aphasia. *Behavioral Sciences*, *10*(9), 141. Article 9. https://doi.org/10.3390/bs10090141
Hameau, S., Dmowski, U., & Nickels, L. (2022). Factors affecting cross-language activation and language mixing in bilingual aphasia: A case study. *Aphasiology, Publication*. https://doi.org/10.1080/02687038.2022.2081960
Herbert, R., Gregory, E., & Haw, C. (2019). Collaborative design of accessible information with people with aphasia. *Aphasiology*, *33*(12), 1504–1530. https://doi.org/10.1080/02687038.2018.1546822

Jevtović, M., Duñabeitia, J. A., & De Bruin, A. (2019). How do bilinguals switch between languages in different interactional contexts? A comparison between voluntary and mandatory language switching. *Bilingualism: Language and Cognition*, *23*(2), 401–413. https://doi.org/10.1017/S1366728919000191

Keuleers, E., Brysbaert, M., & New, B. (2010). SUBTLEX-NL: A new measure for Dutch word frequency based on film subtitles. *Behavior Research Methods*, *42*(3), 643–650. https://doi.org/10.3758/BRM.42.3.643

Keuleers, E., Stevens, M., Mandera, P., & Brysbaert, M. (2015). Word knowledge in the crowd: Measuring vocabulary size and word prevalence in a massive online experiment. *Quarterly Journal of Experimental Psychology*, *68*(8), 1665–1692. https://doi.org/10.1080/17470218.2015.1022560

Klecha, A. (2013). Language and task switching in Polish-English bilinguals. *Psychology of Language and Communication*, *17*(1), 17–36. https://doi.org/10.2478/plc-2013-0002

Kohnert, K. (2004). Cognitive and cognate-based treatments for bilingual aphasia: A case study. *Brain and Language*, *91*(3), 294-302. https://doi.org/10.1016/j.bandl.2004.04.001

Kong, A. P.-H., Abutalebi, J., Lam, K. S.-Y., & Weekes, B. (2014). Executive and language control in the multilingual brain. *Behavioural Neurology*, *2014*, 527951. https://doi.org/10.1155/2014/527951

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods*, *44*(4), 978–990. https://doi.org/10.3758/s13428-012-0210-4

Leemann, B., Laganaro, M., Schwitter, V., & Schnider, A. (2007). Paradoxical switching to a barely-mastered second language by an aphasic patient. *Neurocase*, *13*(3), 209–213. https://doi.org/10.1080/13554790701502667

Lenth, R. V. (2022). *emmeans: estimated marginal means, aka least-squares means* (1.7.2) [Computer software]. https://CRAN.R-project.org/package=emmeans

Lerman, A., Pazuelo, L., Kizner, L., Borodkin, K., & Goral, M. (2019). Language mixing patterns in a bilingual individual with non-fluent aphasia. *Aphasiology*, *33*(9), 1137–1153. https://doi.org/10.1080/02687038.2018.1546821

Lichtheim, L. (1885). On aphasia. *Brain*, *7*(4), 433–483. https://doi.org/10.1093/brain/7.4.433

Li, P., Zhang, F., Tsai, E., & Puls, B. (2014). Language history questionnaire (LHQ 2.0): A new dynamic web-based research tool. *Bilingualism: Language and Cognition*, *17*(3), 673–680. https://doi.org/10.1017/S1366728913000606

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research*, *50*(4), 940–967. https://doi.org/10.1044/1092-4388(2007/067)

Marian, V., & Hayakawa, S. (2021). Measuring bilingualism: The quest for a "bilingualism quotient. *Applied Psycholinguistics*, *42*(2), 527–548. https://doi.org/10.1017/S0142716420000533

Mariën, P., Van Dun, K., Van Dormael, J., Vandenborre, D., Keulen, S., Manto, M., Verhoeven, J., & Abutalebi, J. (2017). Cerebellar induced differential polyglot aphasia: A neurolinguistic and fMRI study. *Brain and Language*, *175*, 18–28. https://doi.org/10.1016/j.bandl.2017.09.001

Meuter, R. F. I., & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language*, *40*(1), 25–40. https://doi.org/10.1006/jmla.1998.2602

Mooijman, S., Schoonen, R., Roelofs, A., & Ruiter, M. B. (2022). Executive control in bilingual aphasia: A systematic review. *Bilingualism: Language and Cognition*, *15*(1), 13–28. https://doi.org/10.1017/S136672892100047X

Mooijman, S., Schoonen, R., Ruiter, M. B., & Roelofs, A. (2023). Voluntary and cued language switching in late bilingual speakers. *Bilingualism: Language and Cognition*, 1–18. https://doi.org/10.1017/S1366728923000755

Muñoz, M. L., Marquardt, T. P., & Copeland, G. (1999). A comparison of the codeswitching patterns of aphasic and neurologically normal bilingual speakers of English and Spanish. *Brain and Language*, *66*(2), 249–274. https://doi.org/10.1006/brln.1998.2021

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, *9*(1), 97–113. https://doi.org/10.1016/0028-3932(71)90067-4

Paplikar, A. (2016). *Language-mixing in discourse in bilingual individuals with non-fluent aphasia*. City University of New York.

