Bilingualism: Language and Cognition

cambridge.org/bil

Review Article

Cite this article: Reifegerste J (2021). The effects of aging on bilingual language: What changes, what doesn't, and why. *Bilingualism: Language and Cognition* **24**, 1–17. https://doi.org/10.1017/S1366728920000413

Received: 21 June 2020
Revised: 21 June 2020
Accepted: 21 June 2020
First published online: 26 August 2020

Keywords:
aging; bilingualism; second language; lexical processing; grammatical processing

Address for correspondence:
Jana Reifegerste,
Email: jana.reifegerste@gmail.com

The effects of aging on bilingual language: What changes, what doesn't, and why

Jana Reifegerste

Potsdam Research Institute for Multilingualism, University of Potsdam, Germany and Brain and Language Laboratory, Department of Neuroscience, Georgetown University, Washington DC, USA

Abstract

Substantial research has examined cognition in aging bilinguals. However, less work has investigated the effects of aging on language itself in bilingualism. In this article I comprehensively review prior research on this topic, and interpret the evidence in light of current theories of aging and theories of bilingualism. First, aging indeed appears to affect bilinguals' language performance, though there is considerable variability in the trajectory across adulthood (declines, age-invariance, and improvements) and in the extent to which these trajectories resemble those found in monolinguals. I argue that these age effects are likely explained by the key opposing forces of increasing experience and cognitive declines in aging. Second, consistent with some theoretical work on bilingual language processing, the grammatical processing mechanisms do not seem to change between younger and older bilingual adults, even after decades of immersion. I conclude by discussing how future research can further advance the field.

1. Introduction

The past thirty years have seen a steeply increasing interest in the topic of bilingualism in aging. Indeed, a Google Scholar search for relevant terms on this topic reveals an exponential increase in the scientific literature; see Figure 1.

This increase is hardly surprising. First, average global life expectancy has tripled over the course of human history (Wilmoth, 2000). In many countries, increases in life expectancy are explained in large part by decreasing death rates among the elderly (Mathers, Stevens, Boerma, White & Tobias, 2015; Wilmoth, 2000). In other words, not only is the global population increasing overall, but there is also a disproportional increase in the number of older adults. Second, we are living in an increasingly globalized world, and speaking more than one language is the norm these days (Baker & Prys Jones, 1998; Harris & Nelson McGhee, 1992; Tucker, 1999).

As a consequence, there is now a greater number of older people and of bilingual people in the world than ever before, rendering bilingualism in aging an important research topic. However, a closer look at the scientific literature on aging and bilingualism reveals that the lion's share of this work has investigated this topic from a 'cognitive reserve' angle, examining the cognitive abilities of aging bilinguals. These studies focus on the question of whether speaking more than one language confers benefits for non-language aspects of cognition in late life, such as attention or cognitive control (Abutalebi et al., 2015; Bak, Nissan, Allerhand & Deary, 2014; Bak, Vega-Mendoza & Sorace, 2014; Bialystok, Craik & Klein, 2004; Bialystok, Craik & Luk, 2013; Borsa et al., 2018).

In contrast, far fewer empirical studies have assessed the effects of aging on language itself in bilinguals. Moreover, theories of bilingual language processing have focused on language in younger individuals rather than in older adults or in aging. Thus, a comprehensive review of age effects on language in bilingualism[1] may provide an impetus for such models to be extended to aging. In this review I focus on two critical aspects of language in aging bilinguals, lexicon and grammar, specifically the representation and processing of simple words and of complex words (morphology) and sentences (syntax)[2].

I will distinguish between age effects on language PERFORMANCE (section 2), and on the MECHANISMS underlying language processing (section 3). The first type of age effect addresses to what extent chronological age influences HOW RAPIDLY AND ACCURATELY individuals perform in

[1] A note on terminology: this article uses the term 'bilingual' in a broad sense to refer to individuals who acquired more than one language at some point over the course of their life, regardless of when the languages were acquired and to what level of proficiency. Where relevant, I will use the terms 'early bilinguals' versus 'late bilinguals' and address the role of age-of-acquisition and proficiency.

[2] To date, there has been relatively little research on the effects of aging on other aspects of bilingual language, such as phonetics, phonology, or pragmatics; more studies in these areas are desirable. Moreover, in this paper I will not discuss the acquisition of a second language in aging, although this constitutes a relevant and interesting research topic; see, for example, Grognet (1997), Ingvalson et al. (2017), Kürten et al. (2012), and Lenet et al. (2011).

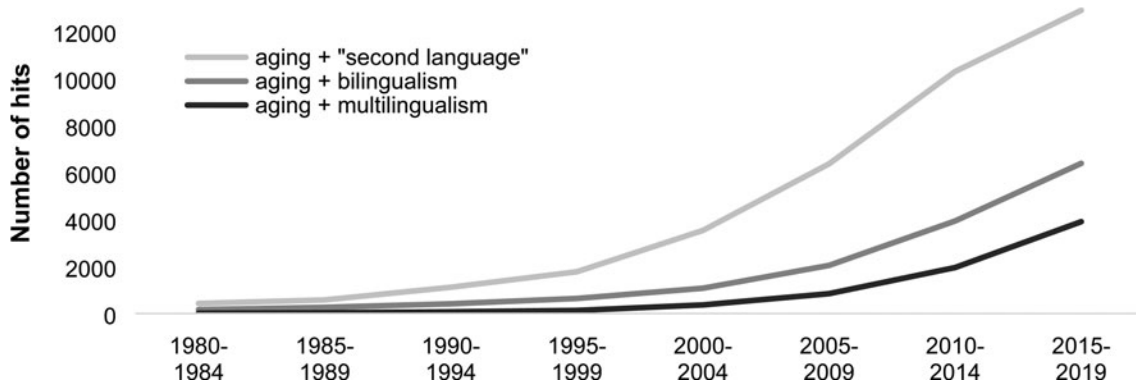

Fig. 1. Hits in Google Scholar for terms related to the topic of aging and bilingualism/multilingualism/second language (Retrieved June 14, 2020). A similar pattern is also found when controlling for the overall number of scientific papers from a given period.

language tasks. In particular, it is concerned with whether older second-language (L2) speakers are overall slower/faster and less/more accurate than younger L2 speakers at language tasks (i.e., effects of age for L2 speakers), and how these effects of age on speed and accuracy in L2 compare to those found in native (L1) speakers. The second type of age effect is concerned with HOW language is processed in aging bilinguals. That is, to what extent does chronological age affect the MECHANISMS that are involved in L2 processing, and do the mechanisms employed by aging L2 speakers become more or less similar to those employed by age-matched L1 speakers? Specifically, do L1/L2 differences in processing mechanisms that may (or may not) exist at earlier stages in life persist, decrease, or increase in aging?

This distinction between performance and the mechanisms underlying performance can be thought of as the distinction between EXPLANANDUM (i.e., a phenomenon to be explained) and EXPLANANS (i.e., the reasons for the phenomenon). The notion that age may differentially affect these two may seem surprising. However, as we will see, there are in fact remarkable differences in the extent to which chronological age affects measures of performance, on the one hand, and their underlying mechanisms, on the other.

2. The effects of aging on measures of language performance

In order to examine the effects of aging on language performance (RTs and accuracy), I will first lay out the principles and theories that lead to predictions for how aging affects performance in bilingual language (section 2.1). Second, I will examine to what extent the existing evidence lines up with these predictions (section 2.2).

2.1. The effects of aging on measures of language performance: principles and predictions

Across many domains of cognition, aging can be characterized as exerting two competing forces on performance, which can largely (though perhaps not completely) be captured under the terms crystalized and fluid abilities. On the one hand, the additional exposure and experience related to aging yield increased (crystalized) knowledge. Though traditionally viewed mainly in terms of factual knowledge, this could also be skill-based knowledge (see, e.g., Veríssimo, Verhaeghen, Goldman, Weinstein & Ullman, under review). On the other hand, as people age, various underlying (fluid) abilities that aid problem solving under novel conditions – such as processing speed, cognitive control, attention, and working memory – generally decline, largely due to deterioration in the underlying neural substrates (Fjell, Sneve, Grydeland, Storsve & Walhovd, 2017; Hasher & Zacks, 1988; Mather & Harley, 2016; Raz, Ghisletta, Rodrigue, Kennedy & Lindenberger, 2010; Salthouse, 1996). Stine-Morrow (2007) applied this concept of a “dynamic interplay between gains and losses” to (native) language performance in aging (p. 299).

These two principles should also hold for second language abilities: all else being equal (e.g., age of L2 acquisition, amount and type of daily exposure to the L1/L2), an older bilingual speaker as compared to a younger bilingual speaker both garners the benefits of increased language-related knowledge and is faced with declines in various neurocognitive abilities underlying language.

I address the two principles in the following two sections (2.1.1: increasing knowledge; 2.1.2: declining cognitive abilities) separately. In each section I first lay out the relevant principle, and then how the principle has been tied to performance measures in language tasks in YOUNGER ADULTS (citing evidence from both younger monolinguals and younger bilinguals), yielding CORRESPONDING PREDICTIONS for language abilities in aging in L2.

2.1.1. Age-related increases in language knowledge

Increasing age yields INCREASING LEXICAL KNOWLEDGE in both monolingual and bilingual speakers, due to greater cumulative exposure to the target language. Such lexical knowledge increases are generally measured as age-related increases in vocabulary size (Bialystok & Luk, 2012; Burke & Shafto, 2008; Facal, Juncos-Rabadán, Rodríguez & Pereiro, 2012; Stine-Morrow, Loveless & Soederberg, 1996).

