10 Pathological Language-Switching/Mixing and Its Relationship to Domain-General Cognitive Control

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1 Introduction

Language-switching (or, alternatively, code-switching) and language-mixing are typical and common bilingual behaviours that have been the focus of interest both in sociolinguistic (e.g. Lanza [1997] 2004) and psycholinguistic research on bilingualism (e.g. Myers-Scotton [1993] 1997). Code-switching and -mixing behaviour can be influenced by social and individual factors, such as the topic, the interlocutors, or an individual's language mode (e.g. Grosjean 1985). Switching and mixing can also be deliberately used to achieve various communicative goals (Grosjean 1985). The terms *language-mixing* and *language-switching* are not interchangeable. According to Paradis (1977) and Albert and Obler (1979), mixing refers to intermingling two or more languages within the same utterance. Switching, instead, refers to the alternation between different languages across utterances, not within utterances. Most scholars have adopted the definition above (e.g. Fabbro 1999b; Fabbro, Skrap, and Aglioti 2000; Leemann et al. 2007). However, some scholars use the term *language-mixing* to refer to both code-mixing and code-switching (e.g. Lerman et al. 2019), while the term *language-switching* is typically used in psycholinguistic experiments, including single-word tasks (e.g. Meuter and Allport 1999; Declerck and Philipp 2015). In the present chapter, we distinguish between language-switching and language-mixing, adopting the most widely accepted definition (e.g. Paradis 1977; Albert and Obler 1979). Nevertheless, we will use the term *language-switching* when referring to single-word studies, as the majority of such studies do so.

There is a great deal of work in the psycholinguistics of language-switching and mixing that has focused on bilingual language acquisition and the extent to which the two languages are differentiated in early childhood (e.g. Genesee 1989; Lanza 1992). Recently, there has been a lot of interest in the possible advantages of lifelong bilingualism in cognitive control (executive functions, EFs), and studies have investigated various aspects of bilingual experience that might be related to cognitive control (e.g. Luk, De Sa, and Bialystok, 2011; Soveri et al. 2011). One such aspect is language-switching

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or mixing, which, in addition to requiring retrieval of lexical and morphosyntactic elements in the target language, is assumed to pose demands on cognitive control. Overall, well-functioning EFs such as inhibitory control, set-shifting, and monitoring are believed to be central to smooth bilingual language use, including staying in one language and switching to another when appropriate (e.g. Green 1998). In addition, one needs to pay attention to and monitor one's language use for possible errors and inaccuracies, including whether the language used is the correct one in the communicative situation. Since such domain-general EFs (i.e. EFs not restricted to language) are assumed to be active in language-switching, lifelong bilingual experience with frequent switching has been hypothesised to train these functions, leading also to a bilingual advantage in nonverbal EF tasks (e.g. Bialystok et al. 2009). Hence, research has focused on the possible enhancing role of language-switching or mixing behaviour in one's general cognitive control abilities.

Empirical evidence for the role of cognitive control in language-switching comes primarily from so-called *asymmetric switching costs* observed in language-switching tasks performed in the laboratory. In such experiments, participants typically name pictures in one language, and naming times are measured for trials in which the language of the naming needs to be switched and compared to trials where the same language is repeatedly used. Switch trials tend to elicit a processing cost, and this cost has also been shown to be asymmetric: switches from L2 to L1 take more time than switches from L1 to L2 (e.g. Meuter and Allport 1999). This unintuitive asymmetry has been suggested to reflect suppression of a stronger L1 during production of a weaker L2. Resolving this inhibition when switching back to L1 is assumed to be cognitively costly. The common assumption is that such control processes involved in language processing are largely shared with domain-general cognitive control (e.g. Abutalebi and Green 2007). For example, suppression of the other language engages domain-general inhibitory processes also involved in other (nonlinguistic/nonverbal) tasks. This assumption, however, deserves further scrutiny.

The central assumption behind the assumed bilingual *training* effects is that, since the domain-general EFs *engaged* by language-switching are also used in nonlinguistic/nonverbal tasks, language-switching can train also processes important in nonlinguistic/nonverbal EFs. While such training effects in bilingualism have been recently strongly debated (e.g. Paap et al. 2015; Bialystok 2017) and questioned by meta-analyses (see, for example, de Bruin et al. 2015; Lehtonen et al. 2018), it is still an open question to what extent the *engagement* hypothesis holds; in other words, to what extent domain-general EFs are involved in bilingual language use. An alternative hypothesis is that the cognitive system develops specialised solutions for different subfunctions while learning to perform a task, and that language control would be specific and distinct from nonlinguistic/nonverbal cognitive control (Jylkkä 2017).

An interesting perspective on the relationship between language-switching or mixing and cognitive control emerges from studies on bilingual persons with aphasia[1] (PWA) who exhibit behaviour that appears as uncontrolled language-switching or mixing. A number of such cases have been reported, but whether they truly reflect a control deficit or perhaps a communicative strategy to compensate for deficient abilities in one language remains an unresolved issue (see e.g. Goral, Norvik, and Jensen 2019). This question also touches upon the relationship and possible overlap between language control and domain-general cognitive control: if a language control deficit seems to underlie the switching/mixing behaviour of such participants, is this impairment also accompanied by a nonverbal control deficit? The present review focuses on these issues.