Patra, A., Bose, A., & Marinis, T. (2020). Lexical and cognitive underpinnings of verbal fluency: Evidence from Bengali-English bilingual aphasia. *Behavioral Sciences*, *10*(10), 155. Article 10. https://doi.org/10.3390/bs10100155

Qualtrics. (2005). [Computer software]. https://www.qualtrics.com/

R Core Team. (2022). *R: A language and environment for statistical computing*. (4.2.2) [Computer software]. https://www.R-project.org/

Revelle, W. (2022). *psych: Procedures for Personality and Psychological Research* (2.2.9) [Computer software]. Northwestern University.

Riccardi, A. (2012). Bilingual aphasia and codeswitching: Representation and control. In M. R. Gitterman, M. Goral, & L. K. Obler (Eds.), *Aspects of multilingual aphasia* (Vol. 8, pp. 141–157). Multilingual Matters.

RStudio Team. (2023). *RStudio: Integrated Development for R*. (2023.March.1) [Computer software]. RStudio, PBC. http://www.rstudio.com/

Ruiter, M. B., Kolk, H. H., Rietveld, T. C., Dijkstra, N., & Lotgering, E. (2011). Towards a quantitative measure of verbal effectiveness and efficiency in the Amsterdam-Nijmegen Everyday Language Test (ANELT). *Aphasiology*, *25*(8), 961–975. https://doi.org/10.1080/02687038.2011.569892

Ruiter, M. B., Otters, M. C., Piai, V., Lotgering, E. A. M., Theunissen, J. E. M. C., & Rietveld, T. C. M. (2023). A transcription-less quantitative analysis of aphasic discourse elicited with an adapted version of the Amsterdam-Nijmegen Everyday Language Test (ANELT). *Aphasiology*, *37*(10), 1556–1575. https://doi.org/10.1080/02687038.2022.2109124

Satoer, D., Piai, V., Visch-Brink, E., & De Witte, E. (2020). *TeleTaalTest-NL. Telefonische test voor mensen met neurologische taalstoornissen*. Erasmus MC University Medical Center.

Schafer, J., Opgen-Rhein, R., Zuber, V., Ahdesmaki, M., Silva, A. P. D., & Strimmer, K. (2021). *corpcor: Efficient Estimation of Covariance and (Partial) Correlation* (1.6.10) [Computer software]. https://strimmerlab.github.io/software/corpcor/

Schröder, A., Gemballa, T., Ruppin, S., & Wartenburger, I. (2012). German norms for semantic typicality, age of acquisition, and concept familiarity. *Behavior Research Methods*, *44*(2), 380–394. https://doi.org/10.3758/s13428-011-0164-y

Sclera vwz. (2019). *Sclera vwz. Pictogrammen, visualisaties & vorming*. https://www.sclera.be

Segal, D., Stasenko, A., & Gollan, T. H. (2019). More evidence that a switch is not (always) a switch: Binning bilinguals reveals dissociations between task and language switching. *Journal of Experimental Psychology: General*, *148*(3), 501–519. https://doi.org/10.1037/xge0000515

Sikora, K., & Roelofs, A. (2018). Switching between spoken language-production tasks: The role of attentional inhibition and enhancement. *Language, Cognition and Neuroscience*, *33*(7), 912–922. https://doi.org/10.1080/23273798.2018.1433864

Sikora, K., Roelofs, A., & Hermans, D. (2016). Electrophysiology of executive control in spoken noun-phrase production: Dynamics of updating, inhibiting, and shifting. *Neuropsychologia*, *84*, 44–53. https://doi.org/10.1016/j.neuropsychologia.2016.01.037

Sikora, K., Roelofs, A., Hermans, D., & Knoors, H. (2016). Executive control in spoken noun-phrase production: Contributions of updating, inhibiting, and shifting. *Quarterly Journal of Experimental Psychology*, *69*(9), 1719–1740. https://doi.org/10.1080/17470218.2015.1093007

Sikora, K., Roelofs, A., Hermans, D., & Knoors, H. (2019). Executive control in language production by children with and without language impairment. *International Journal of Language and Communication Disorders*, *54*(4), 645–655. https://doi.org/10.1111/1460-6984.12470

Timmer, K., Calabria, M., Branzi, F. M., Baus, C., & Costa, A. (2018). On the reliability of switching costs across time and domains. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.01032

Van Casteren, M., & Davis, M. H. (2006). Mix, a program for pseudorandomization. *Behavior Research Methods*, *38*(4), 584–589. https://doi.org/10.3758/bf03193889

Van der Linden, L., Dricot, L., De Letter, M., Duyck, W., De Partz, M.-P., Ivanoiu, A., & Szmalec, A. (2018). A case study about the interplay between language control and cognitive abilities in bilingual differential aphasia: Behavioral and brain correlates. *Journal of Neurolinguistics*, *46*, 37–68. https://doi.org/10.1016/j.jneuroling.2017.12.011

