Introduction to psycholinguistic and neurolinguistic approaches to language attrition

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7. Psycholinguistic and neurolinguistic perspectives on language attrition

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7.1. Introduction and quick historical overview

The field of language attrition has long been dominated by linguistic, applied linguistic and sociolinguistic approaches, and psycho- or even neurolinguistic approaches have had some difficulties to become established. However, the idea that language attrition is governed by processes and mechanisms that are fundamental in the human mind/brain has steadily become a pillar underlying most attrition research. One of the first questions to be raised from a psycholinguistic perspective was the question whether attrition is a competence or performance issue. In other words, does attrition affect linguistic 'knowledge' or rather 'control of that knowledge' (Bialystok & Sharwood Smith, 1985) or 'on-line processing of knowledge' (Sharwood Smith & van Buren, 1991)? While our present conception of competence and performance has radically changed, one of the major discoveries of language attrition research has certainly been that the answer to this question seems to depend considerably on the age at which a modification of language use arises (commonly referred to as the 'age of acquisition of the L2' or AoA). One of the most consistent findings in language attrition research is that there may be profound changes in the linguistic system of a speaker who reduces the use of a language or even stops using it altogether (namely in adoptees, see

Pierce, Genesee & Klein, this volume) as a child (i.e. pre-puberty migrants), whereas in migrants who have grown up mostly monolingually (i.e. post-puberty migrants), language attrition, at least as far as the L1 is concerned, manifests itself mainly at the level of on-line processing of the L1 (see Bylund, this volume; Köpke & Schmid, 2011; Schmid, 2014).

Most of the early attrition studies were mainly interested in how attrition at the competence level affected the linguistic system and attrition phenomena were mostly examined in order to test the predictions of different linguistic theories with respect to the vulnerability of specific structures. In a similar way, attempts have been made to compare attrition to other processes of language change and language development, as was proposed by De Bot and Weltens (1991) in a seminal paper that invited researchers to consider attrition as one of numerous processes of language development through the lens of either the recapitulation or the regression hypothesis. The regression hypothesis which in its original form stipulated mirror symmetries between child language acquisition and language loss in aphasia (Jakobson, 2014, see also Barkat-Defradas et al, this volume) has received most attention and has yielded interesting findings with respect to the vulnerability of different linguistic levels at different times also in non-pathological attrition process (e.g., Keijzer, 2010). But however interesting and valuable these approaches are, documenting mirror symmetries between child language, attrited systems and/or pathological language loss itself does not have explanatory power over why these similarities occur. Hypotheses like regression have to be placed in a psycholinguistic framework taking into account cognitive factors such as competition in order to gain explanatory power.

Issues pertaining to the cognitive processes and brain mechanisms underlying attrition have slowly emerged. It was not before 2004, more than 20 years after the first publications on

language attrition, that a first special issue focussing specifically on neurolinguistic aspects of attrition was published (Köpke, 2004). However, recent evolutions in theories of language development (e.g., Dynamic Systems Theory (DST), see also Opitz, this volume) and intensification of research on bilingual language processing as an overarching field to which attrition also belongs reflect the current interest into psycho- and neurolinguistic processes and mechanisms involved in bilingualism, including language attrition. The aim of the present section is to provide the reader with an overview of research that takes into account the neurofunctional and cognitive bases of language and how they are informative to invoke in attrition research. Before presenting an outlook on the different chapters assembled in this section, we will outline the main concepts and hypotheses on the basis of psycho- and neurolinguistic studies of attrition. More specifically, we will present research considering language attrition either as an affair of language processing, of memory or of brain mechanisms. While many of these issues still remain speculative, we will discuss what they may entail for attrition and even how attrition data in turn could help to better understand bilingual language processing and brain mechanisms.