1.1 Definitions of Pathological and Non-Pathological Language-Mixing and Switching

Both *pathological language-mixing* and *pathological language-switching* refer to the alternation between different languages without control by a given speaker (Fabbro, Skrap, and Aglioti 2000). It is assumed that *pathological* mixing and switching are exhibited by speakers with deficient cognitive control (e.g. Abutalebi, Miozzo, and Cappa 2000; Ansaldo, Saidi, and Ruiz 2010; Fabbro 1999a). When this control fails and the speaker's language selection does not adhere to the language of the interlocutors and context, mixing and switching may result in communication breakdown. Communication breakdown occurs when the interlocutor does not understand one (or more) of the languages that the multilingual speaker uses within or across utterances, and so s/he fails to comprehend the speech of the person who mixes or switches between languages.

Not all researchers, however, agree on the usefulness of the term *pathological* language-switching or mixing. Goral, Norvik, and Jensen (2019), for example, pointed out that not only PWA but also healthy speakers exhibit mixing/switching behaviours, with the differences between neurologically healthy speakers' and PWA's mixing/switching behaviours being quantitative rather than qualitative – PWA tend to mix/switch to a greater extent compared to neurologically healthy speakers (e.g. Bhat and Chengappa 2005; Gardner-Chloros 2009; Paplikar 2016). Thus, also based on their results, Goral, Norvik, and Jensen (2019) joined Grosjean (1985) and argued against the use of the terms *pathological mixing* and *pathological switching* in future studies on multilingual aphasia, suggesting that multilingual PWA adopt a cooperative, not competitive, language activation schema (Green and Wei 2014), and use language-mixing/switching as a communicative strategy. As per Goral, Norvik, and Jensen (2019), therefore, multilingual PWA's languages do not compete for selection, but complement each other, so that PWA can draw on all of their linguistic resources (i.e. on all of their languages) in order to communicate. Language-switching/mixing could, thus, be seen as a result of this communicative strategy. Goral, Norvik, and Jensen (2019) attributed the switching/mixing behaviour of the speakers who participated in their study to word-retrieval problems. One could argue, however, that it is not a functional communicative strategy to switch to a language that the interlocutor does not understand. Instead, when encountering word-retrieval problems, multilingual speakers would rather resort to circumlocutions adhering to the shared language(s), if they were able to control the language of the utterances. In other words, it is central to consider whether language-switching or mixing is taking place with an examiner that the multilingual PWA knows or assumes to be multilingual who understands all of his/her languages. In such cases, mixing/switching between languages would not lead to communication breakdown, even if mixing/switching is not encouraged in the situation. Therefore, it could be seen as a communicative strategy of the participant, and not as an inability to control one's languages.

We suggest that the two opposing views above could be reconciled by using the presence of communication breakdown as a diagnostic of pathological switching/mixing. In case the participant tends to switch to another language to convey a message, and if that language is shared between the interlocutors, this switching behaviour can be considered to be purposeful and, therefore, non-pathological. The same may apply to a controlled testing situation where the participant decides to say something rather than keep quiet, even if the utterance is in the incorrect/non-target language. Again, this kind of switching can be seen as an intentional communicative strategy. In contrast, participants' frequent switching/mixing in inappropriate situations (i.e. with monolingual interlocutors), which leads to communication breakdown, appears to be beyond the control and communicative intentions of the speaker. We argue that such switching behaviour can be considered pathological switching. Furthermore, we suggest that this holds regardless of whether the speakers who frequently switch or mix languages in inappropriate situations know that they should not switch/mix languages given the situation. The presence or lack of such awareness may reflect well-functioning or deficient-monitoring abilities, respectively, but monitoring abilities and inhibitory control, for example, are assumedly separable functions and, thus, can be impaired independently. Moreover, impairment in either function could lead to pathological switching/mixing. In the present review, we aim to scrutinise the reported research of pathological switching/mixing from this perspective, addressing whether the communicative strategy explanation advocated by Goral, Norvik, and Jensen (2019) applies to all or most cases of "pathological" switching/mixing considered in the literature.

1.2 Does Language-Switching Share Aspects of General Task Switching?

Research on pathological switching can shed light on cognitive control processes in "healthy" language-switching. Despite the common view that language-switching engages domain-general EFs, including inhibitory control, studies investigating the engagement hypothesis have not always produced clear-cut results that would support it. In fact, there are behavioural studies showing no clear overlap between one's language-switching efficiency and EF abilities, i.e. questioning the view that language-switching abilities would be (partly) dependent on one's general inhibition and shifting abilities (e.g. Jylkkä et al. 2018a, 2018b). Furthermore, bilingual language control and nonverbal cognitive control seem to show differential effects in ageing (e.g. Weissberger et al. 2012), suggesting these processes are not entirely shared.

At the level of the brain, one can ask whether the same areas are active for language-switching and domain-general task switching. The earliest studies associated left parietal and frontal areas with a language-switching mechanism (see e.g. Fabbro 1999a, 1999b). More recently, brain-imaging studies on healthy bilinguals have found language-switching to activate a number of different brain regions, those related to core aspects of language processing, such as the posterior temporal cortex, parietal areas, and the left inferior frontal cortex (Broca's area), as well as those related to cognitive control, such as the dorsolateral prefrontal cortex, anterior cingulate, and basal ganglia (see e.g. Moritz-Gasser and Duffau 2009, for a review). A meta-analysis that focused particularly on the regions involved in cognitive control during language-switching showed that the left frontal areas, bilateral temporal areas, as well as basal ganglia regions (e.g. the caudate nuclei) were most reliably activated by these aspects of switching (Luk et al. 2012). This network of areas has also been shown to be active in nonverbal switching (De Baene et al. 2015) and other domain-general EF tasks, providing evidence for overlap between language control and domain-general EFs. However, many separable functions can rely on the same coarse neuroanatomical regions, so this evidence can only be suggestive for that view.