Van der Linden, L., Verreyt, N., De Letter, M., Hemelsoet, D., Marien, P., Santens, P., Stevens, M., Szmalec, A., & Duyck, W. (2018). Cognate effects and cognitive control in patients with parallel and differential bilingual aphasia. *International Journal of Language and Communication Disorders*, *53*(3), 515–525. https://doi.org/10.1111/1460-6984.12365

Verhoef, K., Roelofs, A., & Chwilla, D. J. (2009). Role of inhibition in language switching: Evidence from event-related brain potentials in overt picture naming. *Cognition*, *110*(1), 84–99. https://doi.org/10.1016/j.cognition.2008.10.013

Verreyt, N., De Letter, M., Hemelsoet, D., Santens, P., & Duyck, W. (2013). Cognate effects and executive control in a patient with differential bilingual aphasia. *Applied Neuropsychology: Adult*, *20*(3), 221–230. https://doi.org/10.1080/09084282.2012.753074

Wei, L., & García, O. (2014). *Translanguaging: Language, Bilingualism and Education*. Palgrave Pivot.

Weissberger, G. H., Wierenga, C. E., Bondi, M. W., & Gollan, T. H. (2012). Partially overlapping mechanisms of language and task control in young and older bilinguals. *Psychology and Aging*, *27*(4), 959–974. https://doi.org/10.1037/a0028281

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer.

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., & Yutani, H. (2019). Welcome to the Tidyverse. *Journal of Open Source Software*, *4*(43), 1–6. https://doi.org/10.21105/joss.01686

Zoom Video Communications Inc. (2012). *Zoom* (5.10.1) [Computer software].

Appendices

Appendix A. Information about the additional languages spoken by participants

PWA	L1	L2	L3	L4
P01	Dutch	English	German	
P02	Dutch	German	English	
P03	Dutch	English	German	
P04	Dutch	English	German	
P05	Dutch	English		
P06	Dutch	German		
P07	Dutch	English	French	German
P08	Dutch	English	German	French
P09	Dutch	English	French	German
P10	Dutch	German	English	French
P11	Dutch	English	German	
P12	Dutch	English	French	German
P13	Dutch	German	English	
P14	Dutch	German	English	
P15	Dutch	English	German	French
P16	Dutch	English	German	
P17	Dutch	English		

Appendix B. Stimuli lists

Experiment version Dutch – English		Experiment version Dutch – German		
Dutch	English	Dutch	German	*English translation*
Been	Leg	Aardappel	Kartoffel	*Potato*
Bezem	Broom	Broek	Hose	*Trousers*
Boom	Tree	Dobbelsteen	Würfel	*Die*
Dak	Roof	Eiland	Insel	*Island*
Eend	Duck	Fiets	Fahrrad	*Bike*
Fiets	Bike	Geit	Ziege	*Goat*
Fles	Bottle	Golf	Welle	*Wave*
Haai	Shark	Hek	Zaun	*Fence*
Hek	Fence	Jurk	Kleid	*Dress*
Hond	Dog	Kast	Schrank	*Closet*
Jurk	Dress	Kikker	Frosch	*Frog*
Ketting	Chain	Kip	Huhn	*Chicken*
Kikker	Frog	Krant	Zeitung	*Newspaper*
Kip	Chicken	Kwast	Pinsel	*Brush*
Knoop	Button	Mand	Korb	*Basket*
Kraan	Tap	Mier	Ameise	*Ant*

(*Continued*)

(Continued).

Experiment version Dutch – English		Experiment version Dutch – German		
Dutch	English	Dutch	German	*English translation*
Lepel	Spoon	Pak	Anzug	*Suit*
Mand	Basket	Peer	Birne	*Pear*
Mes	Knife	Pompoen	Kürbis	*Pumpkin*
Munt	Coin	Potlood	Bleistift	*Pencil*
Paard	Horse	Riem	Gürtel	*Belt*
Pijl	Arrow	Schilderij	Bild	*Painting*
Riem	Belt	Slak	Schnecke	*Snail*
Slak	Snail	Stropdas	Krawatte	*Tie*
Sleutel	Key	Touw	Seil	*Rope*
Spiegel	Mirror	Trein	Zug	*Train*
Stoel	Chair	Ui	Zwiebel	*Onion*
Touw	Rope	Vlinder	Schmetterling	*Butterfly*
Wolk	Cloud	Vork	Gabel	*Fork*

Appendix C. Error classification (adapted from De Bruin et al., 2018)

