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Language mixing patterns in a bilingual individual with non-fluent aphasia

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Background: Language mixing in bilingual speakers with aphasia has been reported in a number of research studies, but the reasons for the mixing and whether it reflects typical or atypical behaviour has been a matter of debate. **Aims:** In this study we tested the hypothesis that language mixing behaviour in bilingual aphasia reflects lexical retrieval difficulty. **Methods & procedures:** We recruited a Hebrew-English bilingual participant with mild-moderate non-fluent agrammatic aphasia and assessed his languages at three timepoints. We analysed the participant's Hebrew and English production for retrieval during single-word naming, sentences, and discourse, and identified all instances of language mixing. **Outcomes & Results:** We found that there was a greater frequency of language mixing during production of more difficult lexical items, namely the post-morbidly less proficient language (compared to the more proficient language), function words (compared to content words), and single-word naming (compared to retrieval in the context of connected speech tasks), but not for verbs (compared to nouns). **Conclusions:** In this bilingual participant with non-fluent aphasia, language mixing behaviour closely resembles lexical retrieval difficulty. Thus, we suggest that bilingual speakers with aphasia may mix their languages as a strategy to maximise communication.

Keywords: language mixing; aphasia; codemixing; codeswitching; bilingual; lexical retrieval

Introduction

In healthy speakers, language mixing is a frequent occurrence that depends on setting, topic and communication partners and is not considered a sign of language impairment (e.g., Cheng & Butler, 1989; Walters, 2005). Similarly, language mixing in healthy speakers is not considered to be reflective of difficulty with language control (Abutalebi

& Green, 2007), such as a problem inhibiting one language over another, or a problem with monitoring which language is being used at any given time (Green, 1998; Green & Wei, 2014). In bilingual speakers with aphasia, there is some debate as to how to interpret language mixing, such as whether it is a sign of an impairment to the language system or to the language control system, whether it is intentional or unintentional, and whether language mixing is used as a strategy to improve communication or not (e.g., Abutalebi, 2000; Fabbro, Skrap, & Aglioti, 2000; Perecman, 1984; Riccardi, 2012). In this study we look at the language mixing patterns of a bilingual participant with mild-moderate non-fluent agrammatic aphasia to better understand the phenomenon of language mixing and its relation to his impairment in producing words in different contexts (i.e., lexical retrieval deficits).

Mixing languages

The terms codeswitching, codemixing, and language mixing are often used interchangeably in the literature, despite subtle differences. In this paper we use the term ‘code’ to refer to a language component – ranging from individual morphemes to entire utterances (Ayeomoni, 2006). ‘Codeswitching’ is then the alternation of languages between utterances, whereas ‘codemixing’ is the alteration of languages within utterances (Ayeomoni, 2006; Paradis, 1977). We refer to ‘language mixing’ as a general term encompassing both codemixing and codeswitching (Riccardi, 2012).

Bilingual speakers often switch between languages in certain social and pragmatic situations (e.g., Cheng & Butler, 1989). Language mixing is socially motivated by the identity of the bilingual individual, and the context of use (e.g., setting, topic and participants). It is structurally and psycholinguistically motivated by both lexico-semantic features of the two languages, and difficulties in lexical access in a less proficient language (e.g., Green & Wei, 2014; Iluz-Cohen & Walters, 2012; Paplikar,

2016; Walters, 2005). Language mixing is rule-governed and requires good grammatical knowledge of two language systems (Toribio, 2001); it is not random, and is not necessarily a sign of linguistic deficit (Cheng & Butler, 1989; Grosjean, 1985; McClure, 1977; Walters, 2005). Indeed, in some societies switching is normal and expected; it is used to improve the flow of conversation and to advance social standing (Cheng & Butler, 1989; Paplikar, 2016).

Language proficiency has been suggested as a key factor affecting language mixing patterns in healthy bilingual speakers (Kroll, Bobb, Misra, & Guo, 2008; Paradis, 1997). Less language mixing is hypothesised to occur when the target language is the more proficient one because lexical items in the target language are more easily activated, or the non-target language more easily inhibited, or both, than when the target language is the less proficient language (e.g., Druks, Ayedelott, Genethliou, Jacobs, & Weekes, 2012; Druks & Weekes, 2013; Faroqi-Shah, Frymark, Mullen, & Wang, 2010; Kiran, Sandberg, Gray, Ascenso, & Kester, 2013; Riccardi, 2012).