Only a few studies on aphasia have thus far directly explored the relationship between language control and domain-general control. The results from studies by Dash and Kar (2014) and Gray and Kiran (2016) suggest that there is a dissociation between the two, lending support to a model of domain-specific cognitive control. Green et al. (2010) found a double dissociation (in two PWA) between performance in a nonverbal control task (Flanker) and performance in a linguistic control task (Stroop). The authors attributed this to different lesion sites of the participants: basal ganglia with the language control deficit and parietal cortex with the nonverbal control deficit. Verreyt et al. (2013), in turn, found evidence for a general control deficit underlying a bilingual PWA's greater impairments in one of the two languages, supporting the domain-general control view. As the findings are variable and based on limited samples, more studies from different perspectives are needed to settle the controversy.

1.3 Aims of the Review

The present review summarises research on the reported "pathological" switching in brain-damaged individuals, particularly PWA. First, we evaluate whether the reported switching/mixing patterns can be interpreted as reflecting a communicative strategy used to compensate for deficient linguistic resources, or an impaired ability to control language use. Second, we focus on cases that demonstrate truly pathological (uncontrolled) switching/mixing and on these participants' performance in EF measures. If domain-general EFs are critically engaged in language-mixing/switching, individuals exhibiting pathological switching/mixing should also show deficits in nonverbal EF tasks, particularly in EF components assumed to be crucial for language-switching: inhibition, set-shifting, and monitoring. Third, we will make a note about participants' lesion sites and what we know about the role of different brain regions in healthy bilingual participants. A better understanding of the nature of language selection problems and their neural underpinnings in brain-damaged individuals can shed light on the role of cognitive control in bilingual language use and, thus, the relationship between language control and domain-general cognitive control.

2 Review of Original Studies on Pathological Mixing/Switching[2]

In this narrative review, we focus on studies addressing the issue of *pathological* switching/mixing or switching/mixing as a communicative strategy in participants with brain damage that in most cases resulted in aphasia.[3] Our focus is particularly on three aspects of the studies of so-called pathological mixing and switching: 1) whether language-mixing and/or switching is observed in genuine monolingual situations (that is, in situations where the participant with brain damage knows that the examiner can understand only one of their languages) where switching can be assumed to lead to communication breakdown and, thus, constitutes "true" pathological mixing/switching; 2) participants' performance on cognitive tasks, particularly in EF tasks; and 3) lesion site in the brain. These aspects of the studies are also summarised in Table 10.1.

Abutalebi, Miozzo, and Cappa (2000) reported a case with subcortical polyglot aphasia. The participant had Armenian as her L1 and started learning English at the age of 4 at school. As an adult, she learned Italian informally after settling in Italy. She had kept using all three languages actively and retained high proficiency in all of them. After a left-hemispheric stroke, with the lesion localised in the left caudate nucleus in the basal ganglia, she developed non-fluent aphasia that comparably affected all three languages, and also started spontaneously switching from one language to the other. As a result, monolingual interlocutors could not understand her. She was fully aware of her impairment. In a three-language naming task,

Table 10.1 Summary of the Reviewed Studies, Reporting Whether the Language-Switching/Mixing Behaviour Results in Communication Breakdown, Participants' Performance on Cognitive Tests, and Lesion Site

Study	*Instances of communication breakdown*	*Cognitive performance*	*Lesion site*
Abutalebi, Miozzo, and Cappa (2000)	Yes	Normal performance: fully oriented, no agnosia or apraxia, normal right-left recognition and discrimination as well as episodic memory and STM	Left basal ganglia (caudate nucleus)
Aglioti et al. (1996)	Likely no	Normal IQ, fully oriented, normal visuospatial WM, WCST score within a normal range	Basal ganglia
Ansaldo, Saidi, and Ruiz (2010)	Yes	*NA*	Left basal ganglia (caudate nucleus) and internal capsule
Calabria et al. (2014)	Likely no	Impaired nonverbal EFs (colour–shape switching task, Attention Network Test), slowed processing speed, WM deficits, verbal long-term memory borderline	White-matter lesions in the basal ganglia (caudate), left superior temporal lobe, corpus callosum, cerebellum, mesencephalon
Fabbro, Skrap, and Aglioti (2000)	Yes	Verbal disinhibition; no intellectual, attentional, motor, long-term memory or STM deficits	Left anterior cingulate and frontal lobe. Marginally also right anterior cingulate area.
Goral, Norvik, and Jensen (2019)	Likely no	*NA*	*NA*
Kong et al. (2014)	Likely no	Impaired EFs (Stroop, WCST)	Major lesion in left frontal lobe & minor lesion in left temporal-parietal areas

(*Continued*)

Table 10.1 (Continued)