Category	Definition/example (target word: *hond*, "dog")
Incorrect items (not included in response-time analysis)	
No answer	No (complete) answer within 5000 ms (includes late but correct answers, incomplete answers)
False start	Wrong word-initial sound, corrected: *ro- hond* • Excluding sounds that share ≥2 word-initial phonemes with target word in competing language • Excluding sounds that share ≥2 word-initial phonemes with target adjective of competing property
Intrusion	Target word in competing language: *dog* ≥2 Target phoneme(s) of word in competing language: *do- hond*
Selection: between-dimensional	Competing adjective of non-target dimension in within-language switching task: *small* instead of *red* Both adjectives produced: *small red dog*
Selection: within-dimensional	Wrong adjective of target dimension in within-language switching task: *blue* instead of *red; big* instead of *small* Both adjectives within the same dimension produced: *small big dog*
Semantic	Meaning-based lexical error: *cat*, or for adjectives: *green, long*
Phonemic	Sound-based lexical error, the given answer has phonological overlap with 2/3 phonemes of target word; is a non-word but is *not* realised with correct syllable onset: *zond*.
Unrelated	Error with no phonological or semantic relation to target: *table*
Correct items (<u>not</u> included in response time analysis)	
Break	Long pause (>250 ms, filled or not) between adjective and noun in within-language switch task: *small . . . dog*. Onset of target noun needs to be within 5000 ms limit.
Correct items (included in response time analysis)	
Correct	Answer matches target word in target language: *dog*
Correct: Identical	Identical to target word in target language

(*Continued*)

(Continued).

Category	Definition/example (target word: *hond*, “dog”)
Correct: Phonemic	Correct with phonemic deviation: the given answer is realised with correct syllable onset (i.e., target consonant, cluster, or vowel); has phonological overlap with 2/3 phonemes of target word; is a non-word.
Correct: Grammatical	Correct with slight grammatical deviations (e.g., diminutive, plural, word order, wrong conjugation adjective)
Correct: Semantic	Correct with slight semantic deviations (e.g., dialect variant, synonym)
Pause	Filled pause before correct answer: *eh . . . dog*
Hesitation	Repetition of the word-initial target phoneme(s): *d- dog* Repetition of the first adjective: *small- small dog*

Appendix D. Details of the Principal Component Analysis

To reduce the number of variables and reduce the risk of multicollinearity, we conducted a principal components analysis (PCA) on the seven participant-related variables (i.e., ANELT effectiveness, ANELT efficiency, spontaneous speech classification, age, education level, self-rated L1 and L2 proficiency). The Kaiser-Meyer-Olkin (KMO) measure rejected the sampling adequacy for the analysis, leading to the exclusion of education *level* (*KMO* = .25) and *L2 proficiency* (*KMO* = .30). Bartlett’s test of sphericity, $\chi^2(10) = 24.0$, $p = .008$, indicated that the correlations between the items were sufficiently large for PCA. We ran an initial analysis to obtain eigenvalues for each component in the data. Two components had eigenvalues above Kaiser’s criterion of 1 and together explained 75% of the variance. These components were retained in the final analysis. The standardised factor loadings after rotation (“varimax”) are presented below:

There was one *meaningful* component, tapping language ability. *Age* as a sole variable contributed to the other component. Therefore, we only included principal component 1 and calculated factor scores (“aphasia factor”) for this component.

Variable	Item	RC1	RC2	h^2	u^2	com
ANELT effectiveness	3	0.89		0.80	0.20	1.0
Spontaneous speech classification	2	0.85		0.73	0.27	1.0
Self-rated L1 proficiency	5	0.80		0.64	0.36	1.0
ANELT efficiency	4	0.75		0.62	0.38	1.2
Age	1		0.99	0.97	0.03	1.0
		RC1	**RC2**			
Eigenvalue		2.72	1.04			
Proportion Variance		0.54	0.21			
Cumulative Variance		0.54	0.75			
Proportion Explained		0.72	0.28			
Cumulative Proportion		0.72	1			

Note. *RC1*: Principal component 1, *RC2*: Principal component 2, h^2: proportions of common variance, u^2: amount of unique variance, *com*: item complexity.

Appendix E. Model output of regression models

1. *Accuracy language mixing*

Generalised linear mixed-effects regression model: accuracy outcome predicted by task (single/voluntary/cued), language (L1/L2), aphasia factor, age, education level, L2 proficiency. Random slope for language over participants and item. Three-level predictor task was sum-coded, such that Contrast 1: cued (1), free (0), single (−1), and Contrast 2: cued (0), free (1), single (−1).