In younger adults, increases in vocabulary size (in both monolinguals and bilinguals) have been tied to improvements in lexical performance measures – faster responses and/or greater accuracy – in a wide range of tasks, including lexical decision (Mainz, Shao, Brysbaert & Meyer, 2017; Yap, Balota, Sibley & Ratcliff, 2012), verbal fluency (Bialystok, Craik & Luk, 2008b; Hedden, Lautenschlager & Park, 2005; Shao, Janse, Visser & Meyer, 2014; Unsworth, Spillers & Brewer, 2011), picture naming (Bialystok et al., 2008b; Rodríguez-Aranda & Jakobsen, 2011), reading aloud (Gilhooly, 1984; Yap et al., 2012), spoken word recognition (Banks, Gowen, Munro & Adank, 2015), and lexical prediction (Federmeier, McLennan & De Ochoa, 2002).[3]

[3]While such a positive relationship between vocabulary size and lexical performance may appear intuitive, it is in explicit contrast to theories proposing that larger vocabularies should result in greater competition among lexical competitors, leading in turn to

https://doi.org/10.1017/S1366728920000413 Published online by Cambridge University Press

Thus, together the two factors – i) the observed age-related vocabulary increases and ii) the evidence from younger adults indicating a positive relation between vocabulary size and lexical performance measures – yield the prediction that aging in bilinguals (as well as monolinguals) could result in performance improvements in lexical tasks.

Turning to grammar, as we will see, there has been less work that has investigated either i) the effect of age on GRAMMATICAL (RULE) KNOWLEDGE, or ii) whether the extent of grammatical knowledge is correlated with performance in grammatical tasks in younger adults.

One reason for this may be that the operationalization of grammar knowledge is less straightforward than that of lexical knowledge. Grammaticality judgments are one reasonable measure of grammar knowledge (e.g., see Juncos-Rabadán, 1994). However, these should be untimed, since timed judgments might bias against older adults due to age-related processing speed decreases. A large-scale study by Gathercole et al. (2014) examined (apparently untimed) grammaticality judgments across the lifespan, in monolingual English native speakers and Welsh–English early bilinguals living in England and Wales, respectively. The study found that older adults performed better than younger adults on English sentences, though no difference between the age groups was found for Welsh sentences. This suggests that grammatical knowledge may be stable or improve in aging, in both bilingual and monolingual speakers.

Another method that may capture 'general' grammar knowledge is the use of proficiency or placement tests (e.g., Oxford Placement Test, Goethe Test), especially if they are untimed and do not focus much on lexical abilities. Keijzer (2013) assessed age effects on performance at the 'C-Test of Proficiency', a cloze test designed specifically to assess grammar proficiency in L1 and L2 speakers. Participants were middle-aged, young-old, and old-old L1-English speakers and L1-Dutch/L2-English speakers, all living in Australia. All participants were given a C-Test in English, and the Dutch speakers were also given the test in Dutch. Proficiency in all cases decreased with increasing age, consistent with decreasing grammatical knowledge in aging, despite older adults' much longer exposure to the two languages.[4] Nevertheless, it remains unclear whether these findings are generalizable, given that a) the C-Test was administered under time pressure (biasing against the oldest group) and b) education was negatively correlated with age (again biasing against the oldest group).

Thus, some evidence from grammaticality judgments suggests that grammar knowledge increases or remains unchanged with age, in both bilinguals and monolinguals, though the picture remains somewhat unclear.

What might be the effects of grammar knowledge on grammatical task performance? Within young-adult L2 speakers, performance in placement or proficiency tests (as well as length of exposure to an L2) has been shown to correlate positively with overall performance measures in various tests involving grammatical skills, including timed grammaticality judgments (Bruhn De Garavito & White, 2002; Foote, 2010; Han & Ellis, 1998; Sagarra & Herschensohn, 2010, 2012), sentence repetition (Meir, Walters & Armon-Lotem, 2016), sentence production (Blom & Baayen, 2013; Perpiñán, 2015), structurally-guided prediction (Dussias, Valdés Kroff, Guzzardo Tamargo & Gerfen, 2013; Leal, Slabakova & Farmer, 2016), and tasks tapping (morpho-)syntactically-guided comprehension (Montrul, 2011; White, Valenzuela, Kozlowska-MacGregor & Leung, 2004). However, given that it is still unclear whether grammatical knowledge improves, remains static, or even decreases in aging, it is difficult to make strong predictions about potential age-related changes in grammatical performance measures based on such knowledge.

Having discussed the (potentially) positive effects of older adults' increased knowledge on performance in lexical and grammatical tasks, I will now turn to the (potentially) negative effects of declining cognitive abilities on performance in these tasks.

2.1.2. Declines in age-sensitive cognitive abilities

Increasing chronological age during adulthood is associated with DECLINES IN NUMEROUS COGNITIVE ABILITIES, many of which underlie performance in lexical and grammatical tasks, at least in younger adults. Perhaps most dramatically, aging leads to various types of slowing, including of perceptual speed, cognitive speed, and motor speed (Kail & Salthouse, 1994; Salthouse, 1996; Salthouse & Kail, 1983). Within younger adults, faster performance in tasks assessing processing speed has been linked to faster performance in lexical tasks (Hertzog, Raskind & Cannon, 1986; Jardim de Paula, de Souza Costa, Laiss, de Miranda & Malloy-Diniz, 2013; Madden, 1992; Unsworth et al., 2011), leading to the prediction that age-related slowing may also yield slower performance for older adults in language tasks, in both first and second language.

Similarly, executive functioning, cognitive control, and working memory have generally been found to decline as adults age (Burke & Osborne, 2007; Carpenter, Miyake & Just, 1994; Dobbs & Rule, 1989; Foos, 1989; Hasher & Zacks, 1988; Hedden & Park, 2001; Kramer & Kray, 2006; Light & Anderson, 1985; Pliatsikas et al., 2018; but see McDonough, Wood & Miller, 2019; Veríssimo et al., under review). In turn, lower performance in all of these abilities has been associated with worse performance in tasks assessing lexical and grammatical abilities in younger monolinguals and bilinguals (Jackson & Bobb, 2009; Jardim de Paula et al., 2013; Linck, Osthus, Koeth & Bunting, 2014; Shao et al., 2014; Shao, Meyer & Roelofs, 2013; Shao, Roelofs & Meyer, 2012; Unsworth et al., 2011). Thus, it is reasonable to predict that age-related declines in such cognitive functions should lead to lower performance for older adults in language tasks that depend on these functions.

Further, one of the hallmarks of healthy aging is declines of declarative (episodic) memory (De Chastelaine, Mattson, Wang, Donley & Rugg, 2015, 2016; Nyberg, Lövdén, Riklund, Lindenberger & Bäckman, 2012; Park et al., 2002; Prull, Gabrieli & Bunge, 2000). A growing literature has linked declarative memory to performance measures in language tasks, such as lexical prediction (i.e., the anticipation of upcoming words) and lexical recall (Covington & Duff, 2016; Davis & Gaskell, 2009; Duff & Brown-Schmidt, 2012, 2017; Hamrick, Lum & Ullman, 2018; Reifegerste et al., 2020a; Ryskin, Qi, Covington, Duff &

slower performance in lexical tasks (Diependaele, Lemhöfer & Brysbaert, 2013; Ramscar, Hendrix, Shaoul, Milin & Baayen, 2014).

[4]All the L1-Dutch/L2-English speakers had grown up in the Netherlands speaking Dutch and all had acquired English as a late-learned L2 (after the age of at least 13). However, they differed in education (more education for the middle-aged than young-old than old-old groups; 19, 16, and 13 years, respectively), age-of-arrival in Australia (later ages-of-arrival for the younger groups; 34, 27, and 23 years, respectively), and, perhaps unsurprisingly, length of residence in Australia (shorter residence for the younger groups; 9, 37, and 55 years, respectively). Age-of-acquisition of English was not provided, though the authors did mention that the middle-aged participants were more likely to have received formal English instruction while living in the Netherlands than the older groups.

Brown-Schmidt, 2018; Ullman, 2001a, 2004, 2016; Warren, Rubin, Shune & Duff, 2018). Thus, these aspects of language may be negatively impacted in aging as well.

Lastly, both visual and auditory acuity decline during adulthood (Lindenberger & Baltes, 1994; Madden & Whiting, 2004; Schneider & Pichora-Fuller, 2000; Scialfa, 2002). In younger adults, these perceptual abilities have been implicated in mono- and bilingual language performance, including in tasks tapping word recognition and syntactic and morphological skills (Breadmore, 2007; Brysbaert & Nazir, 2005; Coppens, Tellings, Van der Veld & Schreuder, 2012; Kachlicka, Saito & Tierney 2019; Kelly, 1993, 1996; O'Regan, Lévy-Schoen, Pynte & Brugaillère, 1984; Saito et al., under review; Wauters, Van Bon & Tellings, 2006). Thus, perceptual declines in aging might likewise be expected to negatively impact language abilities in aging.

2.1.3. Summary

To summarize, aging is associated with changes that may exert opposing forces on language performance: increases in lexical and perhaps grammatical knowledge that should improve language performance, versus decreases in cognitive and sensory abilities that should instead negatively impact language. The actual outcomes of these forces on lexical and grammatical abilities in aging bilinguals are an empirical issue, and could in principle lead to improvements, declines, no changes, or (nonlinear) combinations thereof.

2.2. The effects of aging on measures of language performance: findings from aging bilinguals

In this section, I will discuss the empirical evidence regarding the role of age on performance in language tasks, in the context of the predictions laid out in the previous section. I will separately address tasks tapping lexical skills and tasks tapping grammatical skills (with the latter including both sentence-level and morphological tasks). In each case, I will first compare younger versus older bilinguals' performance, before examining how these age effects for bilinguals compare to corresponding age effects found for monolinguals. That is, do younger bilinguals perform better or worse than older bilinguals, and how does this difference compare to corresponding age effects for monolinguals? Additionally, I will also discuss the role of language dominance, drawing on the results of studies that have assessed the age trajectories of both languages WITHIN each participant (rather than comparing monolingual and bilingual speakers on the same target language).[5]

Note that (consistent with the vast majority of research on cognitive aging) all of the L2 studies discussed in this article examine age as a between-subjects variable. Moreover, the majority of studies operationalize age as a dichotomous rather than as a continuous variable, contrasting groups of younger adults (usually between 18 and 35 years of age) and older adults (usually above age 55 or 60). Thus, the terms 'aging' or 'increasing age' in fact refer to differences between different age groups.