7.2. Language attrition as an affair of language processing

The interaction of the different languages during on-line processing is a central issue in research on bilingualism. The concept of Cross-Linguistic Influence (CLI) was introduced by Sharwood Smith in 1982, with the intention of replacing the concept of transfer—frequently used in Second language acquisition (SLA) research—by a concept with less of a behaviourist connotation. While Sharwood Smith stated explicitly that CLI should be taken to refer to both influence of the L1 on the L2 and vice versa, the second point received markedly less

attention until recently (see the discussion in Schmid & Köpke, 2017a). But most importantly, the concept of CLI was meant to go well beyond the simple idea of interference between two language systems: CLI happens because different languages are processed through the same processing mechanisms, which leaves space for interactions of different types. Attrition, in this conception, is a direct product of the concomitant processing of two languages (Sharwood Smith, 2005).

This idea was taken up and further developed in Green's 1986 activation, resource and control model. This model of bilingual language processing was very innovative at that time with respect to several aspects, two of which are particularly interesting for attrition. First of all, the model distinguished between selected, active and dormant languages. The *selected* language is the one controlling ongoing verbal activity and the *active* language plays a role in verbal activity even though it is not selected. That languages which are not selected but active may intervene in the processing of the selected language has since Green's 1986 model been amply demonstrated for virtually every linguistic level (see Schmid & Köpke, 2017a for an overview). But what might have been the most interesting concept for attrition research was the idea that there may be *dormant* languages that are stored in long-term memory but do not intervene any longer in ongoing language processing. Although Green's model thus directly pertains to attrition, it has hardly ever been implemented in attrition research (but see Ammerlaan, 1996). It must, however, also be noted that no direct evidence has yet been found indicating that there might be a difference between active languages that do intervene in ongoing language processing and dormant languages that do not. In fact, most current bilingual processing models these days point to non-selectivity of all language systems regardless of their status (cf. Dijkstra & van Heuven, 2002).

The non-selectivity aspect was, however, also incorporated in another construct underlying Green's (1986) model, and has crucially shaped attrition research: the idea that there is constant competition between a speaker's languages. Indeed, the idea of competition between languages clearly provided grist to the mills of attrition research and drew attention to notions such as activation and inhibition, both of which are now seen as pillars in bilingualism research and are perhaps most clearly attested in work on lexical access, for example in lexical decision tasks (for a review, see van Assche, Duyck, & Hartsuiker, 2012). Green's 1986 model and his later Inhibitory Control (IC) model (1998, see below) paved the way in this respect.

The concept of activation in particular was further developed in the Activation Threshold Hypothesis (ATH) proposed by Paradis (e.g., 1993; 2007), initially mostly to explain non-parallel language recovery patterns in bilingual aphasia. Based on the hypothesis that the two languages of a bilingual are organised in two neuro-functionally independent subsystems within the language system, the ATH holds that interaction between the languages is largely determined by frequency of activation of each language and each item that is part of the language, and by the time elapsed since its last activation. Following Paradis (e.g., 1993, p. 138), the Activation Threshold (AT) of a given item or language is lowered each time the item (or the language) is activated. Lowering of the AT enhances facility of activation and lowers cognitive costs associated with activation. However, if the item (or the language) is not activated again, the AT will slowly be raised, and the item (or the language) will get more and more difficult (and costly) to activate. This framework clearly states that facility of activation is directly linked to frequency of use, and as such the ATH is of specific interest for attrition research, where one language is markedly less used in a speaker.

The first to test the predictions of the ATH with respect to first language attrition was Köpke (2002), who investigated two groups of 30 German migrants in France and in Anglophone Canada respectively. This study's main focus was the application of the ATH for lexical vs. grammatical processing. Köpke's findings suggested that grammar is not affected by frequency of activation to the same degree as was the lexicon and these results were also discussed in relation to the related declarative/procedural model (Paradis, 1994, see 7.3 below for a description of the model). Gürel (2004), on the other hand, challenged precisely grammatical processing in a study of the binding strategies for overt and null pronouns in L1 Turkish of 24 Turkish-English bilinguals. Her findings showed, in line with her hypothesis, that attrition affected grammatical processing in a selective manner; following the ATH, Gürel's prediction was that the competition due to differences in frequency of use can only arise when there is a competing structure in the L2. When there are no corresponding linguistic structures in both languages, competition will not arise. This was borne out by Gürel's data: Turkish pronouns that have a correspondence in English tended to be processed as in English, while Turkish pronouns without an English equivalent did not show signs of L2 influence or attrition.