However, mixing languages is also a phenomenon associated with the deterioration of cognitive abilities resulting from dementia (De Santi, Obler, Sabo-Abramson, & Goldberger, 1990; Friedland & Miller, 1999; Mendez, Perryman, Pontón, & Cummings, 1999) or language control deficits after stroke (e.g., Abutalebi, 2000; Fabbro et al., 2000; Perecman, 1984; Riccardi, 2012). For example, after stroke, unintentional language mixing has been estimated to be present in around 7% of cases of bilingual speakers with aphasia (Albert & Obler, 1978), although in many more cases language mixing occurs intentionally (e.g., Muñoz, Marquardt, & Copeland, 1999; Riccardi, 2012). When language mixing does not occur intentionally it often results in a breakdown of communication (Hyltenstam & Stroud, 1994).

The reasons behind post-stroke language mixing are still unclear: some assert that language mixing may be due to an impaired cognitive control mechanism in the brain, resulting in a breakdown of inhibition of the non-target language, or impaired monitoring of language use (e.g., Fabbro et al., 2000; Green & Abutalebi, 2008), while others claim that language mixing could actually be a strategy for improving word retrieval and continuing the flow of communication by retrieving the translation of the target word (e.g., Fabbro et al., 2000; Grosjean, 1985; Muñoz et al., 1999; Riccardi, 2012). This strategy could be intentional or unintentional (Muñoz et al., 1999). Furthermore, Fabbro et al. (2000) suggest that codemixing is a result of an impairment to the language system and therefore related to lexical retrieval impairment whereas codeswitching is a result of an impairment to the language control system.

These underlying reasons for language mixing are not necessarily mutually exclusive and could occur together in any given bilingual individual with aphasia. Cues such as the person with aphasia commenting “I don’t know how to say that in ‘X’ language” can help identify whether the language mixing is due to retrieval difficulties. However, sometimes it is unclear why language mixing occurs. Understanding why and under which circumstances a bilingual individual with aphasia retrieves words in the non-target language can add to our knowledge of bilingual language organisation, as well as contribute to how languages are assessed and treated after a stroke in a bilingual speaker.

Bilingual speakers with aphasia may be similar to healthy unbalanced bilingual speakers who resort to language mixing while attempting to speak in their less proficient language, in that language mixing may be related to lexical retrieval difficulty (e.g., Muñoz et al., 1999). However, in bilingual speakers with aphasia this difficulty is not stable across all words in all contexts and is affected by factors such as grammatical

class and task (e.g., Druks, 2002; Faroqi-Shah, 2012; Kavé & Goral, 2017), in addition to the relative post-morbid proficiency in each language. Language mixing patterns are therefore expected to change based on the relative retrieval difficulty for any given word, and this in turn is related to the type and severity of aphasia, and to levels of current language proficiency.

Lexical retrieval deficits and grammatical class

Lexical retrieval impairment is a language deficit common to all types of aphasia, but differential difficulty has been observed for different grammatical word classes (e.g., Druks, 2002; Faroqi-Shah, 2012). Indeed, some researchers have found that the type of aphasia a person has might be associated with a pattern of retrieval difficulty expected across different grammatical word classes, particularly for nouns and verbs. For example, difficulty in retrieving verbs relative to nouns is more common in agrammatic aphasia, whereas difficulty retrieving nouns relative to verbs is often observed in anomia (Druks, 2002; Kambanaros, 2010; Marshall, Pring, & Chiat, 1998; Raymer & Ellsworth, 2002; Thompson, Lukic, King, Mesulam, & Weintraub, 2012). This has been observed in numerous languages (Kambanaros, 2010), and even when taking into account factors such as imageability, frequency of word use, age of acquisition of each word, morphological structure, and polysemy (how many meanings a single word has) (Faroqi-Shah, 2012). Furthermore, in bilingual speakers with aphasia it has been observed that if verbs are harder to retrieve relative to nouns in one language, then the overwhelming likelihood is that they will be harder to retrieve relative to nouns in the other language too (Faroqi-Shah, 2012; Kambanaros & Vansteenberghe, 2006).

It is interesting to note, however, that difficulty retrieving verbs relative to nouns seems to have a higher incidence in bilingual aphasia than monolingual aphasia; in

monolingual speakers with aphasia the verb disadvantage relative to nouns occurs in around 75% of published cases (of 280 data sets, Mätzig, Druks, Masterson, & Vigliocco, 2009) whereas for bilingual speakers with aphasia the verb disadvantage relative to nouns is much higher - between 92.8-95% of published cases (of 21 data sets, Faroqi-Shah, 2012). While this difference could be attributed to the much smaller data set in bilingual speakers which has been published to date, there could also be a real difference. For example, Faroqi-Shah explains that generally there is less transparent mapping between a verb and its meaning than for a noun and its meaning, contributing to weaker links between verb-translations than noun-translations across languages, as well as verbs having fewer direct translation equivalents than nouns. Therefore this inferior mapping for verbs compared to nouns is magnified in bilingual speakers with aphasia in both within- and cross-language representations - which are already weakened due to the brain lesion (Druks, 2002; Faroqi-Shah, 2012; Faroqi-Shah & Waked, 2010).