2.2.1. Simple words

In tasks tapping lexical abilities, early and late bilingual speakers' RTs increase with increasing age (e.g., lexical decision: Johns, Sheppard, Jones & Taler, 2016; Reifegerste, Elin & Clahsen, 2019; picture naming: Gollan, Montoya, Cera & Sandoval, 2008). These age-related slowdowns mirror those found for (functionally) monolingual L1 speakers across lexical tasks (lexical decision: Balota, Cortese, Sergent-Marshall, Spieler & Yap, 2004; Myerson, Ferraro, Hale & Lima, 1992; Ratcliff, Thapar, Gomez & McKoon, 2004; reading aloud: Balota et al., 2004; Morrison, Hirsh & Duggan, 2002; picture naming: Feyereisen, Demaeght & Samson, 1998; Mortensen, Meyer & Humphreys, 2006). Few studies have directly compared the magnitude of these age-related slowdowns between L1 and L2 speakers – that is, whether the difference between younger and older bilingual speakers is smaller or greater than the difference between younger and older monolingual L1 speakers. The studies that did test for such an interaction between language group and age group did not find one, suggesting parallel age-related slowing for L1 speakers and bilinguals (Gollan et al., 2008; Johns et al., 2016; Reifegerste et al., 2019).

Accuracy shows a more nuanced pattern of results regarding bilingual speakers' lexical abilities in aging. The evidence suggests that effects of age on accuracy in lexical tasks may at least in part depend on the task in question. First of all, of the three lexical-decision studies on bilingual aging I am aware of, two found no accuracy differences between younger and older bilinguals (Goral, Libben, Obler, Jarema & Ohayon, 2008; Johns et al., 2016), while one reported greater accuracy for the older than the younger group of late bilinguals (Reifegerste et al., 2019). Of these studies, two compared the size of the age effect for their bilingual group with that of an L1 control group, and both found parallel age effects (Johns et al., 2016; Reifegerste et al., 2019). Indeed, such findings of age-related accuracy improvements or stability have commonly been found in L1-only lexical-decision studies (Allen, Madden & Crozier, 1991; Allen, Madden, Weber & Groth, 1993; Allen, Sliwinski & Bowie, 2002; Carroll, Warzybok, Kollmeier & Ruigendijk, 2016; Ratcliff et al., 2004; Reifegerste, Meyer & Zwitserlood, 2017; Robert & Mathey, 2007).

Second, a handful of studies have assessed how (early) bilinguals' ability to name words from their meanings (e.g., in picture naming) might change across the lifespan. The results from such studies have been mixed. Two studies found no age differences in younger versus older bilinguals' accuracy at naming pictures (Bialystok, Craik & Luk, 2008a; Johns et al., 2016), whereas one reported age-related declines (Gollan et al., 2008). All three studies found analogous aging patterns for monolingual/L1 speakers: that is, either age-invariance (Bialystok et al., 2008a; Johns et al., 2016) or declines (Gollan et al., 2008). The L1 age-invariance reported in two of these picture-naming studies is surprising, as it contrasts with numerous studies reporting reliable age-related declines in picture-naming tasks in monolingual/L1 speakers (e.g., Barresi et al., 2000; Connor et al., 2004; Feyereisen, 1997; Gollan et al., 2008; Mortensen et al., 2006). One reason for this discrepancy might be that both studies reporting age invariance (Bialystok et al., 2008a; Johns et al., 2016) used the Boston Naming Test (BNT; Kaplan, Goodglass & Weintraub, 1983), which, while useful in clinical settings (Duchek, Balota, Storandt & Larsen, 2007; Howieson et al., 1997), is not always sensitive to word-retrieval declines in healthy aging (LaBarge,

[5]The majority of studies on aging bilinguals' language abilities have compared younger and older bilingual speakers in their L2 with age-matched monolinguals in their L1. A smaller number of studies has assessed L1 and L2 abilities within-participants. This approach circumvents the oft-criticized problem of comparing individuals who may differ on demographic variables, cognitive abilities, and other factors (many of which may not be controlled for). However, within-participant studies instead are faced with the problem of between-item differences, such as word frequency or length differences in the items between the different target languages. Given their complementary nature, I discuss both types of studies.

https://doi.org/10.1017/S1366728920000413 Published online by Cambridge University Press

Edwards & Knesevich, 1986; Schmitter-Edgecombe, Vesneski & Jones, 2000; but see Ross et al., 1995). This overall pattern is in line with Gollan et al. (2008), who did not use the BNT and reported age-related accuracy declines in both monolinguals and bilinguals.

Verbal fluency tasks are also commonly used to assess language abilities. In these tasks participants name as many words as they can, either from a specific semantic category such as animals (category fluency), or starting with a specific letter such as the letter *s* (letter fluency). Because the dependent measure in these tasks is the number of correctly named words in a given amount of time, such tasks assess a combination of both accuracy and speed of word retrieval. Older bilingual speakers usually name fewer words in semantic fluency tasks in their L2 than younger bilingual speakers (Bialystok et al., 2008a; Johns et al., 2016). The picture is less clear for letter fluency, with one study again finding a disadvantage for older bilinguals as compared to younger bilinguals (Bialystok et al., 2008a), while another reported similar performance for younger and older bilinguals (Johns et al., 2016). None of these verbal fluency studies found an interaction between language group and age group, suggesting similar developmental trajectories during aging for L1 and L2. Overall, the observed pattern for verbal fluency in aging bilinguals is in line with studies focusing on L1 speakers, which have generally reported reliable and substantial age-related declines for category fluency, while letter fluency usually shows smaller and/or less reliable declines in aging (Brickman et al., 2005; Meinzer, Flaisch, et al., 2012; Meinzer, Seeds, et al., 2012; Meinzer et al., 2009; Tombaugh, Kozak & Rees, 1999).

A handful of studies has also examined the aging trajectories of lexical abilities for two languages WITHIN bilinguals – that is, do the two languages within a bilingual speaker's mind show the same changes (or lack thereof) from young into old adulthood? Such studies have mainly focused on whether language dominance might play a role in the extent to which age affects lexical performance (Birdsong, 2014; Gollan, Weissberger, Runnqvist, Montoya & Cera, 2012; Köpke & Schmid, 2004). These studies suggest that age-related declines are more pronounced in the nondominant than the dominant language. For example, Gollan et al. (2012) tested younger and older Spanish–English early bilinguals, who rated themselves as either Spanish-dominant or English-dominant, on Spanish and English versions of a picture-naming task, with accuracy as the dependent variable. Results for Spanish-dominant speakers revealed numerically better performance for older participants as compared to younger participants in the Spanish version of the task, but worse performance in the English version; the English-dominant speakers showed the reverse pattern. Statistical analyses of these comparisons were not provided.

The same group also examined picture-naming latencies and accuracy rates in younger and older English-Spanish early bilinguals (Gollan et al., 2008). The authors contrasted frequency effects between younger and older participants' dominant (English) and nondominant (Spanish) languages, seeking to characterize the role of exposure on the speed and accuracy of lexical access in the two languages. Younger adults showed smaller frequency effects (less of a performance difference between lower- and higher-frequency items) in their dominant than in their nondominant language – for example, smaller RT differences between *octopus* and *house* than between their Spanish equivalents *pulpo* and *casa*. Older adults, however, showed no such difference in frequency-effect size between the two languages. Instead, their frequency effects for both English and Spanish were of similar magnitude to those that younger adults showed for their dominant language English. The authors concluded that extended use of both languages during one's lifetime allowed the nondominant language to "catch up" with the dominant language, yielding comparable frequency effects in the two languages.

Note that whether the L1 or the L2 is considered dominant may differ from person to person as a function of different variables, including the age-of-acquisition of each of the two languages, their ultimate levels of attainment, and the degree and type of experience (or lack thereof) with the languages on a daily basis, among others. Moreover, across a person's lifespan, which of their two (or more) languages a person considers their dominant language may shift, as people move to another country, marry a person with a different language background, or work in a different language environment. This dynamic 'wax and wane of languages' (Grosjean, 2010, p. 85), which might also include the attrition of one's L1, further complicates the picture. See, for example, Chamorro, Sorace and Sturt (2016), Goral (2004), Kasparian and Steinhauer (2017) and Tsimpli, Sorace, Heycock and Filiaci (2004), for theoretical and empirical work on L1 attrition across the adult lifespan.

Finally, the evidence overall indicates that L2 and L1 performance measures in lexical tasks are similarly affected by aging. I suggest that these effects may indeed by explained by age-related cognitive declines as well as increases in knowledge, though I know of no study that has directly examined this issue.

Across studies, we have seen that reliable RT increases are found with increasing age, in both monolinguals and early and late bilinguals. Though none of the bilingual lexical studies independently measured non-linguistic processing speed, it is likely that such age-related RT increases in lexical tasks are at least in part the result of general age-related slowing. Indeed, some research has linked age-related lexical slowdowns in L1 to processing speed (Kail & Salthouse, 1994; Salthouse, 1996, 1998; Salthouse, Pink & Tucker-Drob, 2008; but see Finkel, Reynolds, Mcardle & Pedersen, 2007; Lawrence, Myerson & Hale, 1998), and it is likely that the same holds for slowing in bilinguals.