Later, Schmitt (2010) investigated the prediction of the ATH using data from 5 early Russian-English bilingual speakers who migrated to the US between 8–10 years and were adults at the time of testing. Spontaneous speech data collected in informal sessions were analysed both from a language contact perspective inspired by models proposed by Myers-Scotton (e.g. 2002) and using the perspective of the ATH. Schmitt concluded that while theories on language contact were informative in predicting the vulnerability of different types of grammatical morphemes, the ATH allowed her to account for frequency effects in lexical items. This points to the possibility that competition may arise in a more generalised manner

between lexical items, whereas, in the grammatical domain, competition remains restricted to very specific conditions, as demonstrated by Gürel (see also Dussias, this volume). What is furthermore interesting in Schmitt's findings is the implicit conclusion that attrition phenomena are hard to capture in one single framework. Rather, integrated combinations of different frameworks are needed in order to explain the complexity of attrition.

The straightforward relationship between frequency of use and attrition, as suggested by the ATH, has been seriously questioned in recent years (see Schmid, this volume, for an in-depth discussion). Instead, growing attention has been paid to competition in addition to frequency, as suggested by Gürel (2004). Competition is, of course, not only operating in attrition, but is a force at work in all bilinguals through the parallel activation of the two languages, as shown above. This is why neurolinguistic models of bilingual language processing—with at their foundation the influential Inhibitory Control Model (Green, 1998)—focus on the resolution of competition as the main specificity of bilingual language processing. Competition between the different languages of bilinguals and multilinguals has been demonstrated at nearly all linguistic levels (for recent reviews see Kroll, Dussias, Bice, & Perrotti, 2015, or Schmid & Köpke, 2017a). But the precise conditions for the occurrence of competition still need to be specified more precisely.

A comparison of the results from recent studies on bilingualism and attrition suggests that attrition is not qualitatively different from other manifestations of interaction between the languages in bilinguals. Rather, where 'normal' competition between the bilingual's languages ends and attrition starts seems merely a matter of degree (e.g. Köpke, 2018; Schmid & Köpke, 2017b). Indeed, that attrition is a phenomenon inherently tied to processing mechanisms is an option further developed in this volume by Sharwood Smith, Linck & Kroll, Dussias et al., for instance. Whether interaction in language processing may, ultimately,

lead to a restructuring of linguistic competence—if that exists!—remains an open question. What is clear, however, is that such a question cannot be resolved without taking into account the memory structures that are supposed to underlie such linguistic competence.

7.3. Language attrition as an affair of memory systems

Extending language processing accounts, cognitive scientists have for years investigated how the human brain deals with incoming information: How we learn, process, and how and where new information is retained, including what we know about words, grammatical rules, and so on. But whereas a substantial body of work has detailed how languages are learned and thus how new linguistic memories are formed, notably less attention has been paid to the other side of the coin: how languages are unlearned. Ecke (2004) explored how established psychological theories of forgetting (such as distortion, decay and cue dependency) can be used to explain linguistic attrition. But attrition work can in turn also aid in understanding the link between memory systems and language representation and processing.