Lexical retrieval deficits in single-word naming vs. retrieval in connected speech

Noun and verb retrieval in single-word naming does not necessarily reflect how a person with aphasia will retrieve similar nouns and verbs in connected speech (Kavé & Goral, 2017). Whereas some researchers found parallel patterns of retrieval in single-word naming of nouns and verbs relative to connected speech tasks (e.g., Faroqi-Shah & Waked, 2010; Williams & Canter, 1982), others have found a differential pattern, where retrieval of single-word nouns or verbs is either better or worse than the retrieval of nouns and verbs in the context of connected speech (e.g., Faroqi-Shah, 2012; Ingles, Mate-Kole, & Connolly, 1996; Kambanaros, 2010; Mayer & Murray, 2003). For example, Ingles, Mate-Kole, & Connolly (1996) found that their participant with severe fluent aphasia had reduced single-word naming abilities relative to her retrieval of

nouns and verbs in context. Furthermore, Kambanaros (2010) found that in a group of bilingual speakers with anomia, a single-word noun naming test underestimated noun production in connected speech. However, in the same study by Kambanaros, a single-word verb naming test overestimated verb production in connected speech. In other words, the bilingual speakers produced more nouns but fewer verbs in connected speech than predicted from a single-word noun or verb naming test; this was observed for both languages (Kambanaros, 2010).

Similarly, Schwartz & Hodgson (2002) found that in their participant with non-fluent aphasia, noun retrieval was better in single-word naming tasks than in connected speech; this may be due to the type of aphasia (non-fluent), in which noun retrieval is expected to be better than verb retrieval, at least for single-word naming. In non-fluent aphasia, Faroqi-Shah (2012) explains that a verb retrieval disadvantage is likely to be less prominent in narrative production than in single-word naming, because when telling a narrative there is a flexibility regarding naming verbs that are easier to retrieve – which is not possible in a closed task such as picture naming. Also, differences in imageability that exist between nouns and verbs are reduced in connected speech relative to single-word naming tasks (Faroqi-Shah, 2012).

Nevertheless, other studies observed that retrieval of verbs is better in single-word naming than in connected speech tasks for non-fluent aphasia (e.g., Wilshire & McCarthy, 2002) and retrieval of nouns is better in single-word naming than in connected speech tasks for anomia (e.g., Manning & Warrington, 1996). However, it is unclear if this last participant really did have anomia, as the description given in the article suggests non-fluent aphasia.

In connected speech, a further distinction can be made between content-word retrieval and function-word retrieval. In non-fluent, agrammatic aphasia there is a

salient difficulty in producing certain syntactic structures, resulting in the omission or misuse of many function words (Menn, Obler, Miceli, & O'Connor, 1989), especially pronouns, prepositions and subordinate conjunctions (Friedmann, 2001). Other function words may be relatively spared, such as coordination conjunctions, some forms of negations and determiners (Friedmann, 2001). This contrasts with fluent aphasia, where function words are relatively spared. Little is known about the distribution of language mixing across word types in fluent and non-fluent bilingual aphasia.

In summary, factors such as retrieving particular grammatical classes relative to others, and retrieval in single-word naming *vs.* during connected speech will likely affect retrieval patterns in bilingual speakers with aphasia. Additionally, relative proficiency in each language may influence retrieval success. Therefore, we ask to what extent language mixing behaviour in bilingual aphasia may reflect lexical retrieval difficulty. Moreover, we ask whether the observed patterns of language mixing in a bilingual individual with aphasia are similar in both languages.

In this study, we examined language mixing patterns in a bilingual participant with mild-moderate non-fluent agrammatic aphasia. We hypothesised that the direction of language mixing would be influenced by relative post-morbid proficiency, and therefore more language mixing would be observed in the post-morbidly less proficient language than in the post-morbidly more proficient language. Additionally, we hypothesised that more language mixing would occur with verb retrieval than with noun retrieval, because verbs are expected to be harder to produce than nouns in non-fluent aphasia. Similarly, we hypothesised that more language mixing would occur with function words than with content words, because many function words are hard to produce in non-fluent agrammatic aphasia.

Regarding language mixing patterns for retrieval in single-word naming *vs.* connected speech, we have no specific hypothesis, as there seem to be two possibilities: (1) language mixing patterns will be similar across tasks (Faroqi-Shah & Waked, 2010; Williams & Canter, 1982) and (2) more language mixing will occur in single-word naming than in connected speech, due to the flexibility and support that connected speech provides that single-word naming does not, resulting in easier retrieval for nouns and verbs in connected speech than in single-word naming (e.g., Faroqi-Shah, 2012; Ingles et al., 1996; Kambanaros, 2010; Mayer & Murray, 2003; Schwartz & Hodgson, 2002). This is due to the flexibility and support that connected speech provides that single-word naming does not, which is particularly salient in the more difficult grammatical class retrieval for any given participant.