Accuracy rates show a more complex pattern, which appears to be affected by the nature of the task. Specifically, lexical-decision tasks yield either stable accuracy rates or age-related increases in accuracy in bilingual speakers, while tasks involving recall from meaning (e.g., picture naming or category fluency) yield age-related accuracy declines. As with age effects on RTs, the exact reasons for such age-related declines in bilingual lexical accuracy have not been directly assessed. Nevertheless, various accounts have suggested roles for age-related declines in cognitive functions such as executive function in word-retrieval declines in L1 (see section 2.1.2; see also Burke & Shafto, 2008, and Diaz, Rizio & Zhuang, 2016, for discussion of the role of cognition in L1 lexical abilities in aging). It is likely that such factors similarly affect age-related declines of L2 lexical abilities, notwithstanding potential cognitive reserve in older bilinguals' executive abilities. Age-related increases in accuracy, on the other hand, are most likely a consequence of increased exposure to the language under study, resulting in larger vocabularies. Note that it has been argued that increases in vocabulary size are associated with improved performance especially for lower frequency words (Burke & Shafto, 2008; Caza & Moscovitch, 2005; Gomez, 2002), which can also help explain the positive role for age-related exposure in lexical-decision tasks but not picture-naming tasks, since lexical-decision tasks often include items of lower average frequency than picture-naming tasks.

https://doi.org/10.1017/S1366728920000413 Published online by Cambridge University Press

Interestingly, when examining the trajectories of the two languages WITHIN-PARTICIPANTS, we have seen that studies report differences in the trajectories of the dominant versus the nondominant language, again consistent with a role for exposure. However, the exact nature of such possible exposure effects will need to be clarified in future work – it appears that exposure benefits lexical performance, but is it more beneficial for the dominant or the nondominant language? Several studies have suggested less of an age-related decline in the dominant language (and even numeric age-related accuracy increases in the dominant language in one picture-naming study; Gollan et al., 2012), but at least one study found the nondominant language to "catch up", with older early bilinguals responding faster to low-frequency words in their nondominant language than younger bilinguals (Gollan et al., 2008).

2.2.2. Sentences and complex words

Only two studies have assessed whether age affects bilingual speakers' performance measures (RTs, accuracy) in tasks targeting complex words and sentences (i.e., grammatical skills). I will therefore address these studies in a little more detail.

Reifegerste, Jarvis and Felser (2020b) examined syntactic agreement across the adult lifespan in L1-German speakers and highly proficient L1-English/L2-German speakers. Participants performed a binary-choice sentence-completion task: they indicated whether a sentence preamble such as *The letter from the diplomatic lawyers* should be followed by a singular or a plural verb form. L1 speakers' accuracy rates were generally at ceiling across conditions over the whole age range (though they did become more susceptible to a specific type of agreement error; see section 3.2 below). In contrast, L2 accuracy IMPROVED with increasing age – there was no difference in accuracy levels between the oldest L1 and L2 participants (aged 60+), whereas at younger ages accuracy was lower for L2 than L1. At the same time, L1 speakers' RTs increased with increasing age, whereas L2 speakers showed no signs of slowing in the task; instead, their RTs remained stable across the adult lifespan. Interactions between age and language group confirmed the different age trajectories for both accuracy rates and RTs in the two groups. The authors argued that increasing exposure to the target language increased L2 speakers' accuracy and offset any speed declines that may have occurred as a consequence of age-related slowing. L1 speakers' performance, in contrast, was already at ceiling in young adulthood and could therefore not increase. It is worth noting that agreement computation, the grammatical phenomenon of interest in this study, has been claimed to be notoriously difficult for L2 speakers (Chen, Shu, Liu, Zhao & Li, 2007; Grüter, Lew-Williams & Fernald, 2012; Keating, 2009; Lardiere, 1998; Sato & Felser, 2010; Shibuya & Wakabayashi, 2008; VanPatten, Keating & Leeser, 2012), while it is generally relatively error-free for L1 speakers (Bock, 2004), allowing L2 speakers substantial "room for improvement" over the course of the lifespan.

The other study, by Juncos-Rabadán (1994), compared performance at various language abilities between healthy younger, middle-aged, and older bilingual participants, in both of their early-acquired languages (dominant: Spanish; nondominant: Galician), using the Bilingual Aphasia Test (BAT; Paradis, 1987). The results yielded robust age-related declines across the three age groups in accuracy in several syntactic tasks (syntactic comprehension, sentence production, grammaticality judgment) and in a morphological task (tapping derivational morphology), in both languages. Moreover, the two languages showed similar aging trajectories, with the exception of the morphological task, in which participants were asked to produce an adjective from its derived noun (e.g., *claridad* 'clarity' → *claro* 'clear'). This task instead yielded greater age-related declines for the nondominant as compared to the dominant language (see interaction in Table 3 in the paper), though it is not clear whether the declines for the dominant language were just smaller or nonexistent.

What conclusions can we draw from these two studies? Crucially, it appears that AGE AFFECTS BILINGUAL SPEAKERS' MEASURES OF PERFORMANCE IN GRAMMATICAL TASKS (i.e., speed and accuracy), as is also the case for lexical tasks. In contrast to lexical abilities, in which L1 and L2 performance show largely similar lifespan trajectories, L1 and L2 grammar performance appears to show at least somewhat different aging patterns. Reifegerste et al. (2020b) found generally stable accuracy and increasing RTs for L1 speakers' grammatical skills across the adult lifespan, but accuracy improvements and stable RTs for the L2 group. Although Juncos-Rabadán (1994) reported similar aging trajectories for the dominant and nondominant language in several grammatical tasks, a morphological production task showed different patterns in the two languages, with greater declines for the nondominant language than for the dominant language.

Why do these two studies show different patterns? One reason for the apparent discrepancy might be differences in the ages-of-acquisition (AoAs) of the languages being examined. In the study by Reifegerste and colleagues (2020b), L2 speakers had an L2-AoA of at least 15 years of age, rendering these participants truly late bilinguals. The participants in Juncos-Rabadán (1994), on the other hand, were living in Galicia, a bilingual region of Spain, where they presumably grew up exposed to both languages, though no specific AoA information was provided. As such, the declines in grammatical abilities displayed by participants in Juncos-Rabadán's (1994) study for both languages may be best understood as resembling the declines that are often found for L1 speakers in grammatical tasks (Kemtes & Kemper, 1997; Kwong See & Bouchard Ryan, 1995; Peelle et al., 2010; Reifegerste & Felser, 2017; Stine-Morrow et al., 2000; Waters & Caplan, 2001; but see Altmann & Kemper, 2006; Davidson, Zacks & Ferreira, 2003), which were, to an extent, also found in L1 by Reifegerste et al. (2020b). The L2 findings in Reifegerste et al. (2020b), on the other hand, reflect the trajectory of measures of grammatical abilities of a late-learned L2, for which performance at younger-adult ages may lag behind that of L1 speakers, and for which additional exposure leading to increased knowledge can yield performance increases.

A similar account may help explain why grammar shows different aging patterns in L1 and L2, whereas the L1/L2 patterns are similar for lexical abilities. In particular, the acquisition of (certain aspects of) grammar tends to lag behind the acquisition of lexical items during L2 acquisition (DeKeyser, 2005), which can result in younger-adult L2 speakers not yet performing at ceiling in grammar tasks, especially if the L2 was learned relatively late in life. This allows age-related performance declines in the L2 (that are in fact apparent for native speakers) to be offset by performance increases due to increased exposure to the target language.

Given the evidence presented in this section for age-related changes to outcome measures of bilingual language performance, we may ask whether similar changes are found for the linguistic processing mechanisms that underlie this performance. That is, are the age effects on speed and accuracy in language tasks laid out in this section due to age-related changes in HOW language is processed? Or is it perhaps the case that the same underlying

https://doi.org/10.1017/S1366728920000413 Published online by Cambridge University Press

processing mechanisms are at play for younger versus older bilinguals, but at a different speed and/or with different success? In the next section I address this issue.

3. The effects of aging on underlying linguistic processing mechanisms

Here I will discuss whether aging affects the underlying linguistic processing mechanisms in L2, and how such aging effects (or lack thereof) may tie in with different theories of bilingual language processing. For measures of language performance (see previous section), there is a clear "optimum" that one might strive for: correct responses that are given as fast as possible. The situation is less clear for the linguistic mechanisms underlying language performance, as there is not necessarily a best way to process any given linguistic input or output. For example, there is nothing inherently "better" about decomposing an inflected word into its morphological constituents, as compared to whole-word retrieval from memory. Thus, the critical comparison here with regards to processing mechanisms will be the extent to which L2 processing appears to differ from L1 processing, and how such L1/L2 differences might be affected by aging. Potential outcomes fall into three broad categories (laid out in Figure 2): processing differences that are postulated to exist between L1 and L2 speakers may decrease in extent with increasing age (panel A); differences may increase (or emerge) with increasing age (panel B); or differences may persist and stay relatively stable across the lifespan (panel C). Note that changes in processing differences between L1 and L2 during aging could come about due to changes WITHIN a given mechanism (e.g., increasing difficulties with lexical access) and/or changes regarding WHICH underlying processing mechanisms are relied on (e.g., decomposition vs. whole-word retrieval).

3.1. The effects of aging on underlying linguistic processing mechanisms: theories and predictions

In this section, I will discuss each of the three broad possible trajectories outlined above, along with the theories of bilingual language processing that each pattern appears to be most consistent with. In each case, I will briefly outline the theories, which have thus far addressed processing in young-adult bilinguals, together with relevant supporting findings. I will then discuss their implications for language in aging bilinguals,

First, L1/L2 differences in effects such as morphological priming or agreement attraction at young-adult ages may DECREASE with increasing age, suggesting that the processing mechanisms employed by L2 speakers become more native-like. Such an outcome may be most in line with experience- or usage-based models of L2 processing. Here I discuss two such models.[6]

One model with such implications is the DECLARATIVE PROCEDURAL (DP) MODEL (Ullman, 2001a, 2001b, 2005, 2016, 2020). According to the DP model, language learning and processing depends on two general-purpose learning and memory systems: declarative memory and procedural memory. In L1 speakers, declarative memory is posited to underlie arbitrary aspects of language, such as idiosyncratic lexical knowledge and irregular morphology, while procedural memory subserves rule-based aspects of language, such as in syntax and regular morphology. In contrast, in L2 speakers both lexical and grammatical processing are posited to rely heavily on declarative memory, in particular during early stages of L2 acquisition. Greater experience, however, is argued to lead to more native-like behavioral and neurocognitive grammatical processing, as grammatical knowledge becomes proceduralized – that is, as grammar is learned increasingly in procedural memory. Converging neurocognitive evidence appears to support the model in young adults (Ullman, 2020). According to this view, we may predict that, all else being equal, older L2 speakers, who have had more L2 experience than younger L2 speakers, should have proceduralized the grammar to a greater extent than younger individuals, and thus should be more L1-like in their processing. Moreover, declarative memory, along with its neural substrates (medial temporal lobe structures, including the hippocampus), shows reliable declines as people age (see section 2.1.2), while procedural memory does not (at least with regards to learning simple structures; Frensch & Miner, 1994; Howard, Dennis, Howard, Yankovich & Vaidya, 2004; Howard & Howard, 1989, 1992). This further strengthens the prediction that L2 grammatical abilities should rely more on procedural than declarative memory with aging, and thus should be more L1-like.