	Accuracy			
Predictors	*Odds Ratios*	*St. Error*	*95% CI*	*p-value*
(Intercept)	5.77	1.14	3.91 – 8.52	**<.001**
Task contrast 1	0.69	0.07	0.56 – 0.85	**<.001**
Task contrast 2	2.18	0.29	1.68 – 2.83	**<.001**
Language	1.27	0.14	1.02 – 1.58	**.035**
Aphasia Factor	0.84	0.19	0.54 – 1.30	.424
L2 proficiency	1.83	0.46	1.13 – 2.98	**.015**
Age	1.26	0.22	0.89 – 1.78	.199
Education	1.20	0.31	0.73 – 1.99	.471
Task contrast 1 × Language	1.19	0.13	0.97 – 1.46	.102
Task contrast 2 × Language	0.87	0.12	0.67 – 1.13	.307
Task contrast 1 × Aphasia Factor	1.13	0.16	0.86 – 1.48	.386
Task contrast 2 × Aphasia Factor	1.04	0.20	0.71 – 1.52	.843
Task contrast 1 × L2 proficiency	1.05	0.15	0.79 – 1.39	.743
Task contrast 2 × L2 proficiency	0.80	0.14	0.57 – 1.12	.198
Task contrast 1 × Age	0.84	0.09	0.68 – 1.03	.095
Task contrast 2 × Age	1.18	0.15	0.93 – 1.52	.178
Task contrast 1 × Education	1.13	0.18	0.83 – 1.54	.428
Task contrast 2 × Education	0.66	0.13	0.45 – 0.97	**.033**
Language × Aphasia Factor	1.32	0.18	1.01 – 1.74	**.044**
Language × L2 proficiency	0.93	0.13	0.70 – 1.23	.620
Language × Age	0.94	0.10	0.77 – 1.15	.575
Language × Education	1.03	0.15	0.77 – 1.38	.849
Task contrast 1 × Language × Aphasia Factor	1.02	0.14	0.77 – 1.34	.910
Task contrast 2 × Language × Aphasia Factor	0.76	0.15	0.52 – 1.12	.167
Task contrast 1 × Language × L2 proficiency	1.06	0.15	0.80 – 1.40	.708
Task contrast 2 × Language × L2 proficiency	1.45	0.25	1.03 – 2.04	**.035**
Task contrast 1 × Language × Age	1.06	0.11	0.86 – 1.31	.589
Task contrast 2 × Language × Age	1.16	0.15	0.91 – 1.49	.238
Task contrast 1 × Language × Education	1.05	0.17	0.77 – 1.43	.780
Task contrast 2 × Language × Education	1.24	0.24	0.84 – 1.82	.275
Observations	2104			
Marginal R^2 / Conditional R^2	0.179 / 0.356			

2. Reaction times language mixing

Linear mixed-effects regression model: RTs predicted by task (single/voluntary/cued), language (L1/L2), aphasia factor, age, education level, L2 proficiency. Random slope for language over participants and item. Three-level predictor task was sum-coded, such that Contrast 1: cued (1), free (0), single (-1), and Contrast 2: cued (0), free (1), single (-1).

	Reaction Times (log-transformed)			
Predictors	*Estimates*	*St. Error*	*95% CI*	*p-value*
(Intercept)	7.38	0.03	7.33 – 7.43	**<.001**
Task contrast 1	0.01	0.01	-0.02 – 0.03	.478
Task contrast 2	-0.06	0.01	-0.08 – -0.03	**<.001**
Language	0.04	0.02	-0.00 – 0.07	.068
Aphasia Factor	-0.05	0.03	-0.11 – 0.01	.117
L2 proficiency	-0.04	0.03	-0.10 – 0.03	.289
Age	0.03	0.02	-0.02 – 0.08	.186
Education	0.07	0.04	0.00 – 0.14	**.046**
Task contrast 1 × Language	0.02	0.01	-0.01 – 0.04	.189
Task contrast 2 × Language	-0.01	0.01	-0.03 – 0.02	.513
Task contrast 1 × Aphasia Factor	0.02	0.02	-0.02 – 0.05	.344
Task contrast 2 × Aphasia Factor	-0.03	0.02	-0.06 – 0.01	.153
Task contrast 1 × L2 proficiency	0.01	0.02	-0.03 – 0.04	.775
Task contrast 2 × L2 proficiency	-0.03	0.02	-0.06 – 0.00	.068
Task contrast 1 × Age	-0.02	0.01	-0.05 – 0.01	.132
Task contrast 2 × Age	0.00	0.01	-0.03 – 0.03	.972
Task contrast 1 × Education	0.00	0.02	-0.03 – 0.04	.822
Task contrast 2 × Education	-0.00	0.02	-0.04 – 0.03	.898
Language × Aphasia Factor	-0.02	0.02	-0.07 – 0.02	.309
Language × L2 proficiency	0.01	0.02	-0.04 – 0.06	.659
Language × Age	0.05	0.02	0.01 – 0.08	**.009**
Language × Education	0.02	0.03	-0.03 – 0.07	.500
Task contrast 1 × Language × Aphasia Factor	-0.01	0.02	-0.04 – 0.03	.741
Task contrast 2 × Language × Aphasia Factor	0.06	0.02	0.02 – 0.09	**.002**
Task contrast 1 × Language × L2 proficiency	0.03	0.02	-0.00 – 0.06	.091
Task contrast 2 × Language × L2 proficiency	-0.06	0.02	-0.09 – -0.03	**<.001**
Task contrast 1 × Language × Age	0.01	0.01	-0.01 – 0.04	.283
Task contrast 2 × Language × Age	-0.04	0.01	-0.07 – -0.02	**.002**
Task contrast 1 × Language × Education	0.03	0.02	-0.00 – 0.07	.068
Task contrast 2 × Language × Education	-0.05	0.02	-0.08 – -0.01	**.009**
Observations	1655			
Marginal R^2 / Conditional R^2	0.149 / 0.285			

3. Accuracy voluntary and cued switching

Generalised linear mixed-effects regression model: accuracy (0/1) predicted by switching (switch/repeat), task (voluntary/cued), language (L1/L2), aphasia factor, age, education level, L2 proficiency. Random slope for language over participants and over item.

