LANGUAGE PROCESSING IN BILINGUAL APHASIA: A NEW INSIGHT INTO THE PROBLEM**First author: Full name and affiliation; plus email address if corresponding author**

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Abstract

There is increasing evidence that a bilingual person should not be considered as two monolinguals in a single body, a view that has gradually been adopted in the diagnosis and treatment of bilingual aphasia. However, its investigation is complicated due to the large variety in possible language combinations, pre- and post-morbid language proficiencies, and age of second language acquisition. Furthermore, the tests and tasks used to assess linguistic capabilities differ in almost every study, hindering a direct comparison of their outcomes. Behavioral, electrophysiological and neuroimaging data from healthy population shows that the processing of second language domains (semantics, syntax, morphology) depends on factors such as age and method of acquisition, proficiency level and environment in which the second language was acquired. A number of single and multiple case reports that rely on behavioral testing of bilingual aphasics replicate these results. Additionally, they show

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that the patient's performance depends on the size and location of the lesion, as well as language typology and morphological characteristics. Furthermore, the impairment and recovery patterns and recovery generalization from treated to untreated language depend on the lexical and orthographic distances between the two languages. For healthy bilinguals, language processing is usually studied in comparison to monolinguals. We advocate that a good starting point for identifying patterns specific for bilingual aphasia is to compare patient studies of bilinguals and monolinguals.

According to the most common definition, a person who uses two or more languages on a daily basis¹ is considered bilingual. Currently, more than 50% of the global population is considered bilingual (for a debate on its definition, especially from an educational viewpoint, see Francon²). As suggested by Grosjean³, it would be wrong to consider a bilingual person as two monolinguals in a single body, which also stands true for the diagnosis and treatment of bilingual patients. However, studies on the bi- or multilingual brain are still scarce. This is even more so when it comes to bilingual patients with cognitive disorders in particular aphasia and other types of comprehension deficits. A possible reason for this is the lack of standardized tests, partly due to the large variety in language combinations, the variability between patients and lesion locations. Among the factors that contribute to this variability, which apply to both healthy subjects and aphasia patients, are differences in age of second language acquisition, language dominance, frequency of language switching and the frequency of language use on a daily basis. For patients, the issue is even more complicated as it is not easy to establish and align pre-morbid language proficiency in their second or even third language.

Most research publications on bilingual aphasia are single⁴⁻⁶ or multiple case^{7,8} reports. Studies that include relatively large populations (more than 10 patients) are scarce. Additionally, a significant number of the studies that include bilingual aphasics focus on neurophysiological and neuroanatomical patterns in the bilingual brain, yet the nature of impairment patterns per se and the mechanisms behind them are still inconclusive. For an overview of studies with comparably large numbers of bilingual aphasics treated as one group, rather than as multiple individual cases, see [table 1](#).

Insert Table 1.

In this paper, we will review the studies discussing bilingual aphasia from the viewpoint of the symptoms specific for it, the likely mechanisms of their development and their dependency on the factors crucial for bilinguals in general, such as pre-morbid proficiency level, age and method of second language acquisition (intrinsic vs. extrinsic). We will discuss the similarities and differences of the processing of each language domain with the ones in monolingual aphasia as well as, in some cases, healthy bilinguals, and indicate gaps and new directions for studying bilingual aphasia. As a number of publications already reviewed recovery patterns in bilingual aphasia^{9,10}, we will address them only when they shed light on the patterns of impairment and the mechanisms behind the development of aphasia in bilinguals.

APHASIA: CHARACTERISTICS SPECIFIC FOR BILINGUAL APHASIA

According to the definition provided by National Aphasia Association (NAA - NIH), aphasia is an impairment of language caused by brain injury, affecting the production and/or comprehension of written and/or spoken language. In the case of aphasia (any type), the motor and sensory networks that are involved in speech production and comprehension (articulatory muscles and auditory/visual system) are usually unimpaired. Aphasia is most frequently caused by stroke (National Aphasia Association <http://www.aphasia.org>). Up to 35% of survivor stroke patients suffer from aphasia^{11,12}. Other noteworthy causes are traumatic brain injury, brain tumor and infection.

Several classifications for aphasia are in use. The most general and most used one (Boston Aphasia Classification), which does not distinguish between patient's mono- or bilingual abilities and is based mainly on the clinical manifestations in each language, classifies aphasia as fluent (sensory), non-fluent (motor), global, conduction, trans-cortical (sensory, motor or mixed) and anomic (amnesic). Clinical manifestations and lesion localizations for each mentioned type are presented in [table 2](#).

Insert Table 2.

The vast majority of studies on aphasia involve the patient's mother tongue¹³ and assume that the patient is monolingual. However, as the majority of the world's population is bilingual, when considering patients from that population, it is doubtful to assume that there would be no interference from the other language.

As mentioned previously, a number of factors have been reported that influence the patterns of impairment and recovery of bilingual aphasics. Some of them, such as age of acquisition, proficiency level and method and sequence of acquisition, also define the type of bilingualism of healthy subjects. For instance, bilinguals are distinguished into early and late (based on age of acquisition), balanced and dominant (proficiency level), simultaneous, sequential and compound (order of acquisition), intrinsic and extrinsic (method of acquisition – informal in social contacts or formal in classroom settings). In most cases, the first acquired language dominates: one is usually more proficient in the first acquired language – the mother tongue (L1) – than in a second language (L2). However, in some cases, when the subject emigrates to another country and relies on the language of that country, L2 will dominate¹⁴, at least based on self-reporting. In that situation, the issue of aphasia and the choice of rehabilitation language become especially striking, as self-reporting data is not always reliable and on the other hand, one cannot automatically assume that L1 is the dominant language.