Method

We report here data from a bilingual participant with aphasia who was enrolled in a single-subject design research study. The study was approved by the ethic committee at the City University of New York (Institutional Review Board), and the participant gave written consent to take part in the study.

The participant was a 71-year-old native speaker of Hebrew who started to learn English in late childhood (from age 11). In 2009, he sustained a stroke resulting in an extensive left hemisphere frontal-parietal lesion. He has non-fluent aphasia that is characterised by anomia, agrammatism and frequent language mixing. Pre-morbidly, he was highly proficient in both languages, but Hebrew was reportedly his better language. He mixed languages frequently at home with his bilingual family but used English only at work without mixing languages. Post-morbidly, his proficiency followed the same pattern as his pre-morbid proficiency, in that Hebrew was better spared than English.

The participant reported that impairments were more pronounced in English than in Hebrew, and this was confirmed by the Western Aphasia Battery-Revised (WAB-R) (Kertesz, 2006) which was administered in English, and also in an adapted (but not standardised) Hebrew version. In English, the participant received an Aphasia Quotient of 67.1 (moderate aphasia). In Hebrew, he received an Aphasia Quotient of 80.5 (mild aphasia). His non-linguistic cognitive abilities showed a mild deficit for Visuospatial skills, Attention, and Clock Drawing, and a mild-moderate deficit for Executive Functions based on the non-linguistic subtests of the Cognitive Linguistic Quick Test (CLQT, Helm-Estabrooks, 2001). See table 1 for details of the participant's linguistic and non-linguistic abilities, based on the WAB-R (Kertesz, 2006) and the CLQT (Helm-Estabrooks, 2001).

(Table 1 about here)

Hebrew and English language abilities were tested using the Goral and Borodkin Multilingual Aphasia Protocol (unpublished), which includes two single-word naming tasks, two sentence-level tasks, and two connected speech (discourse) tasks in each language:

- (1) Single-word naming of nouns – a subset of 30 pictures of objects from the *Multilingual Naming Test* (MINT) (Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012) was presented to the participant, one at a time, and he was asked to name them. All items had one translation equivalent across Hebrew and English and were comparable for frequency but not for length (words in Hebrew are longer on average than words in English). No cognates were used.
- (2) Single-word naming of verbs - a subset of 27 pictures of actions from the *Action Naming Test* which is a subtest of the *Verb and Sentence Test* (VAST) (Bastiaanse, Edwards, & Rispens, 2002) were presented to the participant and he

was asked to name them. All items had one translation equivalent across Hebrew and English and were comparable for frequency but not for length. No cognates were used.

- (3) Sentence construction - a subset of 21 pictures taken from the *Object and Action Naming Battery* (OANB) (Druks & Masterson, 2000) were presented to the participants and he was asked to generate a sentence describing each picture. Although this was originally a single-word naming test, only pictures with a clear agent and patient were used to be appropriate as a test of sentence construction. All verbs in this task had one translation equivalent across Hebrew and English and were comparable for frequency but not for length. No cognates were used for either the verbs or the objects in the pictures.
- (4) Sentence production as a response to an everyday WH-question – the participant was asked to respond with one full sentence to 18 WH-questions. For example, “What do you do to keep in shape?”, “What do you like to do on a rainy day”, “What does your family do to celebrate the New Year?” etc.
- (5) Discourse based on a sequence of four pictures– a subset of story sequences from the *Narrative Story Cards* (Helm-Estabrooks & Nicholas, 2003) was used. The participant was asked to look at the pictures and tell the story they depict.
- (6) Discourse in response to a request for a personal story about a given topic (narratives). The participant was asked to talk for a few minutes responding to prompts such as, “Where were you on 9/11?”, “Tell me about a recent vacation”, etc.

For the tasks that used picture stimuli (action naming, object naming, sentence construction, story sequences), the picture stimuli appeared on a computer screen and remained until the participant responded. Eprime 2.0 software (Schneider & Zuccoloto,

2007) was used to display the stimulus items in a random order. After a response was made, the examiner pressed a key to present the next item. For the WH-question based sentence production and for the personal narrative production tasks, the examiner verbally presented the question or the topic, ensuring that the participant understood the type of response required (1-sentence response or a longer response). In the personal narrative task, general prompts were used to elicit further production (e.g., “anything else?”) when needed.