	Accuracy			
Predictors	*Odds Ratios*	*St. Error*	*95% CI*	*p-value*
(Intercept)	6.12	1.15	4.23 – 8.85	**<.001**
Switch	1.18	0.09	1.02 – 1.37	**.028**
Task	0.66	0.05	0.57 – 0.76	**<.001**
Language	1.22	0.15	0.97 – 1.55	.096
Aphasia Factor	0.87	0.18	0.58 – 1.30	.495
L2 proficiency	1.77	0.40	1.14 – 2.76	**.011**
Age	1.05	0.17	0.76 – 1.45	.752
Education	1.11	0.26	0.70 – 1.76	.654
Switch × Task	0.85	0.06	0.73 – 0.99	**.034**
Switch × Language	0.99	0.08	0.85 – 1.14	.845
Task × Language	1.13	0.09	0.97 – 1.31	.105
Switch × Aphasia Factor	1.08	0.11	0.88 – 1.32	.461
Switch × L2 proficiency	0.99	0.10	0.81 – 1.20	.898
Switch × Age	1.12	0.08	0.97 – 1.30	.127
Switch × Education	0.94	0.10	0.75 – 1.17	.571
Task × Aphasia Factor	0.93	0.10	0.75 – 1.14	.474
Task × L2 proficiency	1.09	0.11	0.89 – 1.33	.386
Task × Age	0.88	0.07	0.76 – 1.03	.105
Task × Education	1.12	0.13	0.89 – 1.39	.332
Language × Aphasia Factor	1.21	0.17	0.91 – 1.60	.183
Language × L2 proficiency	1.05	0.16	0.78 – 1.40	.765
Language × Age	0.88	0.10	0.71 – 1.10	.262
Language × Education	0.97	0.15	0.71 – 1.32	.844
Switch × Task × Language	1.09	0.08	0.94 – 1.26	.273
Switch × Task × Aphasia Factor	1.06	0.11	0.86 – 1.30	.605
Switch × Task × L2 proficiency	1.04	0.11	0.85 – 1.27	.678
Switch × Task × Age	1.01	0.08	0.87 – 1.17	.921
Switch × Task × Education	1.19	0.13	0.95 – 1.48	.124
Switch × Language × Aphasia Factor	0.85	0.09	0.69 – 1.04	.123
Switch × Language × L2 proficiency	1.17	0.12	0.96 – 1.43	.125
Switch × Language × Age	1.15	0.09	0.99 – 1.33	.063
Switch × Language × Education	1.26	0.14	1.01 – 1.57	**.039**
Task × Language × Aphasia Factor	1.20	0.13	0.97 – 1.48	.092
Task × Language × L2 proficiency	0.87	0.09	0.71 – 1.06	.168
Task × Language × Age	0.92	0.07	0.78 – 1.07	.258
Task × Language × Education	0.98	0.11	0.78 – 1.22	.836
Switch × Task × Language × Aphasia Factor	1.07	0.11	0.87 – 1.32	.496
Switch × Task × Language × L2 proficiency	0.98	0.10	0.80 – 1.19	.811
Switch × Task × Language × Age	1.00	0.08	0.87 – 1.16	.950
Switch × Task × Language × Education	0.96	0.11	0.77 – 1.19	.701
Observations	1939			
Marginal R^2 / Conditional R^2	0.157 / 0.339			

4. Reaction times voluntary and cued switching

Linear mixed-effects regression model: RTs predicted by switching (switch/repeat), task (voluntary/cued), language (L1/L2), aphasia factor, age, education level, L2 proficiency. Random slope for language over participants, only random intercept for item (convergence issues).