Study	*Instances of communication breakdown*	*Cognitive performance*	*Lesion site*
Leemann et al. (2007)	Yes	Impaired EFs ("perseverations"; unclear if verbal or nonverbal); impaired semantic memory; impaired calculation abilities; ideomotor apraxia; intact nonverbal EFs (e.g. planning) and nonverbal attention; intact visual perception & visual memory	Left frontal operculum (Brodmann areas 44 and 45), left superior temporal lobe (Brodmann area 22), and left insular cortex
Lerman et al. (2019)	Likely no	Mild-to-moderate deficit in nonverbal EFs & mild deficit in attention and visuospatial skills	Extensive left fronto-parietal lesion
Mariën et al. (2005)	Yes	Impaired verbal WM, normal set-shifting/ performance on WCST	Left thalamus and basal ganglia, insular cortex, fronto-parietal and temporal regions, cerebellum. Recovery in switching behaviour was related to improved perfusion in the left frontal and basal ganglia regions.
Nardone et al. (2011)	Possibly	No impairments in general cognitive functioning (MMSE, Raven's coloured matrices), tests of memory and learning, or phonological fluency	Middle frontal gyrus

Note. *NA* = Information not available. WCST = Wisconsin Card Sorting Test.

she demonstrated a mild naming deficit but with particular difficulties in answering in the required language. The mixing was present to a similar extent in all three languages, and the direction of mixing varied. However, she never replaced English or Italian output with Armenian output (L1 but also the least used language). The participant seemed to have correct word names available in different languages during a session, as she was able to produce the correct word names but at an improper time, i.e. in a non-target language (for example, she produced “orologio” when the English word for “clock” was required, and “clock” when the Italian word “orologio” was required). The authors interpreted this finding as indicating a dysfunctional control mechanism. Given that the mixing behaviour took place in genuine monolingual contexts (i.e. in settings where the interlocutors of the participant were monolingual), we also interpret this participant as being a case of true pathological mixing. In a neurological examination, the participant did not show any impairments: she was fully oriented in time and space, showed no signs of apraxia or agnosia, and had normal short-term memory (STM). There is no explicit mention on e.g. inhibition or set-shifting tasks specifically.

Aglioti et al. (1996) presented a case of a bilingual person with stroke-induced aphasia who had subcortical lesions mainly in the basal ganglia. After brain damage, her mother tongue, Venetian, was more deficient than the less practised language, standard Italian. In sessions with a Venetian–Italian bilingual speech-language therapist, the participant had difficulties keeping to the language of the session, particularly during the L1 (Venetian) sessions, even whenever reminded not to switch to Italian. A neurological examination revealed normal performance not only in tests of intelligence and visuospatial working memory (WM), but also in the Wisconsin Card Sorting Test (WCST), reflecting ability to switch between visual sorting rules. Thus, in this case the language-switching deficit reflects an underlying control deficit, and the latter must be language-specific. However, since the interlocutor during the sessions was Venetian–Italian bilingual, one cannot rule out that the use of Italian was a compensatory strategy to circumvent the deficient first language abilities. The participant also had more difficulties when translating into her L1 than L2.

Ansaldo, Saidi, and Ruiz (2010) described a bilingual person with transcortical mixed aphasia as a result of a stroke that caused a subcortical lesion in the left internal capsule and the left caudate nucleus. This participant was a native Spanish speaker who had learned some English in childhood and later used it every day when residing in the USA, including for reading and studying. His symptoms included anomia in both languages as well as “compulsive” language-switching in monolingual communicative situations (i.e. in settings in which the examiners were monolingual). According to the authors, this involuntary switching usually led to communication breakdown, and although the participant was aware of the switching deficit, he was not able to control it. Attempts to control the switching resulted in slowing down of speech production. We also interpret this switching pattern as a case of pathological switching. Unfortunately, there is no report of the performance of this participant in EF tasks.

Calabria et al. (2014) reported on a participant without aphasia but with Multiple Sclerosis, who also demonstrated suspected pathological switching. She was a highly educated 44-year-old Catalan–Spanish bilingual whose first language was Catalan and who had started learning Spanish at the age of 5. She had started showing unusual and nonpredictable language-switching with her daughter, and this behaviour was also noted by her neurologist. In the neuropsychological assessment, the participant also frequently switched to Spanish when speaking in Catalan, despite the fact that the examiner kept speaking in Catalan. The examiner, however, was a Catalan–Spanish bilingual and performed the testing of both languages, so communication breakdown likely did not occur. The participant showed cross-language intrusions in an experimental language-switching task, especially when switching to her first language. As action naming was more impaired in the first than second language, it remains uncertain whether the switching behaviour could have at least partly reflected word-retrieval difficulties and whether the participant exhibited truly pathological switching by the present criteria. She, however, showed impaired performance in two nonlinguistic EF tasks (a switching task and the Attention Network Test), indicating that the putative language selection deficit also extended to nonverbal domains. The lesions of the participant were located in the left temporal lobe and the basal ganglia, as well as some other subcortical structures.