A pattern of age-related decreases in L1/L2 processing differences might also be in line with models that hypothesize that a key locus of L1/L2 differences is L2 speakers' particular difficulties with lexical access – rather than assuming different mechanisms of grammatical processing, as the DP model does. In particular, the LEXICAL BOTTLENECK HYPOTHESIS (Hopp, 2014) proposes that lexical access is less automatized in L2 speakers as compared to L1 speakers, and thus is more effortful, which in turn leads to fewer cognitive capacities being available for L2 syntactic processing. Indeed, within young adults, L2 speakers who display greater lexical access automaticity (e.g., as a function of L2 proficiency) show diminished sentence-processing differences as compared to L1 (Hopp, 2014).

Consistent with such experience-based models, behavioral and brain evidence suggests that young-adult L2 speakers with greater experience and/or proficiency show grammatical processing patterns that are more L1-like (Bel, Sagarra, Comínguez & García-Alcaraz, 2016; Bowden, Steinhauer, Sanz & Ullman, 2013; Friederici, Steinhauer & Pfeifer, 2002; Herbay, Gonnerman & Baum, 2018; Morgan-Short, Finger, Grey & Ullman, 2012; Morgan-Short, Sanz, Steinhauer & Ullman, 2010; Morgan-Short, Steinhauer, Sanz & Ullman, 2012; Perani et al., 1998; Sagarra, Sánchez & Bel, 2019; Steinhauer, 2014; Steinhauer, White & Drury, 2009). Thus, on this view it is reasonable to predict that with increasing L2 experience in aging, lexical access should become more automatized, and thus grammatical processing should become increasingly L1-like.

Second, it is possible that any L1/L2 processing differences observed in young adulthood INCREASE as people age, or that differences not present in younger adults start to emerge with increasing age. Such findings appear to be in line with models of bilingual language processing proposing that on-line L2 grammatical processing (e.g., sentence or morphological processing) is inherently more cognitively demanding than L1 grammatical processing (Cunnings, 2017; Foote, 2011; Hopp, 2006, 2010; McDonald, 2006; McDonald & Roussel, 2010; Sagarra & Herschensohn, 2010). According to most such CAPACITY- or RESOURCE-BASED MODELS, the processing mechanisms underlying native and non-native language processing are inherently similar,

[6]See also Green (2003), MacWhinney (2001), and Paradis (2009) for other experience-based models proposing that L2 grammar in young adults can become native-like as a function of increasing L2 experience and/or proficiency.

https://doi.org/10.1017/S1366728920000413 Published online by Cambridge University Press

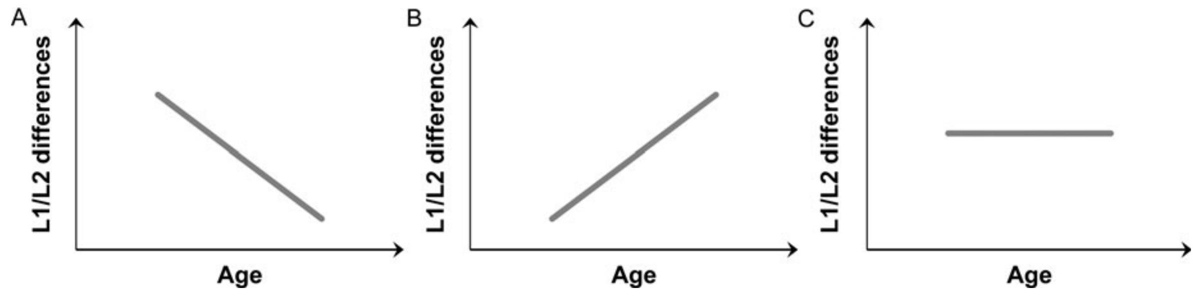

Fig. 2. Broad outcomes of likely age trajectories of L1/L2 processing differences (e.g., as suggested by differences in morphological priming effects): decreasing differences (A), increasing differences (B), or differences (or lack thereof) that persist (C). Combinations of these trajectories are of course also possible (e.g., decreases followed by increases), yielding nonlinear effects. These may be revealed by future studies using continuous age designs across the adult lifespan with nonlinear analyses, rather than studies employing categorical designs that contrast younger versus older adult groups. Moreover, newer statistical approaches, such as generalized additive mixed models (GAMM; Baayen et al., 2017), which are not yet widely used in research on language in aging, will likely reveal more complex patterns.

but L1/L2 differences come about as a consequence of the L2 imposing greater cognitive demands: for example, on working memory (Coughlin & Tremblay, 2013; Herbay et al., 2018; McDonald, 2006; Service, Simola, Metsänheimo & Maury, 2010), speed (Kaan, Ballantyne & Wijnen, 2015), or perceptual phonological decoding abilities (Kilborn, 1992; McDonald, 2006; McDonald & Roussel, 2010). It has also been argued that L2 speakers might experience greater interference than L1 speakers when retrieving information from memory during sentence processing (Cunnings, 2017). Evidence for such accounts in young-adult L2 speakers comes from studies reporting correlations between measures of cognitive resources and grammatical performance (McDonald, 2006; McDonald & Roussel, 2010). Similarly, in a study in which L1 speakers were put under cognitive stress (e.g., increased cognitive load or noise), their grammatical performance mirrored that shown by L2 speakers (McDonald, 2006). Moreover, it appears that certain grammatical phenomena are more prone to interference from limited cognitive capacity than others, in both younger L1 speakers under cognitive stress and younger L2 speakers; for example, regular inflectional morphology seems to be more vulnerable in both such circumstances than word order (Blackwell & Bates, 1995; McDonald, 2006).

Given well-established age-related declines in such cognitive abilities (see section 2.1.2), one implication of these models might be that L1/L2 grammatical processing differences should increase with aging – at least to the extent that L2 speakers' cognitive abilities decline to the same extent and in a similar manner as L1 speakers', which some evidence suggests (Anderson, Saleemi & Bialystok, 2017; Antón, García, Carreiras & Duñabeitia, 2016; Cox et al., 2016; Gathercole et al., 2014; Kirk, Fiala, Scott-Brown & Kempe, 2014; Kousaie & Phillips, 2012; Kousaie, Sheppard, Lemieux, Monetta & Taler, 2014; Nichols, Wild, Stojanoski, Battista & Owen, 2020). In this case, we would expect that older L2 speakers' grammatical processing differs more from that of age-matched L1 speakers, as compared to L1/L2 differences found at younger age. This may hold especially for aspects of grammatical processing that have been shown to be particularly taxing for cognitive abilities, such as inflectional processing (Blackwell & Bates, 1995; McDonald, 2006). Further, these models would predict that measures of older L2 speakers' language processing abilities should correlate particularly with individual-differences measures of cognitive abilities, such as working memory.

Third, the extent of L1/L2 processing differences may remain unchanged with increasing age. In this case, any differences in processing that exist between L1 and L2 speakers PERSIST into old age. A persistence of L1/L2 differences is largely in line with the SHALLOW STRUCTURE HYPOTHESIS (SSH; Clahsen & Felser, 2006a, 2006b, 2006c, 2018), which assumes the existence of two different grammatical processing routes: a full parsing route that yields fully-specified syntactic representations of the input on the one hand, and a shallow, 'good enough' route using other sources of information (e.g., distributional properties of the language, discourse-level/pragmatic cues, lexical-semantic information, associative patterns) on the other. It is argued that L2 speakers rely less on grammatical parsing and more on 'good enough' processes. Reasons for this differential reliance might include insufficient grammatical knowledge (e.g., absent or differently weighted constraints) or differences in L2 versus L1 processing (e.g., greater L2 reliance on non-grammatical information).[7]

Evidence in favor of the SSH comes from studies of younger adults suggesting that even highly proficient L2 speakers (including those with high working-memory abilities; Felser & Roberts, 2007) show less reliance on fully-specified structural representations or grammatical parsing than L1 speakers during online processing – even though their untimed offline performance (e.g., in comprehension questions) often resembles that of native speakers (Felser & Roberts, 2007; Felser, Sato & Bertenshaw, 2009; Marinis, Roberts, Felser & Clahsen, 2005). Instead, L2 speakers in these studies have been found to rely, for example, on lexical-semantic cues during ambiguity resolution (Felser, Roberts, Marinis & Gross, 2003; Papadopoulou & Clahsen, 2003) and long-distance wh-movement (Marinis et al., 2005), on discourse-pragmatic information during anaphor resolution (Felser et al., 2009), or on whole-word processing of morphologically complex inflections (Veríssimo, Heyer, Jacob & Clahsen, 2018). Thus, according to the SSH, L1/L2 processing differences are not necessarily due to a relative lack of exposure or greater cognitive demands. Therefore, studies that find that L1/L2 grammatical processing differences do not change with increasing age may be particularly in line with this theory.

To summarize, when assessing the effects of aging on the mechanisms that underlie L2 processing, with the critical measure being the extent to which L1 and L2 processing differ from one another, it appears that different aging trajectories of L1/L2 processing differences are broadly consistent with different models of

[7]Though note that the SSH explicitly claims that some aspects of L2 grammatical processing could in principle become native-like, such as derivational processing or local dependencies (Clahsen & Felser, 2006c, 2018; Veríssimo et al., 2018).

https://doi.org/10.1017/S1366728920000413 Published online by Cambridge University Press

L2 processing. To the best of my knowledge none of these models in their current forms has made explicit predictions about effects of chronological age on L2 processing, let alone tested such predictions. Thus, any inferences made for bilingual aging here are strictly logical extensions of these models, rather than claims made by the models themselves.