	Reaction Times (log-transformed)			
Predictors	*Estimates*	*St. Error*	*95% CI*	*p-value*
(Intercept)	7.39	0.03	7.33 – 7.46	**<.001**
Switch	-0.03	0.01	-0.05 – -0.02	**<.001**
Task	0.03	0.01	0.01 – 0.04	**.001**
Language	0.03	0.02	-0.00 – 0.06	.077
Aphasia Factor	-0.05	0.04	-0.12 – 0.03	.208
L2 proficiency	-0.05	0.04	-0.13 – 0.03	.260
Age	0.01	0.03	-0.04 – 0.07	.621
Education	0.08	0.04	-0.01 – 0.16	.079
Switch × Task	0.01	0.01	-0.01 – 0.03	.230
Switch × Language	0.00	0.01	-0.01 – 0.02	.797
Task × Language	0.00	0.01	-0.01 – 0.02	.682
Switch × Aphasia Factor	-0.01	0.01	-0.03 – 0.02	.628
Switch × L2 proficiency	-0.01	0.01	-0.04 – 0.01	.270
Switch × Age	0.00	0.01	-0.01 – 0.02	.665
Switch × Education	-0.00	0.01	-0.03 – 0.02	.954
Task × Aphasia Factor	0.01	0.01	-0.01 – 0.04	.282
Task × L2 proficiency	0.02	0.01	-0.01 – 0.04	.190
Task × Age	-0.01	0.01	-0.03 – 0.01	.179
Task × Education	-0.00	0.01	-0.03 – 0.02	.919
Language × Aphasia Factor	-0.00	0.02	-0.04 – 0.04	.988
Language × L2 proficiency	-0.01	0.02	-0.05 – 0.04	.744
Language × Age	0.03	0.02	-0.00 – 0.06	.051
Language × Education	0.01	0.02	-0.04 – 0.05	.700
Switch × Task × Language	0.01	0.01	-0.01 – 0.03	.356
Switch × Task × Aphasia Factor	0.00	0.01	-0.02 – 0.02	.882
Switch × Task × L2 proficiency	0.01	0.01	-0.02 – 0.03	.572
Switch × Task × Age	0.00	0.01	-0.02 – 0.02	.955
Switch × Task × Education	0.01	0.01	-0.02 – 0.03	.516
Switch × Language × Aphasia Factor	-0.00	0.01	-0.02 – 0.02	.950
Switch × Language × L2 proficiency	0.00	0.01	-0.02 – 0.03	.841
Switch × Language × Age	0.00	0.01	-0.01 – 0.02	.641
Switch × Language × Education	0.00	0.01	-0.02 – 0.03	.912
Task × Language × Aphasia Factor	-0.02	0.01	-0.04 – 0.00	.065
Task × Language × L2 proficiency	0.03	0.01	0.01 – 0.06	**.003**
Task × Language × Age	0.02	0.01	-0.00 – 0.03	.077
Task × Language × Education	0.04	0.01	0.01 – 0.06	**.002**
Switch × Task × Language × Aphasia Factor	-0.00	0.01	-0.03 – 0.02	.707
Switch × Task × Language × L2 proficiency	0.01	0.01	-0.01 – 0.03	.442
Switch × Task × Language × Age	0.01	0.01	-0.01 – 0.03	.219
Switch × Task × Language × Education	0.00	0.01	-0.02 – 0.03	.910
Observations	1573			
Marginal R^2 / Conditional R^2	0.144 / 0.297			

5. Language choice: accuracy-difference model

Generalised linear mixed-effects regression model: language choice (L1/L2) in voluntary switching task predicted by accuracy difference score, switching (switch/repeat), aphasia factor, age, education level, L2 proficiency. Random intercepts for participant and item (no slope for language as this was the outcome in this model).

	Language choice (L1/L2)			
Predictors	*Odds Ratios*	*St. Error*	*95% CI*	*p-value*
(Intercept)	0.67	0.28	0.30 – 1.50	.330
Accuracy difference	0.30	0.06	0.20 – 0.44	**<.001**
Switch	0.97	0.09	0.80 – 1.16	.716
Aphasia Factor	0.45	0.24	0.16 – 1.27	.134
L2 proficiency	1.44	0.81	0.48 – 4.32	.518
Age	1.12	0.46	0.50 – 2.51	.777
Education	1.42	0.85	0.44 – 4.58	.554
Accuracy difference × Switch	1.19	0.23	0.82 – 1.74	.356
Accuracy difference × Aphasia Factor	0.94	0.24	0.57 – 1.57	.820
Accuracy difference × L2 proficiency	0.94	0.25	0.55 – 1.59	.811
Accuracy difference × Age	1.20	0.22	0.83 – 1.73	.329
Accuracy difference × Education	0.57	0.17	0.31 – 1.04	.065
Switch × Aphasia Factor	1.47	0.18	1.15 – 1.88	**.002**
Switch × L2 proficiency	0.87	0.11	0.68 – 1.11	.271
Switch × Age	1.36	0.13	1.12 – 1.64	**.002**
Switch × Education	0.67	0.09	0.51 – 0.87	**.002**
Accuracy difference × Switch × Aphasia Factor	1.12	0.28	0.68 – 1.84	.659
Accuracy difference × Switch × L2 proficiency	0.76	0.20	0.45 – 1.28	.308
Accuracy difference × Switch × Age	0.77	0.14	0.53 – 1.11	.158
Accuracy difference × Switch × Education	0.84	0.25	0.47 – 1.51	.563
Observations	853			
Marginal R^2 / Conditional R^2	0.182 / 0.549			

6. Language choice: reaction-time difference model

Generalised linear mixed-effects regression model: language choice (L1/L2) in voluntary switching task predicted by RT difference score, switching (switch/repeat), aphasia factor, age, education level, L2 proficiency. Random intercepts for participant, but not for item due to convergence issues.