The diagnosis of aphasia in bilingual patients starts with the observation and examination of the general symptoms of aphasia, also applicable to monolinguals, and the ones specific for bilingual aphasics. Among the most specific symptoms for bilingual aphasia we note pathological mixing¹⁵ – using both languages during a single utterance, pathological switching¹⁶ –changing the language from one utterance to another, and translation disorders¹⁷. Among translation disorders, the following can be observed:

- inability to translate – although the patient can respond in each language, he/she is not able to translate from one language into another,
- spontaneous translation – unsolicited translation of written or spoken language without being able to translate on request,
- paradoxical translation¹⁸ – the patient can express him/herself in one language and translate into another, and

- translation without comprehension – the patient is unable to understand speech addressed to him/her but spontaneously translates it.

It is believed that both translation and language switching (also termed as code-switch) are automatic processes that, in the case of brain lesion, are disinhibited and thus cannot be controlled by the patient. This claim is also supported by the fact that an impairment of the frontal regions (prefrontal cortex), which are responsible for cognitive control, can cause pathological switching¹⁶. As we will further see, impairment in cognitive control also plays a significant role in the development of some of the impairment patterns of bilingual aphasia (i.e., differential, selective)¹⁹.

For a further, more detailed evaluation of aphasia in a bilingual patient, besides standard aphasia tests (e.g. Aachen Aphasia Test – AAT) for monolinguals, applied to each of the bilingual's languages, special tests and questionnaires are used, such as the popular and widely translated bilingual aphasia test (BAT)²⁰. Parts 1 and 3 of this test are used for assessing the translation capabilities and other characteristics of a bilingual suffering from aphasia. Among these characteristics are pre-stroke language proficiency, age and history of acquisition of each language, and the frequency and pattern of use before and after the incident.

Given the impairment pattern, bilingual aphasia can be classified as parallel, differential and selective. In most cases both languages are impaired²¹ (parallel aphasia) but there are reports where one or more languages were preserved after the incident (selective aphasia)²² or where one language was more impaired than the other (differential aphasia)²³. Similarly, Paradis described six recovery patterns⁹: parallel, differential, selective, successive (one language starts to improve only after the other is fully recovered), antagonistic (one of the languages is better preserved than the other, but when the more impaired language starts to improve, the patient's ability to communicate in the other language diminishes), and alternative antagonistic or blended, (during recovery two languages mix and blend uncontrollably)¹⁶. Interestingly, in some cases the choice of preserved language (L1 or L2) depends on the localization of the lesion, e.g., subcortical lesions more often lead to an impairment of L1 rather than L2²⁴.

In order to understand the psycholinguistic mechanisms behind the development of particular symptom in bilinguals suffering from aphasia, we will discuss the impairments that have been observed in each language domain (semantics, syntax and morphology) in these patients. However, before that, it is instructive to first glance at the models of language representation (mostly semantics and syntax) in an unimpaired bilingual brain.

MODELS ON LEXICO-SEMANTIC AND SYNTACTIC PROCESSING IN HEALTHY BILINGUALS

Recent evidence from behavioral, neuroimaging and electrophysiological studies seem to support the hypothesis of a non-selective lexical access to the bilingual lexicon²⁵. According to this model, lexical access is not specific for one language and does not depend on language context: when the bilingual sees a word in one language, he/she automatically activates its translation and all related items in both languages. Afterwards, during lexical selection, words from the non-target language are demoted by means of competition and active inhibition. Additionally, a number of neuroimaging studies^{26,27} revealed that the majority of bilinguals have both shared and separated brain regions for processing both languages²⁸.

Contrary to processing of semantics and its neural representation, data collected from healthy bilinguals on syntax processing^{29,30} is more ambiguous. There are two main models of syntax processing in the bilingual brain. The declarative/procedural model claims that both proficiency level and age of acquisition play a significant role

in determining which brain regions would be responsible for syntax processing of a particular language (for a detailed review on this model, see Ullman³¹). According to this model, the processing of L1 syntax takes place in procedural memory (thus more subcortical), whereas syntactic structures of L2 are located in declarative memory (thus more cortical) as processing of L2 syntax is more rule-based. Therefore, despite equally high proficiency levels, bilinguals who obtained their L2 later in life would process syntax differently from those that obtained it during early childhood (before the so-called critical age). This model is mostly based on the previously mentioned observation of impairment patterns where subcortical lesions led more often to an impairment of L1 rather than L2²⁴.

In contrast, according to the integrative model³⁰, syntactic structures of both languages are shared and represented in the same brain areas. This model was mainly developed from and supported by cross-lingual syntactic priming studies on healthy population and patients with aphasia^{32,33}.

Independent of the studied model, it is important to note that syntactic structure can differ strikingly between languages. Hence, if a patient performs worse or better on a syntactic task in one language compared to the other, this might be because it was his/her first (early acquired) or second (formally learnt) language, or because of the existing distinctions between syntactic structures of those languages (e.g., 'free' versus 'fixed' word order). At the same time, when evaluating types of syntactic errors, one should be aware of the likelihood of those errors in that particular language.

As described above, a number of clinical manifestations of aphasia, such as comprehension- and/or production deficit and agrammatism (inability to comprehend and/or produce correct grammatical structures) are common to both mono- and bilingual aphasia and for the latter they apply to both languages. When investigating the said symptoms in both languages in bilingual aphasics, we can compare his/her performance in those languages, and investigate their interaction including the possible interference of one language into the processing of the other. The differential impairment in each language domain leads to a wide range of clinical manifestations of aphasia ([table 3](#)). In order to understand the mechanisms underlying these manifestations, in the next sections we will discuss the impairment in each of mentioned domains on single word- and sentence- level, clinical manifestations caused by these impairments and the factors influencing the performance in these domains.

Insert Table 3.