Testing was administered by speech language pathologists (SLPs) or SLP students, native or highly proficient speakers of both languages. Each language was tested separately. These different language sessions were conducted on the same days but counterbalanced for order of language tested. Although those administering the tests were all Hebrew-English bilingual speakers, in the Hebrew sessions the tester spoke and responded only in Hebrew, and in the English sessions the tester spoke and responded only in English. The six tasks were administered at three different timepoints over the course of 18 months. At each testing time the complete battery was administered over 3-4 days, with 1/3 of the testing battery in each language administered each day.

All testing sessions were video recorded with permission from the participant, and the data were transcribed after each session, with a research assistant checking the transcriptions for reliability. Following this, the data from the six tasks were analysed, with point-by-point inter-rater reliability (IRR) performed on 1/3 of the data, by two raters who were blinded to each other’s scoring. IRR for scoring was above 90% agreement for all tasks; IRR was also calculated using Krippendorff’s Alpha coefficients (Hayes & Krippendorff, 2007) and was found to be high, $\alpha=0.82$.

We counted all words produced, including repetitions, self-corrections (whole words only), semantic paraphasias and phonemic paraphasias regardless of language.

Then, all language-mixed words were counted, for each task separately.¹ The data was collapsed across the three testing times to increase the sample size. We used the following criteria to analyse the data and to determine language mixing:

- All content words and all function words were counted separately. In Hebrew, this meant that bound function words were counted separately to the content words that they were bound to (e.g., *beYarden* ['in Jordan'] = *be* (1) *Yarden* (1) = 2 words – 1 function word and 1 content word).
- Content words included nouns, verbs and adjectives. All other words were considered function words. These included adverbs (which the participant rarely produced), conjunctions, prepositions, determiners, pronouns, auxiliary verbs and discourse markers. Discourse markers were considered to be verbal output used to direct the flow of a conversation but that were syntactically detachable and did not add any significant meaning, based on the definition of Neumann, Walters, & Altman (2017).

¹ The only exception to this was the use of the word *'ve* ['and' in Hebrew] when the target language was English. The participant used this word very frequently during the connected speech tasks, in the context of a filler, probably to indicate to the listener that he had more to say. This disproportionately inflated the relationship between language-mixed and non-language-mixed words when the target language was English. This was not the case when the target language was Hebrew; then the word *'ve* was used more appropriately, often as a conjunction. Therefore, *'ve* was removed from the analysis when the target language was English but not when the target language was Hebrew.

- Most of his language mixing was codemixing rather than codeswitching. Therefore, all words were calculated individually, except for set phrases such as “thank you”, names of places, or songs, which were counted as 1 unit.
- Borrowed words were not counted as language mixing, but cognates were, e.g., ‘*kibbutz*’ was not counted as language mixing when English was the target language, but ‘*televizia*’ [‘television’ in Hebrew] was counted as language mixing when English was the target language.
- Names were not counted as language mixing unless two forms of the name were used in the same task on the same day, e.g., ‘*Jordan*’ and ‘*Yarden*’ [‘Jordan’ in Hebrew] used in the same narrative.
- Words that were ambiguous as to which grammatical class they belonged to (namely, nouns or verbs, when produced as single words in some contexts) were scored as follows: Any linguistic marker indicating that the word was intended as a noun or a verb allowed for the word to be scored as such. Words with no marker (e.g., “exercise” in response to the question “What do you do to keep in shape?”), were scored as a noun, unless the word was produced in the same form in another context during the testing session where it was clearly intended as a verb (e.g., “I exercise every day”).

Statistical analyses were conducted on the data using two simultaneous logistic regressions. The first regression determined the contribution of target language (Hebrew vs. English), grammatical class (nouns vs. verbs), and type of task (single-word naming vs. connected speech) to language mixing. A second regression determined the contribution of target language (Hebrew vs. English), and a different grammatical class distinction (content vs. function words) to language mixing.

Results

A frequency table for target language (Hebrew *vs.* English), grammatical class (nouns *vs.* verbs) and type of task (the two single-word naming tasks *vs.* the two connected speech tasks) is presented in table 2.

(Table 2 about here)

A simultaneous logistic regression with target language (Hebrew *vs.* English), grammatical class (nouns *vs.* verbs), and type of task (single words *vs.* connected speech) as predictors of language mixing yielded an overall significant result, $\chi^2(3, N = 2824) = 68.99, p < .001$, Nagelkerke's $R^2 = .06$. As Table 3 indicates, target language and type of task, but not grammatical class, significantly predicted language mixing, such that language mixing was three times more likely to occur when the less proficient English was the target language than when the more proficient Hebrew was the target language. Language mixing was also two times more likely to occur in single-word naming tasks than in connected speech.

(Table 3 about here)

We also explored whether another grammatical class distinction, namely between content and function words, predicted language mixing. Since function words were not elicited in the single-word naming task that we used, this analysis was restricted to connected speech tasks only.