Specifically, the declarative/procedural (DP) memory model of long-term memory has frequently been invoked in an attrition context (Paradis, 1994; Ullman, 2001). Ullman (2001, p. 106) defines declarative memory as being involved in the learning and use of factual knowledge (i.e., facts and events) that can typically be verbalized, so this knowledge is explicit. Procedural memory, by contrast, is involved in the learning and use—or rather control—of cognitive and motor skills that are sequenced in nature. This type of memory is typically automatized and therefore mostly implicit. In relation to language, lexical knowledge is typically labeled declarative, with grammar being assigned to procedural knowledge, but—interestingly in the context of attrition—there is a difference between earlier

vs. later learned languages in bilingual settings: whereas lexical knowledge—both in the L1 and L2—is declarative, grammar knowledge of the first language is mostly automatized and so procedural while L2 grammar mostly remains declarative (Köpke, 2007). It has been claimed that declarative knowledge can never become procedural, not even in very advanced L2 learners (Paradis, 2004). This, of course, has consequences for language attrition. It has been hypothesized that especially in post-puberty migrants not much grammatical interference from the L2 to the L1 will be witnessed, as both rely on distinct memory systems, but that L1 and L2 vocabulary items are likely to show considerable interference (Köpke, 2007), a claim that has been substantiated by empirical attrition research. Attrition itself can also feed back into theorizing within the DP model: How does declarative vs. procedural knowledge interact in attriters? Is it possible that procedural grammatical knowledge becomes weakened in attriters to the point where declarative knowledge takes over? And what role does age at emigration play in this? This taps into the evidence presented above that post-puberty migrants mostly show language processing difficulties in their L1 but no changes in their linguistic repertoires *per se*.

Earlier work on attrition as an affair of memory systems has in common that it has tended to rely on memory metaphors of misplacing language structures or words, ranging from file cabinets to storage bins (cf. Ecke, 2004). Even discussions regarding the DP model presuppose different storage facilities, although this has never been empirically substantiated. While neuropsychological evidence does point to different neural substrates subserving procedural and declarative memory, the question of storage is indeed not without controversy. Underlyingly, all memory metaphors view the mind as a processor, much like a computer, where files can be stored, replaced, and deleted. This idea has recently been completely rejected, framed by a Radical Embodied Cognition framework (cf. Chemero, 2013). Instead, changes in language skills within that framework are best captured as stemming from a direct

interaction between organisms and the world they live in: depending on a speaker's environmental input, language learning, unlearning, or even relearning occurs (Keijzer & de Bot, 2018). Although language use and environment are generally seen as important external predictors of attrition (cf. Köpke, 2007; Schmid, 2011), they are not commonly viewed as inherent determiners of the attrition process. But from a Radical Embodied Cognition perspective, languages (words and structures) are never truly lost but are rather associated with or embedded in a given context and upon triggers pertaining to that environment can be recalled. There is empirical attrition work to substantiate this claim, most iconically work that has been done on the savings paradigm.

First introduced by MacLeod (1976), the savings account makes predictions about which type of linguistic information is retained after periods of non-use of newly learned words. More specifically, MacLeod found meaning to be retained at the detriment of word forms. In other words, semantic information rather than phonological information tends to be 'saved'. Contrary to other memory metaphors, the savings paradigm works on the basis of input and associations. It was first applied to language attrition research by de Bot & Stoessel (2000), who investigated the retention of L2 Dutch after years of non-use by two German adults who had spoken Dutch for years following a move to the Netherlands but at the time of testing had not used the language for several years. Crucially, they also added a relearning task and found that the experimental participants scored significantly better on the relearning task than a control group who learned Dutch anew. This and a series of studies following it (e.g., Hansen, Umeda, & McKinney, 2002; Schneider, Healy, & Bourne, 2002) not only confirmed that residual (especially lexical) linguistic knowledge is present in memory, but that it can be retriggered based on input. In other words, associations are reactivated upon changing input patterns.