SINGLE WORD PROCESSING IN BILINGUAL APHASIA

Lexico-semantic processing

Lexical access is an important part of single word processing. Its impairment is often manifested by **word-finding** difficulties in both production and comprehension. This leads to poor performance in tasks such as word-picture matching, word-word or picture-picture matching (semantic priming) in comprehension. In production, word-finding difficulty often leads to paraphasias (semantic, phonological), circumlocutions, perseverations- and word omissions during conversation or spontaneous speech, as well as a delay or errors during picture naming task. The interference of the other language, which is observed in bilinguals, additionally causes a "wrong language" error as well as an impairment in cognate/homograph production and comprehension. For a detailed investigation of this problem in comprehension we refer to Siyambalapitiya et al.⁴. They studied a 70-year-old Italian-English (pre-morbidly L1 dominant) late chronic (2 years post-onset) non-

fluent aphasic with a test on within- and cross-language semantic, cognate¹ and non-cognate repetition priming. Her comprehension was mildly-to-moderately impaired in her L1 (Italian – mother tongue) and moderately impaired in her L2 (English – later acquired language). In healthy controls, during semantic priming, word processing is facilitated (i.e., a shorter reaction time in a button-press task) when preceded by a related word³⁴. The authors observed an at least partial preservation of within- and cross-lingual semantic priming in their subject, based on which they suggested that the non-selective lexical access hypothesis also holds for patients suffering from aphasia. In this patient, L2 → L1 semantic priming was better preserved than L1 → L2 priming and the reaction time in response to cross-language semantic priming was faster compared to the within-language one. On the contrary, repetition priming for both cognates and non-cognates was more spared for L1 → L2 than for the opposite direction. Additionally, for L2 → L1 repetition the reaction time to cognates was slower compared to non-cognates. Putting the results together, the authors concluded that the mechanism of impairment was confined in the delay or inhibition of lexical access in their patient rather than a deficit in lexical representation of words as the priming was partially preserved. This interpretation is in accordance with the observation in monolingual aphasics^{35,36}. Additionally, they suggested that the cross- and within-language semantic priming in their patient had different mechanisms, as cross-language priming was faster than within-language priming.

When investigating lexical access impairment in bilingual aphasics in production, contrary to the previous study, Roberts and Deslauriers³⁷ observed a facilitated **cognate naming** in both healthy controls and bilingual anomic aphasics with equal pre- and post-morbid proficiency levels in both languages (parallel impairment pattern) compared to non-cognates. Their patients named non-cognates correctly more often in L1 (French) than in L2 (English). For the patient group, unlike healthy controls, a “no response” was observed more often than a semantic error (naming a different item from the same semantic category). In both healthy controls and aphasics, “wrong language” was the third most frequent error. The authors observed the effect of cognate status on naming accuracy, frequencies of “wrong language” errors and self-correction for both aphasics and non-aphasics. In all cases, the cognate status had a facilitating effect on correct word naming. In the case of the “wrong language” error, a possible strategy could be that the subject is cueing him/herself in the other language and then tries to translate it. When translation is impaired, i.e., not successful, as in the case of aphasia, the “wrong language” error occurs. This strategy supposedly is also valid for healthy bilinguals, but their self-cueing takes place at a much faster pace and in the majority of cases ends up successfully. Additionally, Verreyt (2013, see chapter 4) and Verreyt and colleagues (2013)^{19,38} observe a facilitating effect of cognate status on comprehension when testing the patient with both differential and parallel aphasia on a generalized lexical decision task (words from both languages require a “yes” response and non-words a “no” response). However, in Verreyt and colleagues³⁸ this effect was eliminated (note, that they were testing patients with differential aphasia only) when they used a selective lexical decision task in which case the words from only one language require a “yes” response and the non-words and the words from the other language a “no” response. As latter studies also investigated the patient’s cognitive control abilities, they were in a position to shed some light on the mechanisms underlying the difference in performance between two languages and in cognate facilitation between tasks (generalized vs. selective lexical decision). According to them, cognitive control in patients with

¹ A word that has similar lexical and semantic representation across two or more languages such as ‘conclusion’, which has the same meaning in English as in Italian where it is spelled as ‘conclusione’.

differential aphasia is more impaired than in parallel aphasia, which led to the absence of a cognate facilitation effect when the demand on cognitive control increases (like in the case of selective lexical decision task). This would also explain the diversity in the results of Sylambalapitiya⁴ and the equal relative frequency of observed “wrong language” errors in healthy subjects and patients in the work of Roberts and Deslauriers³⁷, as their patients were parallel aphasics, hence, their cognitive control was relatively preserved.

Based on these studies, we can assume that manifestation of particular symptoms of bilingual aphasia (pathological language switching and mixing), as well as some impairment- and recovery patterns (differential, selective and blended) develop due to an impaired cognitive control over the interferences between these languages, rather than to a selective impairment of one of the bilingual’s language systems. Hence, in mentioned impairment patterns, the interference of the better-preserved (stronger) language hinders the processing of the weaker language.