A frequency table for target language (Hebrew *vs.* English) and grammatical class (content words *vs.* function words) is presented in table 4. When the target language was the post-morbidly less proficient language (English), 42% of the language-mixed function words comprised of those function words known to be difficult for people with agrammatic aphasia: pronouns and prepositions (there were no subordinate conjunctions in the data set) (e.g., Friedmann, 2001; Menn et al., 1989). When the target language was the post-morbidly more proficient language (Hebrew),

32% of language mixing in function words occurred when retrieving these types of function words.

(Table 4 about here)

Language mixing was regressed onto target language (Hebrew *vs.* English) and grammatical class (content words *vs.* function words) using simultaneous logistic regression. The analysis yielded an overall significant result, $\chi^2(2, N = 5171) = 209.28$, $p < .001$, Nagelkerke's $R^2 = .09$. In this model, language mixing was almost 5 times more likely to occur when the less proficient English was the target language than when the more proficient Hebrew was the target language and 1.37 times more likely to occur for function word than content words (see Table 5).

(Table 5 about here).

Discussion

We analysed the language mixing patterns of a Hebrew-English bilingual participant with mild-moderate non-fluent aphasia with the aim of testing the hypothesis that language mixing behaviour in bilingual aphasia reflects lexical retrieval difficulty. We predicted greater frequency of language mixing during production of more difficult lexical items, namely: the post-morbidly less proficient language (compared to the more proficient language), verbs (compared to nouns), function words (compared to content words), and single-word naming (compared to retrieval in the context of connected speech tasks). We found support for three of these predictions: there was a greater frequency of mixing when the target language was the post-morbidly less proficient English, of function words (compared to content words), and of single-word noun and verb retrieval (compared to retrieval in connected speech). We found no significant contribution of verb retrieval *vs.* noun retrieval in predicting language mixing.

Our first hypothesis predicted that the direction of language mixing would be influenced by relative post-morbid proficiency, and we indeed found that significantly more language mixing occurred when the target language was the less proficient English than when it was the more proficient Hebrew. We interpret the participant's asymmetric pattern of mixing the two languages as an index of lexical retrieval difficulty – language retrieval is easier for this participant in Hebrew, so he switches into Hebrew more than he switches into English. These results support the reports in the literature that healthy, unbalanced bilingual speakers often mix into their more proficient language (e.g., Ayeomoni, 2006; Druks et al., 2012; Druks & Weekes, 2013; Faroqi-Shah et al., 2010; Kiran et al., 2013; Riccardi, 2012) as do unbalanced bilingual speakers with aphasia (Muñoz, Marquardt, & Copeland, 1999).

Our second hypothesis predicted that our participant with non-fluent aphasia would exhibit more language mixing of verbs than of nouns because verbs are harder to retrieve in non-fluent aphasia (e.g., Druks, 2002; Marshall et al., 1998; Raymer & Ellsworth, 2002; Thompson et al., 2012). This prediction was not supported by our results. We interpret this finding thus: numerically our participant produced less verbs than nouns, but this difference was most obvious in his less proficient English (overall when the target language was English, 99 nouns and 55 verbs were produced in Hebrew; when the target language was Hebrew, 57 nouns and 10 verbs were produced in English). Even though this provides some support to our premise that the participant would have more difficulty retrieving verbs than nouns, it is possible that great difficulty in retrieving verbs would result in no retrieval at all, whether in the target or the non-target language, thereby reducing the expected language mixing. Indeed, the participant almost never retrieves verbs in his less proficient English when the target language is his more proficient Hebrew – across all tasks, in only ten instances does the

participant mix languages during verb retrieval (out of 489 cases of verb retrieval overall). We suggest that future research should focus on language mixing in nouns and verbs in participants with different types of aphasia – especially comparing non-fluent aphasia with anomic aphasia – and with varying degrees of severity. This would identify whether differences in the frequency of switching occur in participants with more difficulty producing verbs (non-fluent aphasia) or more difficulty producing nouns (anomic aphasia) (Druks, 2002; Kambanaros, 2010; Marshall et al., 1998; Raymer & Ellsworth, 2002; Thompson et al., 2012), as well as identify whether the level of retrieval difficulty overall (rather than one grammatical class compared to the other) is a factor in how language mixing occurs.

Our third hypothesis predicted that more language mixing would occur with function words than with content words, because certain function words, such as pronouns and prepositions, are difficult to produce in non-fluent agrammatic aphasia (e.g., Friedmann, 2001; Menn et al., 1989). This prediction was supported by our results, suggesting that our participant's difficulty retrieving these types of function words is reflected in his patterns of language mixing in both languages.