3.2. The effects of aging on underlying linguistic processing mechanisms: findings from aging bilinguals

In this section I will discuss findings from empirical research examining the effects of age on the processing mechanisms underlying L2, as compared to L1, and how these empirical findings line up with the trajectories outlined in section 3.1. As in the previous section, I focus here on grammar, including both syntax and morphology, as I am not aware of any study that has assessed age effects on the mechanisms involved in L2 (vs. L1) lexical processing.

3.2.1. Syntax

As regards syntax, a study by Reifegerste et al. (2020b) (see also section 2.2.2), which tested L1-German and L1-English/L2-German speakers, suggests some interesting insights into sentence-level processing in a late-learned L2 across the adult lifespan. The study investigated agreement attraction errors, a syntactic phenomenon in which the verb of a clause agrees not with the subject noun phrase (NP) of that clause but rather with a "distractor NP" (e.g., **The key to the cabinets were rusty*). Though L1 agreement computation is relatively error-free in general, both younger and older L1 speakers do sometimes make and fail to notice such attraction errors (Bock & Miller, 1991; Pearlmutter, Garnsey & Bock, 1999; Reifegerste, Hauer & Felser, 2017; Wagers, Lau & Phillips, 2009). These errors are more common in clauses with singular subject NPs and plural distractors (**The key to the cabinets were…*) than in clauses with plural subject NPs and singular distractors (**The keys to the cabinet was…*) (Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Haskell & MacDonald, 2005). Reifegerste et al. (2020b) replicated this asymmetry for L1 speakers across the adult lifespan. However, L2 speakers of all ages instead displayed a symmetric attraction pattern in their accuracy rates, with attraction effects of similar size for singular-plural and plural-singular preambles. The authors argued that one explanation for the different patterns might lie in differences in how the L1 speakers and the L2 speakers encoded the subject NPs. The asymmetric pattern displayed by L1 speakers is often argued to be a consequence of different representations of singular versus plural NPs. For example, it has been proposed that the latter's plural feature renders it more likely to overwrite the number feature of the (unmarked) singular subject NP than vice versa (Bock, 2004; Eberhard, 1997; Eberhard, Cutting & Bock, 2005; Pearlmutter et al., 1999), or that plural NPs are more salient in memory than singular NPs (Phillips, 2013; Staub, 2009). L2 speakers' symmetric attraction pattern across the lifespan then suggests that (in contrast to L1 speakers) their representations of singular NPs and their representations of plural NPs are similar to one another, and that this did not appear to change with increasing age. This could come about, for example, because both younger and older L2 speakers are more likely to assign (equally) shallow structures to singular and plural NPs, in contrast to L1 speakers' more full-fledged hierarchical representations.

Interestingly, the older L2 participants in this study are the same as those mentioned in section 2.2.2, whose overall accuracy rates were on par with those displayed by age-matched L1 speakers. Yet, their particular accuracy pattern was different from that of age-matched L1 speakers, suggesting L1/L2 differences in the underlying grammatical processing mechanisms. Moreover, as we have seen, these patterns did not appear to be modulated by age across the adult lifespan, suggesting that the processing mechanisms were not affected by aging in either L1 or L2.

A second key finding from this study concerns the involvement of (age-sensitive) cognitive abilities. The size of the symmetric attraction effect displayed by the L2 speakers was modulated by measures of both non-linguistic working memory and non-linguistic interference control. That is, there were smaller attraction effects for L2 participants with greater working-memory spans and better interference control. For L1 speakers, on the other hand, none of the various individual-differences measures assessed (including also processing speed and short-term memory) modulated the size of the attraction effect. These findings suggest a greater involvement of cognitive functions, such as working memory or interference control, in L2 sentence-level processing, as compared to L1 processing, across the adult lifespan.

3.2.2. Morphology

A handful of studies by Clahsen and Reifegerste have assessed the mechanisms underlying L1 and L2 regular morphological processing in aging. Such studies tap the effect of age on grammatical processing at the word level. In a masked priming study, Reifegerste et al. (2019) investigated derivational and regular inflectional priming in younger and older L1-German speakers and participants who had learned German as a late-learned L2. Whereas both the L1 and L2 speakers showed significant derivational priming (e.g., *Warnung* – *warnen*, 'warning' – 'to warn'), only the L1 speakers showed an inflectional priming effect (e.g., *gewarnt* – *warnen*, 'warned' – 'to warn'). Crucially, the respective priming patterns displayed by L1 and L2 speakers were not affected by chronological age. The authors argued that, in line with previous studies (e.g., Veríssimo et al., 2018), a person's ability to extract inflectional rules from the input during language acquisition becomes progressively compromised after childhood, and thus even several decades of additional exposure to the target language are not sufficient to lead to native-like inflectional processing in adult L2 learners who acquired the target language after childhood. Such findings of relative age invariance in regular morphological priming effects were also reported by Clahsen and Reifegerste (2017), who found no effects of age on L1 and L2 speakers' respective cross-modal priming effect sizes for regular German participles.

Lastly, an fMRI study by Prehn, Taud, Reifegerste, Clahsen and Flöel (2018) assessed the neural substrates of morphological processing as older L1 and L2 speakers performed grammaticality judgments on correctly or incorrectly inflected regular and irregular German participles. Despite having learned their late-acquired L2 to high proficiency, older L2 speakers showed particular difficulty at rejecting incorrect forms (of either regularity type). This difficulty was mirrored by increased activation in the bilateral medial superior frontal gyrus (SFG) when older L2 speakers responded to incorrectly (vs. correctly) inflected participle forms, as compared to the L1 control group. In previous studies, this area has been associated with task monitoring in general (du Boisgueheneuc et al., 2006; Schel et al., 2014). Moreover, it is part of/proximal to an area of the brain thought to underlie language control, which includes the dorsal anterior cingulate cortex (dACC) and the pre-supplementary motor area (pre-SMA), among other regions (cf. the Language Control model and Adaptive Control Hypothesis; Abutalebi & Green, 2016; Green & Abutalebi, 2013). The authors suggest that L2 morphological processing in aging requires the recruitment of additional executive control resources, as compared to L1 processing. However, the study did not include a young-adult control group, so it is not clear whether such an increased demand of executive control during L2 morphological processing would be equally present throughout adulthood; whether it might come about at later stages (perhaps as a function of such abilities declining); or whether it might decrease with older age (due to increasing exposure facilitating processing).

3.2.3. Summary and implications for theories of bilingual language processing

In sum, one study examining the role of chronological age in L2 versus L1 sentence-level processing, and a handful of studies investigating the processing of complex words in aging L2 and L1 speakers, suggest that age does not seem to substantially affect underlying grammatical processing mechanisms, in either L1 or L2. Thus, these studies indicate that even several decades of (often immersive) exposure to a (late-learned) L2 do not render an L2 speaker's underlying processing mechanisms native-like. Rather, processing differences that existed in early adulthood persist during aging.

Interestingly, the age-related persistence of processing mechanisms discussed above for both agreement and inflectional morphology may in fact be related to the processing of regular inflection, in both nouns and verbs (e.g., *keys* and *warned*). It has often been argued that whereas such forms are generally compositional in L1 speakers (e.g., [key]+[-s] or [warn]+[-ed]) (Clahsen, 1999; Clahsen, Eisenbeiss & Sonnenstuhl, 1997; Pinker, 1999; Pinker & Ullman, 2002; Sonnenstuhl, Eisenbeiss & Clahsen, 1999), they are assumed to be stored and processed as whole words (potentially without any morphosyntactic structure; e.g., [keys] or [warned]) in L2 (Clahsen & Felser, 2006c; Ullman, 2001b, 2020). Crucially, as we have seen, this distinction appears to persist across the L2 adult lifespan (Jacob, Fleischhauer & Clahsen, 2013; Jacob, Heyer & Veríssimo, 2017; Reifegerste et al., 2019), and may help explain not only the inflectional morphological findings (section 3.2.2) but also the results from syntactic agreement (section 3.2.1). Such age invariance, as well as this particular pattern, seems to be line with predictions of the Shallow Structure Hypothesis (Clahsen & Felser, 2006a, 2006b, 2006c, 2018), which posits that L2 speakers are more likely than L1 speakers to assign shallow or "flat" structures (rather than full-fledged hierarchical structures) to complex grammatical representations.

In contrast, the findings presented above are not obviously consistent with experience- or usage-based models such as the Declarative/Procedural model or the Lexical Bottleneck hypothesis, which may expect that increased exposure to the language leads to more native-like processing. It remains unclear why such models have substantial explanatory power in younger adult L2 speakers, for whom greater experience and/or proficiency are associated with greater L1-like grammatical processing (see section 3.1), even while such changes are not observed during aging.

Interestingly, some evidence from the studies discussed above also suggests that L2 grammatical processing across the adult lifespan yields greater involvement of cognitive abilities, such as working memory and cognitive control, as compared to L1 processing (Prehn et al., 2018; Reifegerste et al., 2020b). At first blush, this may appear to be in line with capacity- or resource-based models, which argue for a greater need for such limited resources during L2 than L1 grammatical processing. However, while Reifegerste et al. (2020b) found that L2 speakers' performance at the working-memory and interference-control tasks was inversely correlated with attraction effects in the agreement-processing task, high levels of performance at these non-linguistic cognitive tasks did not yield a native-like pattern at the agreement-processing task in L2 speakers: across all levels of such cognitive abilities, L1 speakers showed an asymmetric attraction pattern, while L2 speakers showed a symmetric attraction pattern (see section 3.2.1). This suggests that capacity- or resource-based models cannot fully account for L2 grammatical processing mechanisms across the lifespan.