Studies on lexico-semantic access in bilinguals (including the previously mentioned ones) show the importance of pre-morbid language proficiency for the patient’s performance. However, despite its crucial role in investigating bilingual aphasia, researchers are still searching for the most optimal assessment method. Usually it is done via self – reporting and questionnaires that probe the history of pre-morbid language use. One should note that self-reporting does not always objectively reflect the subject’s proficiency level as it was shown not to predict the performance on either overt picture naming³⁹ or semantic priming⁴⁰. Currently, one of the most used and most detailed questionnaires is LUQ (language use questionnaire)⁴¹. It includes questions about hourly language use during a workday and over the weekend, as well as the age of acquisition of each language and the perception of language proficiency by the patient and his/her close relatives. Kiran and colleagues⁴² and Gray and Kiran⁴³ assessed pre-morbid language performance of their patients via the LUQ. Interestingly, from the components of LUQ, only language ability rating (LAR) correlated with post-morbid performance. This was supposedly due to the fact that LAR reflects but does not distinguish between the history of language acquisition and language proficiency. Gray and Kiran⁴³ also showed that LAR can be considered a strong predictor for post-stroke performance of naming skills, rather than comprehension. Unlike a simple self-report, LAR includes questions from real-life situations such as “can you participate in a complex conversation in that language and detail your opinion, and so on.” It also includes a separate assessment of the ability to listen and participate in casual and formal conversations. In addition to an assessment with LAR, Kiran and colleagues⁴² tested their patients on picture-naming- and category generation tasks. Similarly to Roberts and Deslauriers³⁷, they observed the same types of errors for both healthy and aphasic bilinguals. They concluded that the basic mechanisms of lexical retrieval are the same for healthy controls and aphasics. Hence, similarly to monolingual aphasics, lexical information is not lost, but rather lexical access and retrieval are probably inhibited (impaired integration of word meaning into context³⁶) or delayed³⁵. Gray and Kiran⁴³ also suggested that comprehension abilities as well as performance on a task gauging semantic access were associated in both languages (here, Spanish – English) in bilingual aphasics, which also supports the hypothesis of non-selective lexical access²⁵ even after development of aphasia.

Morpho-syntactic processing

Impairment in morpho-syntactic processing often leads to agrammatism in aphasic patients. Clinically morpho-syntactic impairment on a single word-level is manifested in terms of omission (e.g., pronouncing only the word

stem instead of its inflected form) and substitution (e.g., pronouncing an infinitive form instead of inflected form) errors, naming difficulties of the words of a specific grammatical class (verbs vs. nouns), etc. This problem is common in both mono- and bilingual aphasics (especially the ones with Broca aphasia); though for the investigation of bilinguals some specificities need to be taken into account, such as characteristics of language acquisition, differences between morpho-syntactic structures of languages and their interaction. Furthermore, some additional error types (e.g., 'wrong language' response) can be observed in these patients, which reflect the interference of the two languages.

In a case study of a Spanish-Catalan bilingual patient with primary progressive aphasia (non-fluent type)⁴⁴, verb naming was hampered more in both languages compared to noun naming. According to self-report, this patient was less proficient in L2 than in L1 both pre- and post-morbid. Here, comprehension and semantic access were unimpaired as reported by subtests on comprehension, including Pyramids and Palm Trees test. The main error type in verb naming for the patient's L1 was 'no response' and 'wrong language' for L2, which was actually the translation of the correct word. As the error pattern of naming for L2 was the same as for L1 (verbs worse than nouns), albeit with different performance levels, the authors concluded that the neural and cognitive mechanisms of L1 and L2 processing in this patient were the same. This can be seen as evidence in support of the integrative model of syntax processing. Additionally, they considered language membership as an organizational level in the hierarchy of language processing, which was considered lower than the level of grammatical class. Similarly, Ling Dai and colleagues⁴⁵ described a post-stroke Cantonese-Mandarin bilingual patient with chronic anomia that displayed more impairment in verb naming than in noun naming. However, unlike the previous study, here, this discrepancy was noticed in the patient's non-dominant (L2) language only. Unlike the case of Hernandez and colleagues, here, the main error-type for both languages was semantic paraphasia (replacing a word with a semantically related word). They assumed that the combination of relatively low proficiency, late age of acquisition and rare post-stroke use could explain the selective L2 word-class discrepancy. Additionally, the difference between the studies might also be due to the difference in investigated language pairs (Indo-European family for Hernandez and colleagues⁴⁴ vs. Chinese family for Ling Dai and colleagues⁴⁵), more specifically the higher level of pre-morbid language-switching between Indo-European language pairs compared to Chinese language pairs. The nature of the impairment and the location of the lesion in these two cases were also different with the left hippocampus and perisylvian cortex lesion and primary progressive aphasia in Hernandez and colleagues⁴⁴ and post-stroke left front-temporo-parietal impairment in Ling Dai and colleagues⁴⁵. However, despite this discrepancy, the impairment of production rather than comprehension united these two cases. In addition to a grammatical category-specific impairment, Kambanaros⁴⁶ showed the instrumentality specific impairment in bilingual aphasia, where Greek-English bilingual patients with anomia unlike in the monolingual cases⁴⁷, were naming noun-related verbs worse than non-noun related verbs (e.g. hammer → to hammer vs. broom → to sweep), but only in their second language (English).

FACTORS INFLUENCING SINGLE WORD PROCESSING IN BILINGUAL APHASIA

As mentioned previously, factors that influence language processing in healthy bilinguals also play an important role in the clinical manifestation of bilingual aphasia, the development of impairment and recovery patterns. Among those factors we note the pre- and post-morbid proficiency level in each language, age and method of language acquisition, linguistic environment (mono- or bilingual; if bilingual, how frequent the language

switching is) of the patient before and after the incident. Other important factors are language characteristics such as language typology and orthographic and phonological distance between the two languages. We will now address each factor in more detail.