Fabbro, Skrap, and Aglioti (2000) described a bilingual person with brain damage (resulting from a tumour) whose L1 was Friulian and L2 Italian. This participant had a lesion primarily affecting the left anterior cingulate and areas of the left frontal lobe, and marginally involving the right anterior cingulate area. Neuropsychological evaluation revealed no intellectual, attentional, motor, long-term memory, or STM disorders. He displayed, however, "verbal disinhibition," a term that presumably refers to lack of inhibition in the verbal modality. According to a neurolinguistic evaluation, the participant did not demonstrate language-mixing or any other language impairment, but he only exhibited notable language-switching, as he often alternated between Friulian and Italian across different utterances. Although he had been instructed to speak in only one language (Italian on day/session 1 and Friulian on day/session 2), he did not manage to inhibit his compulsive tendency to alternate between his two languages across utterances. He was always aware of the examiner's instructions, as he often commented on his switching behaviour or apologised for it. Thus, one could assume that this participant's switching pattern was unintentional, but his intact monitoring system was able to note the errors. It could also be argued, however, that, since the examiner was a Friulian–Italian bilingual speaker, the participant presumably knew that the examiner could understand both Friulian and Italian, and so resorted to language-switching to enhance communication efficiency. Under this assumption, the participant could have used language-switching as a "communicative strategy" (see Goral, Norvik, and Jensen 2019), and therefore his switching behaviour cannot necessarily be characterised as pathological. However, he exhibited the same switching behaviour even when he addressed people who could not understand Friulian (e.g. hospital staff in Trieste). Since language-switching in this context resulted in communication breakdown, we argue that this participant exhibited instances of both non-pathological language-switching (e.g. during his interactions with the examiner) and pathological language-switching (e.g. during his interactions with the hospital staff). Although his neuropsychological assessment did not tap into nonverbal inhibition, and given that he showed no signs of memory limitations and was able to detect errors in his behaviour, one could assume that his pathological language-switching behaviour partly stemmed from control problems. The fact that he displayed verbal disinhibition suggests that not all aspects of his language control abilities were fully intact.

Goral, Norvik, and Jensen (2019) examined language-mixing behaviour in aphasia. They did not make a distinction between *mixing* and *switching* but used these terms interchangeably. Goral et al. analysed connected language production elicited from 11 multilingual persons with stroke-induced chronic aphasia. Different combinations of languages were represented in this sample of PWA. Most of the PWA were tested on all of their languages. Data collection took place in relatively monolingual settings in two countries (Norway, USA) in that all examiners avoided language-mixing or switching. However, the "participants knew that the examiners or the interpreters ... spoke at least two if not all of each participant's languages" (Goral, Norvik, and Jensen 2019, 920). The authors reported production data from a personal narrative and from a picture sequence description. Participants with more severe aphasia exhibited a mixing/switching behaviour more frequently than those with milder aphasia. Furthermore, testing participants in their weaker language resulted in increased language-mixing/switching as compared to testing them in their strongest language. According to Goral et al., these two pieces of evidence support the idea that PWA use language-mixing or switching as a strategy to cope with word-finding difficulties (*anomia*). Since the mixing/switching behaviour attested in Goral et al.'s participants with aphasia appears to be largely voluntary and controlled, and given that none of them switched to a language not known to their interlocutors (and thus communication breakdown never occurred), we agree with the authors that none of their participants with aphasia exhibited pathological code-switching/mixing. Goral et al. did not report data on naming, cognitive control or memory abilities of their participants, nor did they provide information on their lesion sites.

Lerman et al. (2019) provided a more detailed analysis of a Hebrew–English bilingual participant reported in Goral, Norvik, and Jensen (2019). This participant developed non-fluent aphasia following a stroke that resulted in an extensive fronto-parietal lesion in the left hemisphere. Neuropsychological assessment showed a mild-to-moderate deficit in EF, measured by nonverbal subtests (Symbol Cancellation, Clock Drawing, Symbol Trails, Design Memory, Mazes, Design Generation) of the Cognitive Linguistic Quick Test (Helm-Estabrooks 2001), and a mild deficit in attention and visuospatial skills. This participant was also administered tasks tapping into naming abilities and language production at the sentence and discourse level in both Hebrew and English. The participant exhibited an asymmetric mixing/switching pattern, as significantly more language-mixing/switching took place when the target language was the participant's weaker language, English, than when it was his stronger language, Hebrew. The authors argued that this asymmetric pattern partly stemmed from lexical retrieval difficulty, which was greater in his weaker than stronger language. Lerman et al.'s claim that their participant's mixing/switching behaviour was due to lexical retrieval problems was further supported by the fact that he predominantly exhibited language-mixing (i.e. alternation of English and Hebrew within utterances), not language-switching (i.e. alternation of English and Hebrew across utterances). Just like Goral, Norvik, and Jensen (2019), Lerman et al. (2019) argued that their bilingual participant used language-mixing as a strategy to maximise communication. The authors also reported that, although Hebrew and English were examined in monolingual contexts, the experimenters were Hebrew–English bilinguals. Hence, the participant's mixing/switching behaviour never led to communication breakdown, and, therefore, based on the diagnostic of pathological mixing/switching we employ here his mixing/switching behaviour was not pathological.