More research on the effect of aging on bilingual grammar processing is clearly needed. Of particular importance here is to extend this line of work to older early bilinguals – all studies that assessed the linguistic mechanisms employed by older bilinguals investigated participants who started acquiring the L2 in their teens or later. This is particularly critical as previous work has highlighted the role of AoA for grammatical processing in young and middle adulthood (e.g., Birdsong & Flege, 2001; Flege, Yeni-Komshian & Liu, 1999; McDonald, 2000; Veríssimo et al., 2018); see also section 2.2.2. Future research should assess the generalizability of the findings presented in this section, in order to refine the picture of age effects on the linguistic mechanisms involved in bilingual grammatical processing.

4. Conclusion

4.1. Summary

Here I summarize the main points of this article, focusing first on general measures of performance and then on underlying linguistic processing mechanisms. Regarding performance measures of language (RTs and accuracy; section 2), we have seen that age-related improvements, declines, and an absence of changes are all observed in bilingual speakers. These patterns are likely due to a combination of the opposing forces of increasing experience and cognitive declines. For measures of lexical skills, the bilingual performance changes (or lack thereof) generally parallel those found in monolinguals. In contrast, L1 and L2 lifespan trajectories may diverge for grammatical skills. In particular, some evidence suggests that grammatical phenomena that are difficult in a later-learned L2, such as agreement computation, show no declines or even improved performance with aging, in the face of relative declines in L1. A likely reason for this is the additional exposure to the L2 that comes with increasing age, which in such cases may be especially beneficial. Strikingly, these improvements observed in older L2 speakers can even lead to accuracy or RT performance that is indistinguishable from that of age-matched L1 speakers.

In contrast, such age-related changes in grammatical outcome measures in L2 speakers do not appear to be due to changes in the underlying linguistic processing mechanisms. Rather, the evidence suggests that grammatical processing mechanisms remain the same between younger and older adulthood, in both L1 and

https://doi.org/10.1017/S1366728920000413 Published online by Cambridge University Press

L2. Indeed, even decades of immersion to the target language and the achievement of high proficiency in the L2 do not render a (late) bilingual's grammatical processing mechanisms native-like. Interestingly, L2 grammatical processing across the lifespan appears to incur greater demands on age-sensitive cognitive abilities, such as working memory or interference control, as compared to L1 processing – though even L2 speakers with high levels of performance at such abilities still do not show native-like processing.

How might these processing patterns be best interpreted? Though none of the major theories of second-language processing have made explicit predictions regarding L2 in aging, the findings seem to be consistent with the implications of the Shallow Structure Hypothesis (Clahsen & Felser, 2006a, 2006b, 2006c, 2018), which claims that even highly proficient L2 speakers are likely to rely on 'good-enough' processing in on-line grammatical tasks, in contrast to the structural grammatical parsing employed by L1 speakers. Evidently, this strategy does not appear to change with more exposure to or experience with the L2.

4.2. Future directions

The reader may have noticed that there is need for more studies investigating the effects of age on language in bilingualism. This holds particularly for certain areas, such as age effects on L2 grammar (performance measures as well as processing mechanisms) or on L2 lexical processing mechanisms.

Future studies should ideally employ a continuous-age design, rather than contrasting groups of younger and older adults, to elucidate the (potentially nonlinear) trajectories of language abilities across the lifespan. In fact, the oft-ignored period of middle-age may well constitute a highpoint of aspects of L1 and L2 language performance, since during this period the positive effects of exposure may not yet be substantially counteracted by declining cognitive abilities. Moreover, some studies assessing L1 in aging have begun to combine cross-sectional and longitudinal sampling (Connor et al., 2004; Nyberg et al., 2012; Rönnlund, Nyberg, Bäckman & Nilsson, 2005). Such an approach should be particularly useful when examining L2, as it would help hold constant the many language-related and other variables that are at play in such research, such as AoA, the type and amount of language experience, and even sociological and biological factors such as socioeconomic status and genotype (Noble, Houston, Kan & Sowell, 2012; Ullman, 2020; Wong, Ettlinger & Zheng, 2013; Wong, Morgan-Short, Ettlinger & Zheng, 2012; Wong, Vuong & Liu, 2017).

Identifying contributions of age-related cognitive declines and experience-based improvements can be problematic in L2 studies, particular for the latter. On the one hand, since older adults show a great deal of variability in their cognitive abilities, it is possible to largely disentangle the effects of chronological age and age-related cognitive declines. In contrast, this often does not hold for age and exposure, since most studies sample their younger and older bilinguals from a population that is relatively homogenous in age-of-acquisition or age-of-arrival as well as in the type of subsequent L2 experience (e.g., immersion). This commonly leads to a high degree of collinearity between age and the amount and type of exposure (younger adults = little exposure, older adults = lots of exposure), which makes it difficult to assess their independent roles in language abilities. Future studies seeking to explore the role of exposure should address this issue: for example, by examining groups such as late-life migrants (i.e., older adults with little L2 exposure).

Though in this paper I focused on behavioral studies, examining the neurobiological bases of bilingual/second language in aging should also elucidate the nature of this process. Thus far, there has been little direct empirical work on this topic (see Rossi and Diaz, 2016, for a relevant discussion), and most imaging research on aging bilinguals has focused on the effects of bilingualism on cognitive measures and their neural substrates (Abutalebi et al., 2015; Borsa et al., 2018; Gold, Kim, Johnson, Kryscio & Smith, 2013; Olsen et al., 2015). Note that behavioral differences are often not found where differences in underlying brain activation are in fact observed (Morgan-Short, Steinhauer, et al., 2012; Tokowicz & MacWhinney, 2005), underscoring the likely utility of this approach to assess language processing mechanisms in aging bilinguals.

Lastly, although I argue that the current empirical picture is most compatible with the SSH, this article is not intended to determine which of the several theories of bilingual language processing is (most) correct regarding bilingualism in aging. Such a conclusion would be premature, considering the still relatively small amount of published research on this broad topic. Moreover, none of the theories presented here have yet made explicit predictions for L2 in aging. I am hopeful that, given the increasing interest in this field, future iterations of these accounts will address aging.

4.3. In closing

In this paper I have outlined the current status of empirical research examining the effects of aging on second language and bilingualism, with a focus on the lexicon and on grammar, and have attempted to interpret these findings in the context of principles and theories of aging and of L2 processing. Overall, the evidence suggests that aging can yield multifaceted outcomes in measures of language performance, with improvements as well as no changes and declines, even while the underlying linguistic processing mechanisms involved in L1 and L2 processing appear to remain relatively unchanged. I hope this paper serves as a call for further research in the area of bilingualism and aging, particularly considering the globally aging population and the prevalence of bilingualism.

Acknowledgments. I am grateful to Michael Ullman for many fruitful discussions and very valuable input. Funding was provided by the Deutsche Forschungsgemeinschaft (DFG) 'German Research Foundation' (411781424).

References

Abutalebi J and Green DW (2016) Neuroimaging of language control in bilinguals: neural adaptation and reserve. *Bilingualism: Language and Cognition*, **19**, 689–698. https://doi.org/10.1017/S1366728916000225

Abutalebi J, Guidi L, Borsa VM, Canini M, Della Rosa PA, Parris BA and Weekes BS (2015) Bilingualism provides a neural reserve for aging populations. *Neuropsychologia*, **69**, 201–210. https://doi.org/10.1016/j.neuropsychologia.2015.01.040

Allen PA, Madden DJ and Crozier LC (1991) Adult Age Differences in Letter-Level and Word-Level Processing. *Psychology and Aging*, **6**, 261–271. https://doi.org/10.1037//0882-7974.6.2.261

Allen PA, Madden DJ, Weber TA and Groth KE (1993) Influence of age and processing stage on visual word recognition. *Psychology and Aging*, **8**, 274–282.

Allen PA, Sliwinski MJ and Bowie T (2002) Differential Age Effects in Semantic and Episodic Memory, Part II: Slope and Intercept Analyses. *Experimental Aging Research*, **28**, 111–142.

Altmann LJP and Kemper S (2006) Effects of age, animacy and activation order on sentence production. *Language and Cognitive Processes*, **21**, 322–354. https://doi.org/10.1080/01690960544000006

Anderson JAE, Saleemi S and Bialystok E (2017) Neuropsychological assessments of cognitive aging in monolingual and bilingual older adults. *Journal of Neurolinguistics*, **43**, 17–27. https://doi.org/10.1016/j.jneuroling.2016.08.001

Antón E, García YF, Carreiras M and Duñabeitia JA (2016) Does bilingualism shape inhibitory control in the elderly? *Journal of Memory and Language*, **90**, 147–160. https://doi.org/10.1016/j.jml.2016.04.007

Baayen H, Vasishth S, Kliegl R and Bates D (2017) The cave of shadows: Addressing the human factor with generalized additive mixed models. *Journal of Memory and Language*, **94**, 206–234. https://doi.org/10.1016/j.jml.2016.11.006

Bak TH, Nissan JJ, Allerhand MM and Deary IJ (2014) Does bilingualism influence cognitive aging? *Annals of Neurology*, **75**, 959–963. https://doi.org/10.1002/ana.24158

Bak TH, Vega-Mendoza M and Sorace A (2014) Never too late? An advantage on tests of auditory attention extends to late bilinguals. *Frontiers in Psychology*, **5**, 1–6. https://doi.org/10.3389/fpsyg.2014.00485

Baker C and Prys Jones S (1998) *Encyclopedia of Bilingualism and Bilingual Education*. Clevedon, UK: Multilingual Matters.