A study on semantic priming performed by Kiran and Lebel⁴⁰ revealed diverse outcomes for four non-fluent chronic Spanish-English bilingual aphasics. When testing their patients on cross-language semantic and translation priming in both directions (L1 → L2 and L2 → L1), they observed a priming effect only in some patients, independent of their score on aphasia batteries. As the pre- and post-morbid proficiency varied among these patients, as well as the outcome of the study, the authors concluded that semantic- and translation priming in bilingual aphasics depends on a **complex interaction between pre- and post-morbid language proficiencies, language impairment and priming type (semantic vs. translation)**. Kiran and Tuchtenhagen⁴⁸ conducted the same semantic priming test and added a naming to definition (NTD) test in a late, though pre-morbidly highly proficient Spanish-English bilingual aphasic using abstract and concrete words. During the NTD test, the patient should hear the definition of the word and try to name it. The authors showed that healthy controls performed worse on the NTD of abstract words, compared to concrete words, and that the patient was unable to name almost any abstract word. The patient also performed worse on abstract words in the semantic-priming test. As the patient had equal proficiency levels in both languages, pre- and post-morbidly (parallel impairment pattern), no significant effect of language was present across tasks. The authors concluded that concrete and abstract words have different semantic representations and concrete words share a semantic representation in bilingual aphasics (as well as in healthy adults) unlike abstract words, which are more context-dependent⁴⁹ and hence more difficult to access. Furthermore, they assumed that proficiency level and current language use would be a more reliable determinant of lexical access in bilingual aphasics than age of acquisition. This claim goes along with data from healthy bilinguals, according to which proficiency level rather than age of acquisition determines processing of semantics⁵⁰ and in particular lexical access⁵¹.

In order to address the influencing factors in greater detail, Kiran and Roberts⁷ conducted a study that observed recovery patterns in 2 Spanish/English and 2 French/English bilingual aphasics who followed a semantic feature-based treatment. They claimed that post-stroke performance (language processing) and recovery pattern depend on factors such as age of second language acquisition, post-stroke language impairment, pre-stroke language proficiency⁴², and type and severity of aphasia. Moreover, Kiran and Iakupova⁵² showed that there is a stable, albeit vague connection between these factors.

In addition to the previously mentioned factors, the processing of morpho-syntactic structures depends on structural distinctions of the language. A case study by Cholin and colleagues⁵³ can be presented as a proof of this assumption. Here, a German-English bilingual patient with primary progressive aphasia frequently regularized verbs while naming them (i.e., instead of “caught” for past tense of “catch” saying “caught”) in both his languages. Hence, from this observation one could assume that the patient “preferred” the language with a more regular structure, hence, morphologically more “fixed”. In sum, the previously discussed studies^{44–46,53} showed that the processing of morphological structures of a single word additionally depends on the language typology (structural characteristics), lesion pattern, age of second language acquisition, and post-onset use.

SENTENCE LEVEL INFORMATION PROCESSING IN BILINGUAL APHASIA AND INFLUENCING FACTORS

Disturbed processing of sentence level information leads to an impairment in communication and the inability to express one's thoughts even if both the comprehension and production of a single word are relatively spared. Clinically it includes among others the symptoms typical for word-processing impairment in both semantics and morpho-syntax. Additionally, while producing a sentence, patients can omit articles, confuse pronouns and conduct omission- and/or substitution errors (agrammatism). Patients usually have difficulties comprehending syntactically complex or semantically reversed sentences. Furthermore, bilingual patients often mix and switch languages, which also hinder communication. The investigation of sentence processing in bilingual aphasics provides insight into the factors that influence or even cause some of these symptoms.

Language switching and mixing can be observed in the healthy population as it is very common in some communities. It becomes pathological when it persists even after the patient is explicitly asked to keep the conversation in one language only. Pathological mixing and switching are one of the main clinical manifestations of a blended recovery pattern in bilingual aphasia. Munoz and Maquardt obtained some empirical data on this phenomenon by investigating the influence of a linguistic environment on the patients' abilities to converse in mono- or bilingual environment. They investigated three Spanish-English bilingual aphasics (Broca), who had relatively well preserved comprehension and frequent pre-morbid language-switch, on their ability to stay involved in a conversation depending on language mode (monolingual L1, monolingual L2 and bilingual)⁵⁴. Authors showed that language mode, set by the environment, influences lexical retrieval during conversation in bilingual aphasics. This data is in accordance with the one presented for healthy bilinguals⁵⁵ at least for comprehension. According to an electrophysiological study conducted on healthy German-English bilinguals⁵⁵, a "global context" can influence the processing of ambiguous words such as inter-lingual homographs (words that have the same lexical, but different semantic representations across languages) albeit only for a short period of time. The results from Munoz and Maquardt⁵⁴ further propose that individual variability between patients on the produced errors and the interference from the other language during conversation in monolingual mode supposedly depends on a number of factors including pre-morbid differences in language background (e.g., age of acquisition), proficiency level and pre- and post-morbid environment (monolingual, bilingual), as well as nature of the impairment. After investigating a Chinese – Spanish – Catalan trilingual aphasic patient on both comprehension and production of semantics and syntax, Diegues-Vide and colleagues⁵⁶ concluded that the level of language impairment and consecutive recovery pattern, in addition to the aforementioned factors, depend also on the method of language acquisition (informal or formal, i.e., at school), the level of exposure and pre- and post-morbid language use. Additionally, they showed that the cross-linguistic generalization of recovery from the treated to the untreated language depends on the typology of the language (structural and feature characteristics of a language) and the structural distance between them (e.g., Chinese – Spanish vs. Spanish – Catalan). The latter is especially important for the processing of syntax, as many languages do differ in syntax, even when they share orthographic qualities.