Also moving away from memory metaphors and instead basing language retrieval and failure on associations and input is the theory of retrieval induced forgetting (RIF, cf. Anderson & Spellman, 1995) that has its roots in the cognitive psychological theory of catastrophic interference (McClosky & Cohen, 1989). RIF has relatively recently come to be applied to attrition (see also Larson-Hall, this volume; Linck & Kroll, this volume). Under this theory, it is assumed that when one retrieves a piece of information, related knowledge is inhibited to avoid interference and—with time—such local inhibition can spread to global inhibition of a language system. A classic RIF paradigm consists of three phrases: familiarization, practice, and testing. Levy, McVeigh, Marful, and Anderson (2007) looked at attrition data invoking RIF. Their goal was to test the theory's prediction with a sample of L1 American students taking a semester of Spanish at college. They found that these students became progressively slower to name an L1 English item after the same item had been named 10 times in Spanish. Interestingly, when the word prompt was semantic in nature (e.g. naming the word *snake* upon seeing *venom* and cued with the initial word letter *s*.....), only a facilitation effect occurred; the retrieval induced forgetting effect instead characterized phonological prompts (i.e. presenting a prompt that rhymed with the target word; the same word *snake* but this time with the phonological prompt *break – s*.....). Although the numerically small effect of this study has been critiqued (Runnqvist & Costa, 2012), this research has offered an important step in understanding the nature of forgetting linguistic information and most notably the nature of language storage and retrieval without having to resort to memory metaphors such as storage bins or file cabinets. In terms of theorizing, such recent retrieval-induced forgetting inspired findings challenge the often imposed threshold that past attrition studies have set: speakers need to be away for a minimum of 10 years before L1 attrition effects emerge (cf. Köpke, 2017; Schmid, 2011). More specifically, the (ir)reversible nature of forgetting can be examined more closely: within the RIF framework, L1 will be reactivated upon more L1

input. Combining insights from the savings account and retrieval induced forgetting, it is evidently crucial to not only examine language decline that results from inhibition, but also to relate this to how that language developed in the first place and also whether it can be relearned and the circumstances that facilitate such relearning, or reactivation.

7.4. Language attrition as a brain mechanism

In recent years, the spectacular progress made in neurosciences has allowed us to reconsider a number of ideas about language and the brain that had been taken for granted for decades. While notions based on neurophysiological foundations, such as activation and inhibition for instance, have nourished psycholinguistic research on attrition from the beginning, current insights provided by neurosciences have hardly been taken into account yet in applied linguistics and specifically in research on language attrition. Research with monolinguals has allowed the development of very detailed models of the neural substrate and the time course of language processing (e.g., Friederici, 2012; Hickok, 2013; Hickok & Poeppel, 2004; Indefrey, 2011; Price, 2012). However, these are not, or only marginally, referred to in research on the processing of multiple languages in the bi- or multilingual speaker. Similarly, growing evidence from neurosciences strongly supports the idea of neural multifunctionality, defined as the constant and dynamic interaction of non-linguistic functions, i.e. cognitive, affective and praxic activity, with neural networks specialized for language (Cahana-Amitay & Albert, 2014, p. 1). Such multifunctionality has specifically been investigated with respect to the role of executive functions in language processing in speakers with and without language disorders and these functions have not only been shown to interact closely in cognition, but also rely largely on common neural networks (Zappalà, Thiebaut de Schotten,

& Eslinger, 2012). Despite the extensive debate on executive function benefits in bilinguals (e.g., Kroll & Bialystok, 2013), little to no reference is made to such insights in research on bilingualism or attrition.

The part of research that can be supposed to have the most direct impact on attrition research concerns neural plasticity. Recent research in neuro-rehabilitation, for instance, has challenged the notion of brain plasticity, which in turn questions the foundation of the critical period hypothesis (or related frameworks to account for age effects in language development). Accordingly, evidence from neuroscience clearly demonstrates that brain pathways are adapted when new skills are learned and that rapid functional and structural changes may occur not only in children but also in adults. Studies have shown that increased grey-matter density, associated with skilled behavior, can be measured after short periods of training in people learning to juggle (Draganski et al., 2006; Driemeyer, Boyke, Gaser, Büchel, & May, 2008), receiving training for working memory (Takeuchi et al., 2010) or music (Osterhout et al., 2008). But most importantly for our purpose, structural changes attributed to neural plasticity are also observed when people are involved in learning new speech sounds (Golestani, Molko, Dehaene, LeBihan, & Pallier, 2006) or exposed to a new language (Mecelli et al., 2004; White, Hutka, Williams, & Moreno, 2013). Findings from Osterhout, McLaughlin, Pitkanen, Frenck-Mestre, & Molinaro (2006) and Osterhout, Poliakov, et al. (2008) suggest that ERPs allow us to see changes arising as a function of classroom L2 instruction in the brain's electrical activity, in terms of the ERP components and the location of activity. Recent findings based on analyses of functional and effective connectivity in brain imaging data even suggest that it is possible to capture successful L2 learning using such techniques (Li & Grant, 2016).