We also predicted that a comparison of language mixing during single-word naming *vs.* retrieval in connected speech would follow one of two patterns. Either the patterns would be comparable (e.g., Faroqi-Shah & Waked, 2010; Williams & Canter, 1982), or more language mixing would occur in single-word naming than in connected speech, due to the flexibility and support that connected speech provides that single-word naming does not, resulting in easier retrieval for nouns and verbs in connected speech than in single-word naming (e.g., Faroqi-Shah, 2012; Ingles, Mate-Kole, & Connolly, 1996; Kambanaros, 2010; Mayer & Murray, 2003; Schwartz & Hodgson,

2002). We observed the second pattern: more language mixing of nouns and verbs occurred in single-word naming than during connected speech tasks.

Our results show, therefore, that connected speech tasks may pose fewer content word retrieval challenges for this participant than single-naming tasks. This finding is consistent with previous reports in the literature (e.g., Faroqi-Shah, 2012; Ingles et al., 1996), and may reflect the freedom to avoid the production of words that are difficult to retrieve, afforded in discourse (but not in picture naming). It is important to note, however, that the ability to retrieve words in connected speech tasks is considered to be generally more complex than lexical retrieval of single words, because it involves other linguistic factors such as semantic, phonological, syntactic and morphosyntactic abilities, as well as non-linguistic factors such as advanced planning, working memory, and communication goals (Kavé & Goral, 2017).

Overall our data indicate that for this bilingual participant with non-fluent agrammatic aphasia, a portion of his language mixing can be explained by retrieval difficulty and can be construed as a strategy (intentional or unintentional) to improve communication by producing words in the non-target language when retrieval breaks down in the target language. This interpretation is supported by verbal indications that the participant produced, reporting that he was having trouble retrieving a word in one language, and subsequently retrieving it in the other, which occurred 18 times when the target language was English (and once when the target language was Hebrew). Furthermore, this interpretation is supported by the fact that the majority of the participant's language mixing was codemixing (the alteration of languages within utterances) rather than codeswitching (the alternation of languages between utterances), indicating that the impairment may have been in the participant's language system (e.g., Fabbro et al., 2000; Grosjean, 1985; Muñoz et al., 1999) rather than in the control

system (e.g., Fabbro et al., 2000; Perecman, 1984) and consequently related to lexical retrieval impairment.

In many cases (including our participant) a stroke affects the brain networks associated with both systems and so language mixing in these bilingual patients may have multiple sources. Differences between linguistic categories, such as the distinction between content and function words, as we have seen in this case study, can be viewed as index of lexical retrieval difficulty (i.e., damage in the language system). However, more language mixing in the less proficient language could be an index of both: easier lexical access to words in the more proficient language or difficulty controlling the relative activation and inhibition of the target and non-target language, respectively, resulting in “intrusions” from the more proficient and thus more activated language. Similarly, differences in language mixing during single-word naming as opposed to during connected speech could also be an index of both sources, because of the complexity involved in the connected speech tasks. So, while retrieval difficulty is most likely part of the underlying reason for language mixing in this participant, it is probably not the only driving force behind it. We do not have sufficient evidence to argue conclusively, and we suggest that future studies investigating language mixing in bilingual aphasia focus on the role of impairments to the control system using cognitive assessments that focus on control (e.g., Green et al., 2010) as well as to the influence of relative lexical retrieval impairment.

There are a number of limitations to this study, that may have affected the results observed. First, while languages were separated during testing by having two separate sessions administered by two different testers, one per language, all testers were bilingual Hebrew-English speakers and the participant was aware of this, as is the case in other studies that looked at mixing (e.g., Fabbro et al., 2000). It is unclear how

this knowledge might have affected our participant's language mixing. If language mixing can reduce breakdown in communication, it is possible that bilingual individuals with aphasia are more successful when communicating with bilingual interlocutors than with monolingual ones, although one study that examined this hypothesis did not find support (Paplikar, 2016). Additional research is warranted.

Second, due to the participant's non-fluent aphasia, it was sometimes difficult to identify whether a single word uttered during a task in English was intended as a noun or as a verb, as explained in the method. This is a known problem in the literature when researching participants with non-fluent aphasia (Rochon et al., 2000). We tried to be as consistent as possible in the way we scored our participant's utterances, as we indicated in our scoring system, but this may have affected our results.

Third, because this is a case study, it is not possible to generalise these results to all participants with aphasia. However, we can see from the few reported cases of language mixing in bilingual speakers with aphasia that patterns are emerging regarding proficiency (e.g., Muñoz et al., 1999), and we add to this the content-function word, and single-word-connected speech distinctions found here. These factors, along with further investigation of noun-verb distinctions as specified above, will be interesting to study in other participants with different aphasia characteristics and with different brain lesions (with varying amounts of presumed damage to the cognitive control mechanisms).