A good example of performance dependency on language typology is presented in the study by Alexiadou & Stavrakaki⁶, who tested a late, though highly proficient bilingual patient with non-fluent aphasia on adverb placement and verb movement in sentence context. They tested the patient's performance in a highly inflected, but regular language such as Greek (the patient's L1) vs. a poorly inflected language such as English (L2). According to the aphasia test results, while naming verbs, the patient produced more omission errors in English

and substitution errors in Greek. These results are highly related to language typology, as in Greek, the verb stem is unable to stand alone. When testing this patient on a constituent ordering task (composing a sentence with the most optimal word order from visually and verbally presented anagrams) and a contrastive grammaticality judgment task (deciding which position of a given adverb is the most optimal one for a particular sentence), they noticed that task performance was highly dependent on the position in the syntactic tree, as performance dropped sharply when going up the tree. Note, that although the patient had parallel aphasia, her performance on constituent ordering task was significantly better in Greek (a 'fixed' structure language) than in English (a 'free' structure language). Furthermore, despite having similar performance levels across languages for a contrastive grammaticality judgment task, the error types were different, being milder for Greek than for English. Based on this, the authors concluded that even though the patient had the same level of access to grammatical knowledge to perform the task for both languages, for some reason this access was facilitated in Greek (i.e., the subject's L1). Considering these observations, they suggested that syntax processing might be different depending on language characteristics: morphological complexity in Greek vs. syntactic complexity in English. This statement can be further strengthened with data obtained by Kambanaros⁴⁶ who, again testing Greek-English late highly proficient bilinguals with anomia, showed that the advantage instrumental verbs share⁴⁷, when processed during isolated naming over non-instrumental verbs, diminishes and practically becomes negligible when putting them in a sentence context.

In a study by Abuom and colleagues⁵⁷ syntax processing in 11 agrammatic (Broca) aphasics was studied using a sentence-picture matching test. During this test, the participant should match a verbally presented sentence to one of four pictures among which, besides the correct one, there was also a lexical distractor, a reverse role distractor and a picture that included both distractors. Their post-morbid performance on comprehension of a single word and sentence on semantics was comparably spared and their pre-morbid proficiency was equally good for both languages. The performance on the sentence-picture matching task was equally poor for both languages and no qualitative difference between languages was observed. Furthermore, they noted that most errors occurred for sentences that had the object positioned prior to the subject in semantically reversible sentences like 'A woman was rescued by the man'. This is also in accordance with data obtained from monolingual aphasics⁵⁸ where both task performance and event-related potential responses on semantically reversible passive sentences ("The woman was pushed by the man") were worse than on semantically reversible active sentences ("The man pushes the woman."). Again, similar to monolingual aphasics⁵⁹, the most common error for these patients was the role-reversal error (the patient was choosing the picture according to a subject-object default order: assuming subject first in the sentence, independent of actual order). When manipulating stimuli of languages like Swahili (highly inflecting) and English (poorly inflecting, but dependent on the order of sentence parts) they claimed that, as mentioned before, structural complexity of the sentence rather than morphological complexity (e.g., of a verb) influences the performance of those patients, a result that confirms the dependency of syntax processing on language typology. Additionally, they suggested that, although syntactic representation was intact (as the performance on other types of syntactically manipulated sentences was relatively preserved), linguistic operations to extract information from word order were impaired, which led to the inability to perform the task accurately when the word order in a sentence is not the default one.

Continuing the evaluation of the factors influencing syntax processing, the work by Tschirren and colleagues⁶⁰ is also noteworthy. They showed that syntax processing in aphasic patients depends, besides age of acquisition, as

in healthy bilinguals, also on lesion location. They observed a more significant impairment of L2 syntax in patients with lesions located more anteriorly (pre-rolandic) compared to L1 syntax impairment which was more pronounced when the lesion was posterior. The authors concluded that, unlike L1, processing of L2 syntax requires greater activation of the frontal cortex. This observation is in line with functional neuroimaging studies on bilingual healthy subjects⁶¹ and supports the procedural/declarative model of syntax processing.

In order to assess sentence processing in both semantics and syntax domains, Ravi and Chengappa⁶² tested 20 chronic Kannada-English bilinguals suffering from Broca's aphasia on semantic and grammaticality judgment tasks in both languages. Noticeably, it is one of the few studies that investigated a relatively large population of bilingual aphasics (see [table 1](#)). As predicted from research on monolinguals^{63,64}, the judgment of syntactic structure violation was most difficult for these patients (longer RT and low accuracy) for both languages. The authors observed a difference in performance on correct and syntactically incorrect sentences across languages with a better performance for L1 than for L2. As to reaction time, the difference was observed for correct and semantically incorrect sentences (faster for L1) with an approximately equally long reaction time for syntax violating sentences. Observing a similar pattern of language impairment in both languages (syntax more impaired than semantics), the authors concluded that the impairment of so-called 'central linguistic processing' occurred, which is language non-specific, hence, the integration of the word into the context in bilingual aphasics takes place using the same mechanism for both languages. This study, similarly to the one from Hernandez and colleagues⁴⁴, support the integrative model of syntax processing, now already on the sentence level. Additionally, Abuom & Bastiaanse⁶⁵ showed that language production correlates with comprehension, hence, a lower comprehension level will be associated with an inferior production level in the same language, which for their 13 motor aphasics was English (L2). In addition, considering the performance on tense comprehension and production, they observed an inferior past tense comprehension and production compared to present and future tenses.

From the presented studies on both semantics and syntax processing in sentence context, we can draw the following two conclusions:

- 1) More regular, albeit morphologically richer languages can be processed easier by the bilingual aphasic than a more flexible language (word order changing depending on the sentence) in both production and comprehension⁶⁵ and
- 2) Similar to lexical access impairment, in the majority of bilingual aphasics, the information on both semantic and syntactic representation of the language is preserved, yet the access to this information is either blocked/inhibited or delayed.

The latter plays a crucial role in bilingual aphasia when conducting rehabilitation in the patient's second language. This is especially the case with minorities and other vulnerable social groups (immigrants). It is important to remember that the speech therapist should not adopt the role of a teacher and try to "teach" the patient new words. Rather, he/she should work on recovering what the patient knew before the incident.