	Language choice (L1/L2)			
Predictors	*Odds Ratios*	*St. Error*	*95% CI*	*p-value*
(Intercept)	0.74	0.30	0.33 – 1.64	.455
RT difference	0.68	0.10	0.52 – 0.89	**.006**
Switch	1.13	0.14	0.88 – 1.44	.347
Aphasia Factor	0.76	0.39	0.28 – 2.09	.593
L2 proficiency	1.09	0.62	0.36 – 3.30	.878
Age	0.96	0.39	0.43 – 2.13	.918
Education	1.01	0.59	0.32 – 3.19	.984
RT difference × Switch	0.72	0.10	0.55 – 0.93	**.014**
RT difference × Aphasia Factor	0.97	0.20	0.65 – 1.44	.863
RT difference × L2 proficiency	0.99	0.19	0.68 – 1.43	.949
RT difference × Age	1.06	0.15	0.80 – 1.41	.681
RT difference × Education	0.89	0.17	0.61 – 1.29	.530
Switch × Aphasia Factor	1.69	0.27	1.23 – 2.31	**.001**
Switch × L2 proficiency	0.87	0.16	0.61 – 1.25	.459
Switch × Age	1.21	0.16	0.93 – 1.57	.154
Switch × Education	0.57	0.10	0.40 – 0.81	**.002**
RT difference × Switch × Aphasia Factor	1.15	0.22	0.79 – 1.68	.468
RT difference × Switch × L2 proficiency	0.78	0.14	0.55 – 1.12	.175
RT difference × Switch × Age	1.22	0.17	0.93 – 1.59	.152
RT difference × Switch × Education	0.85	0.15	0.60 – 1.21	.371
Observations	505			
Marginal R^2 / Conditional R^2	0.140 / 0.506			

7. Accuracy cued between- and within-language switching

Generalised linear mixed-effects regression model: accuracy (0/1) predicted by switching (switch/repeat), task (cued/within), aphasia factor, age, education level, L2 proficiency. Random intercepts for participant and item.

	Accuracy			
Predictors	*Odds Ratios*	*St. Error*	*95% CI*	*p-value*
(Intercept)	2.34	0.39	1.69 – 3.26	**<.001**
Task	1.57	0.10	1.39 – 1.78	**<.001**
Switch	1.09	0.06	0.97 – 1.22	.128
Aphasia Factor	1.21	0.24	0.82 – 1.78	.329
L2 proficiency	1.27	0.27	0.84 – 1.92	.265
Age	1.06	0.16	0.79 – 1.43	.696
Education	0.89	0.21	0.56 – 1.40	.609
Task × Switch	0.93	0.05	0.83 – 1.04	.189
Task × Aphasia Factor	0.63	0.05	0.55 – 0.73	**<.001**
Task × L2 proficiency	1.37	0.11	1.16 – 1.60	**<.001**
Task × Age	0.94	0.06	0.83 – 1.06	.306
Task × Education	1.42	0.12	1.20 – 1.68	**<.001**
Switch × Aphasia Factor	1.06	0.07	0.92 – 1.21	.441
Switch × L2 proficiency	1.10	0.08	0.95 – 1.28	.191
Switch × Age	1.09	0.06	0.98 – 1.22	.126
Switch × Education	1.13	0.09	0.96 – 1.33	.129
Task × Switch × Aphasia Factor	1.10	0.08	0.96 – 1.26	.181
Task × Switch × L2 proficiency	0.93	0.07	0.80 – 1.07	.311
Task × Switch × Age	1.00	0.06	0.90 – 1.12	.982
Task × Switch × Education	0.95	0.08	0.80 – 1.11	.494
Observations	1743			
Marginal R^2 / Conditional R^2	0.112 / 0.223			

8. Reaction times cued between- and within-language switching

Linear mixed-effects regression model: RTs predicted by switching (switch/repeat), task (cued/within), aphasia factor, age, education level, L2 proficiency. Random intercepts for participant and item.

	Reaction Times (log-transformed)			
Predictors	*Estimates*	*St. Error*	*95% CI*	*p-value*
Intercept	7.52	0.03	7.46 – 7.58	**<.001**
Switch	-0.03	0.01	-0.06 – -0.01	**.007**
Task	-0.10	0.01	-0.13 – -0.08	**<.001**
Aphasia Factor	-0.03	0.04	-0.11 – 0.04	.404
L2 proficiency	-0.04	0.04	-0.12 – 0.04	.323
Age	0.02	0.03	-0.04 – 0.07	.586
Education	0.09	0.04	0.00 – 0.18	**.038**
Switch × Task	0.01	0.01	-0.02 – 0.03	.474
Switch × Aphasia Factor	-0.00	0.01	-0.03 – 0.02	.814
Switch × L2 proficiency	0.00	0.02	-0.03 – 0.03	.933
Switch × Age	0.01	0.01	-0.01 – 0.04	.313
Switch × Education	0.01	0.01	-0.02 – 0.04	.446
Task × Aphasia Factor	-0.00	0.02	-0.03 – 0.03	.937
Task × L2 proficiency	0.02	0.02	-0.02 – 0.05	.339
Task × Age	-0.01	0.01	-0.04 – 0.02	.442
Task × Education	-0.01	0.02	-0.04 – 0.02	.353
Switch × Task × Aphasia Factor	-0.00	0.01	-0.03 – 0.03	.958
Switch × Task × L2 proficiency	-0.01	0.02	-0.04 – 0.02	.721
Switch × Task × Age	-0.00	0.01	-0.03 – 0.02	.741
Switch × Task × Education	-0.00	0.01	-0.03 – 0.03	.905
Observations	1036			
Marginal R^2 / Conditional R^2	0.152 / 0.249			