As also suggested by these neurofunctional data, the early stages of learning a new task are critical and involve the greatest changes, a challenging finding for our conception of attrition. It is not known yet whether such neurofunctional impact on the L2 also has consequences on the existing L1 at these early stages of L2 immersion. On the other hand, it has also been suggested that expertise in multilingual language and control functions may reduce grey-matter density. Elmer, Hänggi, and Jäncke (2014) compared simultaneous interpreters and multilingual controls and found that simultaneous interpretation practice enhanced grey-matter density in some regions associated with language and control functions but reduced it in others. One can only speculate what the consequences of attrition on brain structure might be since studies on brain plasticity have for the moment focused exclusively on the skills to be learned (e.g. language acquisition) and not on the reorganisation of previously mastered skills (e.g. L1 processing). For the moment, thus, we have only behavioral evidence for (temporary?) changes in processing the L1 during the first stages of learning a new language (e.g., Chang, 2012; this volume) or in enhanced immersion contexts (Dussias & Sagarra; Dussias et al., this volume), in the future, this should be explored with neurophysiological and imaging data, as the contributions to this section suggest.

These new insights about neural plasticity underscore the huge capacity of adaptation and flexibility of the human mind. The notion of mental flexibility lies also at the very heart of the recent debate about the cognitive and neurological advantages of bilingualism, a topic that is out of the scope of the present volume (but see a special issue of Linguistic Approaches to Bilingualism, 2016, on this topic). Attrition has been labelled as a form of unbalanced bilingualism (see Schmid, 2011; Schmid & Köpke, 2017a, b, see also above), and is therefore in a unique position to shed light on bilingual theorizing. However, in order to do so, substantial work still needs to be done on psycho- and specifically neurolinguistic aspects of

attrition: Attrition has to take into account insights from neurosciences, but models of the neural networks of language also need to be able to account for the specification of bilingual language processing and development as in attrition. The links between attrition, as non-pathological language loss, and pathological language loss and disorders have to be elucidated. This is probably most urgent with respect to developmental language disorders where diagnosis of bilingual children is still difficult because we do not know enough on bilingual language development and attrition in young children (see Blom, Boersma, & de Jong, this volume). Finally, the debate on cognitive advantages in bilinguals should also take into account attrition and explain how the notion of cognitive advantages gained through the continuous need to inhibit one language is compatible with the observation that skilled bilinguals are not always able to inhibit the stronger, interfering language.

7.5. Section outlook

Adopting different psycholinguistic and neurolinguistics frameworks, the contributions in the present section not only provide a state of the art of neuro-psycho-linguistic approaches to attrition, but also uniquely show how attrition data can be used to inform psycholinguistic and neurolinguistics theories of language representation and processing.

Chapters 8–10 explore the origins of attrition within the specificities of more general bilingual language processing. Sharwood Smith (Chapter 8) reviews how language processing theories have been invoked in acquisition and attrition research. Treating both as instances of language development allows for a broader discussion of knowledge representations over time with language processing as the main driver underlying such changes. Within this framework,