GENERAL DISCUSSION

Variety in language combinations and the differences in linguistic characteristics, but also personal factors such as language proficiency and age of L2 acquisition, provide us with a range of possibilities to manipulate and investigate linguistic and neuropsychological processes far beyond what can be done in monolinguals. The

downside is that it renders the interpretation and comparison of those studies more difficult, also due to the variability in tasks and tests for investigating proficiency level.

The reviewed studies once again confirm the assumption proposed by Fabbro⁶⁶. From the investigation of patterns of impairment and recovery in bilingual aphasics, he concluded that the mechanism of aphasia in a bilingual patient is due to increased inhibition, raised threshold of activation or unbalanced distribution of resources between the patient's languages after impairment rather than the physical damage to the whole language processing system. In addition, recent literature^{33,38}, suggests that an impairment of cognitive control plays an important role in the development of bilingual aphasia and some of its impairment patterns. Furthermore, Fabbro assumed that symptoms of bilingual aphasia, whence the mechanisms of their development, do not differ from the ones of monolinguals. The only difference is that, instead of register mix and register switch (i.e., changing the conversation setting, e.g., from formal into informal and vice versa in a single utterance (mix) or across utterances (switch)), which is observed in monolingual aphasics, bilingual ones mix and switch languages. Given the results of psycholinguistic investigations presented above, it could be tempting to agree with this claim as, in general, error rates correlate across languages and the general pattern of impairment is usually the same for both languages (nouns less impaired than verbs⁴⁴ or semantics more preserved than syntax⁶²). These results are also similar to those of monolingual aphasics. However differences in performance between languages could only surface when investigating them in more detail, for instance, in terms of error types: one type of error for one language but another type for the other language, as in Alexiadou and Stavrakaki⁶. This could probably be due to the specific characteristics of languages, their typologies, and their lexical and orthographic distance. Among other factors that influence language performance in bilingual aphasics are pre-morbid proficiency level, specificities of language acquisition and language use. Hence, when investigating a bilingual patient with aphasia, one should consider a detailed history of language acquisition and use both pre- and post-morbidly. The researcher or clinician should resolve when and how the patient started to learn L2: at school in a formal setting but also at home, watching TV or reading literature, even if it was around the same age teaching L2 starts at school. How frequently L2 was used before and after the incident, and in which context (formal – work, informal – home, friends); what is the preferred language for watching TV or reading literature, etc. Although all this information is easy to obtain and not very time consuming (also easy to clarify by relatives), it would facilitate the objective assessment of the patient's pre-stroke L2 abilities and the system that is probably involved in processing this particular language (declarative/procedural memory).

Among other factors, the lesion location also plays a significant role in post-morbid performance of each language and their interaction⁶⁰, as it was also shown that, depending on the lesion location, sometimes L2 is better preserved even if it was learnt later and patient was less proficient in it pre-morbidly.⁶⁷ Additionally, researchers should take into consideration that in the bilingual brain both languages are in constant interaction which, according to the recent studies, also holds true for aphasia³⁸. Therefore, any impairment in this interaction can play a significant role in the clinical manifestation of bilingual aphasia making it a unique and distinctive clinical entity.

SUMMARY AND FUTURE DIRECTIONS

There is still an ongoing debate on the mechanisms of language processing in bilingual aphasia, whether they are distinct and different from those in monolingual aphasia. One way to address this is by comparing the data

obtained from bilingual and monolingual aphasics, where L2 is the language of interest and also the mother tongue of monolingual aphasics. Such data can already be culled from published studies on monolingual aphasics. This way one would be in a better position to discover patterns shared by mono- and bilingual aphasics, to discern any differences and to more objectively investigate the effect of mentioned influencing factors on the processing of a particular language in bilingual aphasic.

The current review is a first attempt to combine several studies on the mechanisms of language processing in bilingual aphasics and to compare them, albeit briefly, with data obtained from monolingual aphasics.

Considering the variability in bi- or multilingual aphasics (proficiency level, age and history of acquisition, impairment patterns) and variety of language combinations, it is hard to come up with a single strategy that would be both reliable for the population and still benefit from single case reports. Hence, in order to be able to extrapolate the obtained results to the population of patients, and at the same time tackle individual variability, we would suggest for future studies, when investigating patient groups, to also include the previously mentioned factors as confounds into statistical model of the study.

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Table 1: Group studies on bilingual aphasics

Component	Authors	Cohort	Languages	Field of investigation	Task	observed result	comparison between languages
Syntax	Abuom & Bastiaanse, 2013	13 bilingual agrammatics 13 NBD ²	Swahili English	tense comprehension and production	Sentence-completion Picture – sentence matching	Deficit on comprehension and production of past tense	The same pattern for both languages
	Abuom & Bastiaanse, 2012	6 bilingual agrammatics 12 NBD	Swahili English	verb inflection	Narrative and spontaneous speech	Decrease of number of grammatical and complex sentences, slowing of the speech	The pattern of impairment is the same for both languages (reference to past is more impaired than present) but the verb inflection is better preserved in Swahili (substitution) than in English (omission)

² NBD – non-brain damaged

Language use	Abuom, Shah & Bastiaanse, 2013	11 non-fluent aphasics 11 NBD	Swahili English	reversed order and thematic role in sentences	Sentence-picture matching	Sentence complexity rather than morphological complexity diminish the performance	Agrammatic patients were similarly affected in both languages with the same pattern
	Kambanaros, 2009	12 late bilingual aphasics 12 NBD	Greek English	verb instrumentality and noun – relatedness	Picture (action) naming using sentence with verb Action naming in isolation	No effect of instrumentality for naming in sentence Negative effect of name relatedness on instrumental verb processing	Instrumental verbs produced better in L1 than L2 Name related instrumental verbs were more impaired in L2 than L1. Only for L2 name-related instrumental verbs were better named in isolation than in sentence.
	Gray & Kiran, 2013	19 bilingual aphasics	Spanish English	The general investigation of post-morbid language abilities	Language use questionnaire	Language ability rating was the most objective method for measurement of post-morbid language proficiency in naming	Patients who lost different amount of Spanish and English usually had different pre-morbid proficiency in these languages and vice versa.