In conclusion, our results add to the bilingual aphasia literature and show that for this participant, more language mixing occurred in the post-morbidly less proficient language and in a grammatical category that is more difficult for him (in our case more mixing of Hebrew when the target language was English, and more mixing of function words than content words – especially those function words known to be difficult for people with agrammatic aphasia). Additionally, more language mixing occurred in

single-word naming than in the context of connected speech. Thus, our study has shown that in this bilingual participant with non-fluent aphasia, language mixing behaviour closely resembles lexical retrieval difficulty. Even though retrieval difficulty of specific words can limit the benefit of language mixing - as may have been seen for example by the non-significant difference between language mixing of nouns and verbs, bilingual speakers with aphasia might mix their languages as a strategy to maximise their communication. If indeed bilingual speakers with aphasia use switching to minimise communication breakdown, it is possible that language mixing could be employed as an intervention strategy. This could be a fruitful direction for future studies.

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Disclosure of interest

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Type of file: table

Label: Table 1

Filename: aph-pa 18-211-File002.docx

Table 1: Linguistic and non-linguistic abilities of the participant, based on the WAB-R (Kertesz, 2006) and the CLQT (Helm-Estabrooks, 2001)

Task [max score]	WAB-R English	WAB-R Hebrew	CLQT (Avg)
Spontaneous speech score [20]	12	13	-
Auditory Verbal Comprehension Score for AQ [10]	8.45	9.25	-
Repetition Score [10]	8.0	9.8	-
Naming and Word Finding Score [10]	5.1	8.2	-
TOTAL: [50]	33.55	40.25	-
Aphasia Quotient (TOTAL * 2) [100]	67.1	80.5	-
Symbol Cancellation [12]	-	-	8
Clock Drawing [13]	-	-	11.33
Symbol Trails [10]	-	-	6.33
Design Memory [6]	-	-	5.33
Mazes [8]	-	-	4.33
Design Generation [13]	-	-	6.33

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Label: Table 2

Filename: aph-pa 18-211-File003.docx

Table 2: Frequency table for target language (Hebrew vs. English), grammatical class (nouns vs. verbs) and type of task (the two single-word naming tasks vs. the two connected speech tasks)

	<i>Language-mixed</i>		<i>Non-language-mixed</i>	
	Frequency	Percent	Frequency	Percent
<i>Target Language</i>				
Hebrew	67	30.3	1474	56.6
English	154	69.7	1129	43.4
Total	221	100	2603	100
<i>Grammatical class</i>				
Nouns	156	70.6	1805	69.3
Verbs	65	29.4	798	30.7
Total	221	100	2603	100
<i>Type of task</i>				
Single-word naming (two tasks – object and action naming)	33	14.9	206	7.9
Connected speech (two discourse tasks)	188	85.1	2397	92.1
Total	221	100	2603	100

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Label: Table 3

Filename: aph-pa 18-211-File004.docx

Table 3: Regression Results for Target Language, Grammatical Class and Type of Task as Predictors of Language Mixing.

	<i>B (SE)</i>	Wald	<i>df</i>	<i>p</i> -value	OR	95% CI for OR	
						Lower	Upper
Constant	-3.16 (.14)						
Target language ^a	1.11 (.15)	52.87	1	< .001	3.02	2.24	4.07
Grammatical class ^b	-0.05 (.16)	0.09	1	.77	0.96	.70	1.30
Type of task ^c	0.74 (.21)	13.02	1	< .001	2.10	1.40	3.14

Note. CI = confidence interval; OR = odds ratio

^aHebrew = 0

^bNouns = 0

^cConnected speech = 0

Type of file: table

Label: Table 4

Filename: aph-pa 18-211-File005.docx

Table 4: Frequency table for target language (Hebrew vs. English) and grammatical class
(content words vs. function words)

	<i>Language-mixed</i>		<i>Non-language-mixed</i>	
	Frequency	Percent	Frequency	Percent
<i>Target Language</i>				
Hebrew	102	24.8	2882	60.6
English	310	75.2	1877	39.4
Total	412	100	4759	100
<i>Grammatical class</i>				
Content words	210	51.0	2630	55.3
Function words	202	49.0	2129	44.7
Total	412	100	4759	100

Type of file: table

Label: Table 5

Filename: aph-pa 18-211-File006.docx

Table 5: Regression Results for Target Language and Grammatical Class within Connected Speech Tasks as Predictors of Language Mixing.

	<i>B (SE)</i>	Wald	<i>df</i>	<i>p</i> -value	OR	95% CI for OR	
						Lower	Upper
Constant	-3.51 (.12)						
Target language ^a	1.57 (.12)	175.50	1	< .001	4.81	3.81	8.07
Grammatical class ^b	0.31 (.11)	8.80	1	.003	1.37	1.11	1.68

Note. CI = confidence interval; OR = odds ratio

^aHebrew = 0

^bContent words = 0