Kong et al. (2014) reported of a trilingual (Cantonese–English–Mandarin) 77-year-old female speaker who developed fluent aphasia following a traumatic brain injury. Testing revealed that she had Wernicke's aphasia in all three languages. This participant had a major lesion in the left frontal lobe and a minor lesion in the left temporal-parietal areas. The authors also reported data from a healthy control participant. A modified version of the Stroop colour–word test and the WCST revealed impaired EFs and perseveration errors for the PWA. This patient produced unintelligible neologisms and jargon, and also demonstrated a severe deficit in lexical retrieval during a spontaneous speech task. Moreover, while being tested, she frequently switched between her three languages during conversation, which resulted in reduced comprehensibility. The authors also examined their participants' language-switching/mixing behaviour in confrontation naming and discourse production in all of their three languages. The two participants had to name pictures in Cantonese, English, and Mandarin, as well as to converse with one of the authors on various topics associated with these pictures on separate days for each language. The control participant rarely-to-never switched to a non-target language. This was not the case for the PWA, however. Language-mixing/switching in Cantonese (L1) was more prominent in discourse production than in confrontational naming for the same lexical items. Kong et al. (2014) adopted the view that language-switching/mixing can vary as a function of the amount of stress in the environment (Javier and Marcos 1989), and suggested that connected speech poses more cognitive load on the neural system than confrontation naming. Although Kong et al. (2014) referred to their patient's mixing/switching behaviour as "pathological," they did not state whether the participant knew that their interlocutor/examiner could understand all of her languages. We assume that this was the case, as the same examiner elicited discourse productions in all three languages. Therefore, based on our diagnostic criterion for the presence of pathological mixing/switching, the patient's mixing/switching behaviour could not be considered pathological.

Leemann et al. (2007) reported on a PWA who exhibited paradoxical switching to a barely-mastered and hardly ever used second/foreign language. This participant was an 89-year-old man, a native speaker of French, who had lived in the French-speaking part of Switzerland for all his life. He learned German at school for seven years and also attended a course in German as an adult. However, he hardly ever spoke German in his life, as he only spoke French at work and with his family. He suffered a stroke resulting in a lesion in the left frontal operculum (Brodmann areas 44 and 45), left superior temporal lobe (Brodmann area 22), and left insular cortex. Initially he had global aphasia, and the authors also reported impaired EFs ("perseverations"; the authors do not report whether the task was verbal or nonverbal) and calculation abilities, impaired semantic memory, and ideomotor apraxia. However, the participant had intact aspects of nonverbal EF (e.g. planning) and intact attention, as measured by the Rey–Osterrieth Complex Figure Test (Osterrieth 1944), as well as intact visual perception and intact visual memory. Almost a month after his stroke, the participant started responding to questions and making spontaneous comments. Surprisingly, most of his speech was in German. Importantly, this was the case even in his interactions with his wife, who did not speak German. A systematic investigation of his language abilities took place two months post-onset. No switching was observed when the participant was required to repeat simple words and simple utterances in French and German. However, when he answered everyday life questions asked in French or in German (by native speakers of French or German) during different "French-speaking sessions" and "German-speaking sessions," he switched from French to German (in a French context) to a significantly larger extent than from German to French (in a German context). His switching behaviour, thus, was unidirectional. The authors did not explicitly report if the examiners could understand both French and German or if the participant knew which languages the examiners could understand. It appears, however, that at least in some other contexts of interaction this participant exhibited pathological language-switching/mixing, e.g. using German when talking to his wife. Also, the fact that he resorted to his weaker language supports this interpretation. An alternative explanation could be that this unidirectional switching behaviour could stem from a non-parallel language impairment. That is, it may be that, as a result of his stroke, French was affected much more than German, and thus his switching pattern could be interpreted not as pathological *per se* but as reflecting stroke-induced asymmetrical language impairment. We believe, however, that, even if this were the case, the fact that he used German when he talked to his wife, who could not understand German, could also suggest deficient cognitive control, e.g. difficulties monitoring the situation and the language being used.

Mariën et al. (2005) reported of a 10-year-old bilingual boy with subcortical aphasia. He was an early bilingual, using English (L1) with his parents and Dutch (L2) with friends and at school. He suffered two strokes, after which he showed symptoms of fluent aphasia in both languages, such as empty output, perseverations, and semantic errors. He also exhibited very prominent, spontaneous language-mixing and switching in both directions, also in conversations with monolingual interlocutors. He mixed the two languages at phonological, morphological, lexical, and syntactic levels. As his switching/mixing behaviour appears spontaneous and not strategic and took place in monolingual situations, it can be considered pathological. MRI measurement four months after the second stroke revealed damage in subcortical structures such as the left thalamus and the basal ganglia, in addition to the insular cortex. SPECT measurement also revealed left-hemispheric perfusion defects in the fronto-parietal and temporal regions and in the thalamus, basal ganglia, and cerebellum. Cognitive testing after the second stroke revealed that verbal WM was impaired, whereas visual set-shifting (measured with the WCST) was normal. Some other EFs that would be of interest here could not be reliably assessed as the participant's other incapacities affected his performance on the Stroop task (inhibitory control) and the Trail Making Test (set-shifting). Six months after the second stroke, the pathological switching and mixing behaviour ceased, but the participant still showed impaired naming scores in L2 and a deviant pattern of errors in naming in both languages in comparison to a control group. According to the authors, the participant used language-switching/mixing at this late stage to overcome word-finding difficulties in a controlled and conscious manner, in contrast to the spontaneous switching and mixing present at an earlier stage. SPECT revealed a re-perfusion of the left frontal cortex and left basal ganglia, but a remaining perfusion deficit in the thalamus and left temporo-parietal areas. This pattern suggests that a network encompassing frontal and basal ganglia regions had a central role in the original pathological switching and mixing behaviour of the participant.