Semantics	Kiran, 2014	10 bilingual aphasics 12 NBD	Spanish English	Lexical retrieval	Picture naming tasks (BNT and BPNT ³) Category generation task	Aphasics performed similar types but more errors in both languages and have similar clustering strategy with NBD controls	BNT was better in English than in Spanish, BPNT was better in Spanish than in English Category generation was better in English than in Spanish
	Roberts & Deslauriers, 1999	15 bilingual aphasics (balanced) 15 NBD	French English	Lexical retrieval	Picture naming test with use of cognate vs. non-cognate as a factor	Cognate picture are more correctly named compared to non-cognates Wrong-language error was less frequent for cognates than non-cognates Self-corrections were less for cognates than non-cognates	Cognates were better performed for both languages and better for L2 than for L1

³ BNT – Boston Naming Test; BNPT – Boston Picture Naming Test

Semantics/syntax	Kumar Ravi & Chengappa, 2014	20 bilingual aphasics	Kannada English	Sentence comprehension	Semantic judgment task,	Significant effect of language and sentence type (syntactic violation, correct, semantic violation) on both accuracy and reaction time data In both languages RT was as follows: Cor.<Sem.<Syn. ⁴ , which was opposite for accuracy level	Semantically violated sentences had same accuracy level for two languages Syntactically violated and correct sentences were better for L1 than for L2 Correct and semantically violated sentences were responded faster in L1 than in L2, syntactically violated one equally slow in both languages
					Grammaticality judgment task		

⁴ Cor. – correct, Sem. – semantics, Syn. – syntax

Table 2: Boston Aphasia Classification

	Clinical manifestation				Lesion location
Type	Comprehension	Production	Grammar	Repetition	Neuroimaging
Non-fluent (Broca)	Relatively preserved	Poor up to telegraphic speech	Agrammatism	poor	Inferior frontal gyrus (Broca area), left opercula, insula, and subjacent white matter
Fluent (Wernicke)	Poor	Fluent but mostly meaningless	Mostly normal sentence structure	poor	Posterior part of superior temporal gyrus, middle and inferior temporal gyri, partly parietal cortex
Global	Poor	poor	Poor	poor	Large area of perisylvian region
Amnesic (anomic, nominal)	Relatively preserved	Poor object naming Word – finding difficulties	Good	good	Not well defined ⁵ (can be due to the improvement of symptoms after recovery of Broca and Wernicke aphasia)
Conduction	Good	Fluent, but with paraphasias	Good, mostly complex sentences	Poor	Temporo-parietal junction, insula, primary auditory cortex and supra-marginal gyrus
transcortical sensor	poor	Fluent, but meaningless speech with many semantic paraphasias	Sentences with normal structure	preserved Up to echolalia	Middle and inferior temporal gyri, inferior occipito-temporal regions
transcortical motor	Relatively preserved	poor	Agrammatism is uncommon	Relatively preserved	Dorsolateral frontal lesion extending into the deep frontal white matter
Mixed transcortical	poor	poor	Poor, also due to poor production	Relatively preserved	The combination of lesions observed in transcortical motor and sensor aphasias

⁵ Some researchers link this type to the impairment in angular gyrus (parietal lobe), middle temporal gyrus or parieto-temporal junction.

(isolation)					
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Table 3: Overview of language domain impairments and their clinical manifestations.

Language domain	subdomain	Study method	Clinical manifestation	Bilingual distinctions	Influencing factors
Semantics (language content)	Lexical access	Semantic priming Repetition priming	Word-finding difficulties in picture naming task (production), slow/impaired word-picture/picture-picture matching task performance slow/impaired repetition task performance	Impairment in translation task, Specificities of cognate/homograph processing	Pre-/ and post-morbid proficiency level Current abilities in cognitive control
	Word integration in sentence	Semantic judgment task	Comprehension deficit in patients	In most cases, the post-onset comprehension correlates with pre-morbid proficiency level	Language dominance Cognitive demand of a given task
Morphology (word structure)	Word class processing	Picture naming	Using more verbs or nouns in speech, in extreme cases – telegraphic speech Paraphasias (semantic, literal)	The discrepancy between word-classes can be in one language and not in the other	Proficiency level, Age and method of acquisition,
	Verb processing	Naming verbs in their different forms	Attempts to regularize verbs when naming them in past tense ('caught'), neologism (invention of	From two languages a flexible language is the one that mostly suffers	

			new words)		Post-stroke use
	Noun-related verb processing	Verb naming in isolation and in sentence context	Anomia, difficulties to retrieve the verbs in sentence context	For L2 only, noun related verb naming was more impaired than non-noun related ones	Language typology
Syntax (rules of combination of words into sentences)	Thematic role assignment	Sentence-picture matching task for semantically reversible active and passive sentences	Using mostly active sentences with default SVO structure in speech Conducting role-reversal error for mentioned task	Subject was performing poorer on structurally more complex language rather than in morphologically complex one	Proficiency level, Age and method of acquisition,
	Tense processing	Sentence production and comprehension of tenses	Agrammatism in both production and comprehension	Past tense is more affected in both languages at the similar level compared to the present and future tense	Error types mostly depend on language typology (structural complexity),
	Verb processing in sentence context	Constituent ordering task and contrastive grammaticality judgment task	Agrammatism, increased error rate as the task becomes more complex (cognitive demand increases)	Depending on the language, the error type might be different	Lesion location

Article ID	Article title
COGSCI-062	Aphasias and Theories of Linguistic Representation
COGSCI-090	Mental Representation of Bilingualism

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