attrition is treated as a manifestation of general cognitive processing limitations stemming from competition between two language systems. Also departing from bilingual language control more generally, Linck and Kroll (Chapter 9) posit that attrition is not language loss *per se* but rather reflects the dynamic outcomes of two constantly interacting language systems in flux. Focusing on the attrition of lexical retrieval, they build on the foundations of retrieval induced forgetting as a general memory mechanism that can have explanatory value regarding attrition. In this process, they also present more details regarding the constructs of inhibition and activation to show that even after very brief exposure times to the L2, the L1 can be impacted. In Chapter 10, Dussias, Valdés Kroff, Johns, and Villegas elaborate on this hypothesis, but do so in the context of morpho-syntactic processing. Their perspective can be pivotal in elucidating how the construct of competition differentially impacts the lexicon versus the grammatical system, as discussed above. For the morpho-syntactic domain too, Dussias et al. do not find evidence for true loss occurring as a function of L2 immersion, but rather that attrition is shaped by language processing changes. In this process, the authors show the usefulness of eyetracking as a device to show even fine-grained language processing changes in attriters.

The fact that attrition is governed by changes in bilingual language processing is further taken up by Chapters 11–13, which collectively address the links between pathological language dysfunction, which we know is governed by general cognitive abnormalities, and attrition. Blom, Boerma, and de Jong (Chapter 11) explore how the complementing nature of attrition and bilingual processing literature can help elucidate the diagnosis of bilingual children whose language (learning) abilities raise concern. Blom et al. discuss the difficulties in ascribing the deviances in language abilities to either bilingual processing or language disorders such as Specific Language Impairment (SLI). As the children this concerns often

have a migrant language background, insights from attrition could help in reaching a diagnosis. Higby, Lerman, Korytkowska, Malcolm, and Obler in their paper (Chapter 12) also explore methodological concerns, but in a fundamentally different way: they do not use attrition research to solve methodological issues in bilingual processing but rather point to methodological confounds within attrition research. Moreover, they move from child populations to the other end of the lifespan, namely older adults. Past attrition work has—often incorrectly as Chapters 8 to 10 demonstrate—adopted a minimum of 10 years of residence in the L2 environment as a subject recruitment criterion. Often coupled with a post-puberty age at emigration criterion, this has meant that many attrition findings are based on older adults. In their paper, Higby et al. describe the problem this poses: what is now ascribed to attrition could be more accurately labelled as aging effects. Focusing on the lexical domain, the authors show that aging and attrition exert different influences on lexical retrieval and aging therefore needs to be taken into account in any attrition endeavour. Staying in the older adult lifespan range, Barkat-Defradas, Gayraud, Köpke, and Lefebvre (Chapter 13) also emphasize the need to take aging into consideration, when they suggest to compare non-pathological language attrition with language changes in late-life acquired disorders, most notably Alzheimer's Disease (AD). It is especially the interaction between memory and language processing which has been amply studied in AD projects and that may lead to important insights for attrition research, the authors claim.

The papers in this section present the state of the art of neuro-psycho-linguistic approaches to attrition and pointing to applications of attrition data in bilingual language processing theorizing, but also point to future directions that could further advance the field of attrition. Chapter 14–15, then, introduce two innovative neuroimaging methods to the field of attrition, which until now has relied predominantly on behavioral evidence. Steinhauer and Kasparian

(Chapter 14) present the Event-related Potential (ERP) technique as particularly suited to advance attrition research due to the method's power to detect even subtle cognitive processing changes with a considerable level of detail. Importantly, ERPs cannot only detail L1 lexical processing changes, but can also tap changes in L1 morpho-syntactic processing, shedding unique light on the role of interlanguage competition within both domains. Rossi, Prystauka, and Diaz (Chapter 15) present another method to chart the neural oscillation changes in language attrition: functional Magnetic Resonance Imaging (fMRI). The method is described in detail as well as its application in studies examining L1 attrition in international adoptees (see also Pierce, Genesee, & Klein, this volume). Bringing the section fill circle with the initial Chapters 8–10, Rossi et al. suggest that functional and structural patterns of brain changes tapped through (f)MRI can be used as a test bed for the early stages of attrition, detailing the neural consequences of inhibiting an L1.

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