Nardone et al. (2011) presented a case of a bilingual speaker who suffered a stroke that affected the left middle frontal gyrus. German was his L1, and he had started learning Italian at the age of 6. After the stroke, he showed a compulsive tendency to produce utterances that alternated between the two languages. During neurolinguistic assessment, he was aware that he had to speak in only one language, but he nevertheless often switched to the other language and tended to apologise for it. The examiner was a German–Italian bilingual, and it is not reported whether the participant was aware of this fact. Therefore, it is not clear whether his switching behaviour could at least partly reflect him knowing that the examiner could understand both languages, and therefore it cannot with certainty be categorised as pathological. Neuropsychological tests measuring cognitive functioning (Mini Mental State Examination, Rey's Auditory Verbal Learning Test, Immediate visual memory, Raven's Coloured Matrices, Constructive praxis, Phonological verbal fluency) did not reveal impairments. Interestingly, repetitive excitatory TMS on the left dorsolateral prefrontal cortex led to a significant increase of utterances in the appropriate language, and inhibitory TMS on the same region increased utterances in the inappropriate language. This study provides evidence for the role of the left dorsolateral frontal region in language control. Table 10.1.

3 Discussion and Conclusions

The present narrative review focused on language-switching and -mixing patterns exhibited by bilingual/multilingual speakers with brain damage, with somewhat varying aetiologies but with special emphasis on stroke patients with aphasia. We addressed three questions: 1) Does excessive language-switching and/or -mixing behaviour exhibited by bilingual/multilingual speakers with brain damage constitute a communicative strategy reflecting deficient linguistic resources that are due to brain damage (e.g. Goral, Norvik, and Jensen 2019; Grosjean 1985), or do they reflect deficient cognitive control mechanisms needed in effective bilingual language use (see Green 1998, for a theoretical summary)? 2) What is the relationship between participants' switching/mixing patterns and cognitive control abilities? 3) What is the neural basis (brain correlates) of pathological language-switching and -mixing?

With respect to Question 1, we see that some of the patterns of language-switching/mixing exhibited by PWA could be interpreted as reflecting a strategy of the participants to maximise communication, as they suffered from deficient linguistic abilities, such as word-retrieval problems (e.g. Aglioti et al. 1996; Goral, Norvik, and Jensen 2019; Kong et al. 2014; Lerman et al. 2019). Importantly, however, there were also cases where this interpretation was not likely, as language-switching/mixing appeared to be unintentional and beyond the control of the participant. In such cases, switching/mixing was interpreted as being pathological and reflecting difficulties in language selection and control. For example, the behaviour of the participant reported by Abutalebi, Miozzo, and Cappa (2000), who during the same session produced translation equivalents of target words in her different languages but at inappropriate times, appears as relatively compelling evidence for an impairment of control, instead of deficient linguistic abilities. Also, participants who kept switching and/or mixing in genuinely monolingual communicative situations, which resulted in communication breakdown, suggest that switching/mixing is not always serving a communicative purpose (see especially Ansaldo, Saidi, and Ruiz 2010; Abutalebi, Miozzo, and Cappa 2000; Mariën et al. 2005).

It was not always possible to obtain certainty about the nature (pathological vs. non-pathological) of the language-switching/mixing behaviour exhibited by the multilingual speakers with brain damage. Particularly in cases where the examiner was multilingual (see, for example, Fabbro, Skrap, and Aglioti 2000; Kong et al. 2014), one could only speculate on whether that had affected the switching/mixing behaviour of the participant. Such cases do not provide optimal settings to distinguish whether the switching is pathological, as the examiner can understand all the languages of the participant and communication breakdown can never occur as a result of language-switching/mixing, thus allowing its use as a communicative strategy. We therefore propose that researchers investigating language-switching/mixing patterns should carefully consider situational factors that might affect participants' strategies during the testing situation, as these factors may obscure the possibilities to diagnose pathological language-switching/mixing properly. To distinguish between the two possibilities (control deficit vs. communicative strategy), examiners/experimenters in a testing situation would ideally be monolingual with respect to the language being studied, and participants should be explicitly (and repeatedly, if needed) informed about that. It has to be acknowledged, however, that in many testing situations it is hard to follow the recommendation above, as most people living in a given country are familiar with the "majority language." In addition to controlling the testing situation to the extent possible, not only language test results (e.g. results from tasks tapping lexical retrieval in different languages) but also broader neuropsychological and experimental testing can provide hints on the nature of participants' deficits.

To address Question 2, we scrutinised the participants whose switching/mixing behaviour appears to reflect a control impairment and reviewed whether their pathological language-switching/mixing was accompanied by impaired EFs/cognitive control as measured by EF tasks. As domain-general inhibitory control is assumed to be central to the process of switching between languages (see e.g. Declerck and Philipp 2015, for a review), we expected that participants demonstrating pathological switching should also show defective performance on tasks of inhibition, both verbal and nonverbal. If nonverbal inhibition (tapped, for example, by the Simon task) were found impaired in participants exhibiting pathological language-switching/mixing, this would provide evidence for the view that domain-general cognitive control is engaged in bilingual language control. The same logic applies to other EFs assumed to be important in language-switching, such as set-shifting and monitoring processes. As many of the currently reviewed studies do not include tasks tapping into nonverbal and verbal EFs such as those above, we urge future research to address this more systematically.

Nevertheless, despite the large variation and limits in the reported measures, some initial observations can be made. For example, the child participant of Mariën et al. (2005) showed true pathological switching based on our analysis, but the performance in a set-shifting measure that is largely nonverbal (WCST) was reported to be normal. Furthermore, Leemann et al.'s (2007) case, who exhibited some uncontroversial instances of pathological switching, had intact aspects of nonverbal EF (e.g. planning) and intact nonverbal attention. The participant of Fabbro, Skrap, and Aglioti (2000), who also exhibited some clear instances of pathological switching, showed defects in verbal inhibition. The participants of Kong et al. (2014) and Calabria et al. (2014) showed problems in both linguistic and nonlinguistic tasks requiring cognitive control; however, the communicative situation of the testing was (at least to some extent) bilingual and they could thus not be with certainty categorised as cases of pathological switching by the present criterion. While there is a lot of uncertainty with these few cases, it appears that pathological switching/mixing can sometimes be accompanied by rather well-functioning nonverbal EFs (Mariën et al. 2005; Leemann et al. 2007) but perhaps not as likely by intact verbal EFs (Fabbro, Skrap, and Aglioti 2000; Mariën et al. 2005). This would mean that the control processes for language-switching/mixing are more similar with language-related EFs than they are with nonverbal EFs. Pathological switching would thus not necessarily be caused by damage to domain-general control processes. Instead, the processes of controlling language selection are perhaps at least partly distinct and not fully shared across domains. This would be consistent with some of the few studies on aphasia that explicitly investigated the relationship between language control and domain-general control and found evidence for their separability (Dash and Kar 2014; Gray and Kiran 2016). Even though no clear conclusions can be drawn from the set of data discussed here, this analysis demonstrates the potential of using patient cases for providing complementary insights into the relationship between language control and domain-general cognitive control.

Finally, to address Question 3, we paid attention to the brain correlates of our distinction between pathological vs. non-pathological switching/mixing, to see whether there is consistency in damage location of the cases demonstrating pathological switching (by our definition) in particular, and to what extent these brain areas correspond to the regions known to be relevant for domain-general cognitive control. Interestingly, inspection of the summary of the lesion site information for participants exhibiting pathological vs. non-pathological switching (see Table 10.1) shows that the few cases of clear and predominant pathological switching (Abutalebi, Miozzo, and Cappa 2000; Ansaldo, Saidi, and Ruiz 2010; Mariën et al. 2005) all demonstrate subcortical damage, and particularly in the basal ganglia. For the participants in whom true pathological switching did not look likely or in whom it could not be verified, the pattern of lesions seems more variable, encompassing frontal, temporal, and parietal cortical regions. Notably, a recovery from symptoms of pathological switching in the participant of Mariën et al. (2005) was associated with improved perfusion in left frontal and basal ganglia regions, whereas this measure did not improve in the other regions originally damaged, i.e. temporal, parietal areas, and the cerebellum. This suggests that, in addition to the left frontal cortex, the basal ganglia play a critical role in efficient language selection and switching (as proposed by e.g. Abutalebi and Green 2007; Abutalebi, Miozzo, and Cappa 2000; Green and Abutalebi 2013; see also Adrover-Roig et al. 2011, among others), whereas the other, cortical regions (especially the posterior ones) may be related to the persisting language processing deficits observed in the participant. What remains to be delineated is to what extent bilingual language control networks and nonlinguistic cognitive control networks are overlapping and shared in the brain (see Calabria et al. 2018, for a recent review).

To conclude, Goral, Norvik, and Jensen (2019) make an important point in not categorising all switching/mixing present in bilingual PWA as "pathological" when switching/mixing in fact aims to serve a communicative purpose (see also Grosjean 1985). While we conclude that pathological switching/mixing, defined as a language control deficit, appears to exist, we also argue that future studies should be clearer on this distinction, and, in fact, carefully analyse (and test) whether the switching patterns reflect an underlying cognitive control deficit or a communicative strategy. What is also evident from this review is that, to date, surprisingly few studies on language-switching/mixing in PWA have included systematic testing of EFs, both verbal and nonverbal, in their case reports. Testing multilingual PWA with tasks that have been used to study switching in healthy participants could also elucidate the nature of switching processes. The commonly used picture naming setup with language-switching would allow us to study switching difficulties of brain-damaged speakers in a more controlled situation, and experimental EF tasks could complement the more traditional neuropsychological testing (for such examples, see e.g. Calabria et al. 2014, Dash and Kar 2014; Grunden et al. 2020). A better understanding of cognitive control in language-switching opens up important views on language control mechanisms and the extent they overlap with domain-general cognitive control.

Notes

1 The term *aphasia* refers to language/communication impairment due to brain damage, which usually results from a stroke.

2 In this section, the papers presented and discussed are placed in alphabetical order with one exception: right after Goral, Norvik, and Jensen's (2019) study we present Lerman et al.'s (2019) study (and not Kong et al.'s), because Lerman et al. focus on one of Goral, Norvik, and Jensen's participants, providing a detailed analysis of his linguistic and cognitive performance.

3 Please note that this paper is not meant to be an exhaustive review of all reported cases of language switching and mixing in aphasia. Instead, our aim is to highlight a variety of cases which we think could contribute to the debate on pathological switching/mixing and to the relationship between domain-general EFs and language control. The vast majority of the cases covered here have been diagnosed with aphasia as a result of stroke.

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