Balota DA, Cortese MJ, Sergent-Marshall SD, Spieler DH and Yap MJ (2004) Visual Word Recognition of Single-Syllable Words. *Journal of Experimental Psychology: General*, **133**, 283–316. https://doi.org/10.1037/0096-3445.133.2.283

Banks B, Gowen E, Munro KJ and Adank P (2015) Cognitive predictors of perceptual adaptation to accented speech: Cognitive predictors of perceptual adaptation to accented speech. *The Journal of the Acoustical Society of America*, **137**, 2015–2024. https://doi.org/10.1121/1.4916265

Barresi BA, Nicholas M, Connor LT, Obler LK and Albert ML (2000) Semantic degradation and lexical access in age-related naming failures. *Aging, Neuropsychology, and Cognition*, **7**(3), 169–178. https://doi.org/10.1076/1382-5585(200009)7:3;1-Q;FT169

Bel A, Sagarra N, Comínguez JP and García-Alcaraz E (2016) Transfer and proficiency effects in L2 processing of subject anaphora. *Lingua*, **184**, 134–159. https://doi.org/10.1016/j.lingua.2016.07.001

Bialystok E, Craik FIM and Klein R (2004) Bilingualism, Aging, and Cognitive Control: Evidence From the Simon Task. *Psychology and Aging*, **19**, 290–303. https://doi.org/10.1037/0882-7974.19.2.290

Bialystok E, Craik FIM and Luk G (2008a) Cognitive Control and Lexical Access in Younger and Older Bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **34**, 859–873. https://doi.org/10.1037/0278-7393.34.4.859

Bialystok E, Craik FIM and Luk G (2008b) Lexical access in bilinguals: Effects of vocabulary size and executive control. *Journal of Neurolinguistics*, **21**, 522–538. https://doi.org/10.1016/j.jneuroling.2007.07.001

Bialystok E, Craik FIM and Luk G (2013) Bilingualism: Consequences for Mind and Brain. *Trends in Cognitive Sciences*, **16**, 240–250. https://doi.org/10.1016/j.tics.2012.03.001

Bialystok E and Luk G (2012) Receptive vocabulary differences in monolingual and bilingual adults. *Bilingualism: Language and Cognition*, **15**, 397–401. https://doi.org/10.1017/S136672891100040X

Birdsong D (2014) Dominance and Age in Bilingualism. *Applied Linguistics*, **35**, 374–392. https://doi.org/10.1093/applin/amu031

Birdsong D and Flege JE (2001) Regular-Irregular Dissociations in L2 Acquisition of English Morphology. In *BUCLD 25: Proceedings of the 25th Annual Boston University Conference on Language Development*. Boston, MA: Cascadilla Press, pp. 123–132.

Blackwell A and Bates E (1995) Inducing Agrammatic Profiles in Normals: Evidence for the Selective Vulnerability of Morphology under Cognitive Resource Limitation. *Journal of Cognitive Neuroscience*, **7**, 228–257.

Blom E and Baayen HR (2013) The impact of verb form, sentence position, home language, and second language proficiency on subject–verb agreement in child second language Dutch. *Applied Psycholinguistics*, **34**, 777–811.

Bock K (2004) Psycholinguistically speaking: Some matters of meaning, marking and morphing. In BH Ross (ed), *The Psychology of Learning and Motivation* (Vol. 44). San Diego, CA: Elsevier, pp. 109–144 https://doi.org/10.1016/S0079-7421(03)44004-8.

Bock K and Cutting JC (1992) Regulating mental energy: Performance units in language production. *Journal of Memory and Language*, **31**, 99–127. https://doi.org/10.1016/0749-596X(92)90007-K

Bock K and Eberhard KM (1993) Meaning, Sound and Syntax in English Number Agreement. *Language and Cognitive Processes*, **8**, 57–99. https://doi.org/10.1080/01690969308406949

Bock K and Miller CA (1991) Broken Agreement. *Cognitive Psychology*, **23**, 45–93.

Borsa VM, Perani D, Della Rosa PA, Videsott G, Guidi L, Weekes BS and Abutalebi J (2018) Bilingualism and healthy aging: Aging effects and neural maintenance. *Neuropsychologia*, **111**, 51–61. https://doi.org/10.1016/j.neuropsychologia.2018.01.012

Bowden HW, Steinhauer K, Sanz C and Ullman MT (2013) Native-like brain processing of syntax can be attained by university foreign language learners. *Neuropsychologia*, **51**, 2492–2511. https://doi.org/10.1016/j.neuropsychologia.2013.09.004

Breadmore HL (2007) *Inflectional morphology in the literacy of deaf children*. Ph.D. dissertation, University of Birmingham.

Brickman AM, Paul RH, Cohen RA, Williams LM, Macgregor KL, Jefferson AL and Gordon E (2005) Category and letter verbal fluency across the adult lifespan: relationship to EEG theta power. *Archives of Clinical Neuropsychology*, **20**, 561–573. https://doi.org/10.1016/j.acn.2004.12.006

Bruhn De Garavito J and White L (2002) The second language acquisition of Spanish DPs: The status of grammatical features. In AT Pérez-Leroux and JM Liceras (eds), *The Acquisition of Spanish Morphosyntax*. Dordrecht: Springer, pp. 153–178 https://doi.org/10.1007/978-94-010-0291-2.

Brysbaert M and Nazir TA (2005) Visual constraints in written word recognition: evidence from the optimal viewing-position effect. *Journal of Research in Reading*, **28**, 216–228.

Burke DM and Osborne G (2007) Aging and Inhibition Deficits: Where are the Effects? In D Gorfein and C MacLeod (eds), *On the place of inhibitory processes in cognition*. Washington, DC: American Psychological Association Press, pp. 163–183.

Burke DM and Shafto MA (2008) Language and aging. In FIM Craik and TA Salthouse (eds), *The handbook of aging and cognition*. New York: Psychology Press, pp. 373–443 https://doi.org/10.1097/00011363-198109000-00010.

Carpenter PA, Miyake A and Just MA (1994) Working memory constraints in comprehension: Evidence from individual difference, aphasia and aging. In MA Gemsbacher (ed), *Handbook of psycholinguistics*. New York, NY: Academic Press, pp. 1075–1122.

Carroll R, Warzybok A, Kollmeier B and Ruigendijk E (2016) Age-Related Differences in Lexical Access Relate to Speech Recognition in Noise. *Frontiers in Psychology*, **7**, 990. https://doi.org/10.3389/fpsyg.2016.00990

Caza N and Moscovitch M (2005) Effects of cumulative frequency, but not of frequency trajectory, in lexical decision times of older adults and patients with Alzheimer's disease. *Journal of Memory and Language*, **53**, 456–471.

Chamorro G, Sorace A and Sturt P (2016) What is the source of L1 attrition? The effect of recent L1 re-exposure on Spanish speakers under L1 attrition. *Bilingualism: Language and Cognition*, **19**, 520–532. https://doi.org/10.1017/S1366728915000152

Chen L, Shu H, Liu Y, Zhao J and Li P (2007) ERP signatures of subject–verb agreement in L2 learning. *Bilingualism: Language and Cognition*, **10**, 161–174. https://doi.org/10.1017/S136672890700291X

Clahsen H (1999) Lexical entries and rules of language: A multidisciplinary study of German inflection. *Behavioral and Brain Sciences*, **22**, 991–1060. https://doi.org/10.1017/S0140525X99002228

Clahsen H, Eisenbeiss S and Sonnenstuhl I (1997) Morphological structure and the processing of inflected words. *Theoretical Linguistics*, **23**, 201–249. https://doi.org/10.1515/thli.1997.23.3.201

Clahsen H and Felser C (2006a) Continuity and shallow structures in language processing. *Applied Psycholinguistics*, **27**, 107–126.

Clahsen H and Felser C (2006b) Grammatical processing in language learners. *Applied Psycholinguistics*, **27**, 3–42. https://doi.org/10.1017.S0142716406060024

Clahsen H and Felser C (2006c) How native-like is non-native language processing? *Trends in Cognitive Sciences*, **10**, 564–570. https://doi.org/10.1016/j.tics.2006.10.002

Clahsen H and Felser C (2018) Some notes on the shallow structure hypothesis. *Studies in Second Language Acquisition*, **40**, 693–706.

Clahsen H and Reifegerste J (2017) Morphological processing in old-age bilinguals. In M Libben, M Goral and G Libben (eds), *Bilingualism: A Framework for Understanding the Mental Lexicon*. Amsterdam: Benjamins, pp. 217–248

Connor LT, Spiro A, Obler LK and Albert ML (2004) Change in Object Naming Ability During Adulthood. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, **59**, P203–P209. https://doi.org/10.1093/geronb/59.5.P203

Coppens KM, Tellings A, Van der Veld W and Schreuder R (2012) Vocabulary development in children with hearing loss: The role of child, family, and educational variables. *Research in Developmental Disabilities*, **33**, 119–128. https://doi.org/10.1016/j.ridd.2011.08.030

Coughlin CE and Tremblay A (2013) Proficiency and working memory based explanations for nonnative speakers' sensitivity to agreement in sentence processing. *Applied Psycholinguistics*, **34**, 615–646. https://doi.org/10.1017/S0142716412000616

Covington NV and Duff MC (2016) Expanding the Language Network: Direct Contributions from the Hippocampus. *Trends in Cognitive Sciences*, **20**, 869–870. https://doi.org/10.1016/j.tics.2016.10.006

Cox SR, Bak TH, Allerhand M, Redmond P, Starr JM, Deary IJ and MacPherson SE (2016) Bilingualism, social cognition and executive functions: A tale of chickens and eggs. *Neuropsychologia*, **91**, 299–306. https://doi.org/10.1016/j.neuropsychologia.2016.08.029

Cunnings I (2017) Parsing and Working memory in bilingual sentence Processing. *Bilingualism: Language and Cognition*, **20**, 659–678. https://doi.org/10.1017/S1366728916000675

Davidson DJ, Zacks RT and Ferreira F (2003) Age preservation of the syntactic processor in production. *Journal of Psycholinguistic Research*, **32**, 541–566. https://doi.org/10.1023/A:1025402517111

Davis MH and Gaskell MG (2009) A complementary systems account of word learning: Neural and behavioural evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **364**, 3773–3800. https://doi.org/10.1098/rstb.2009.0111

De Chastelaine M, Mattson JT, Wang TH, Donley BE and Rugg MD (2015) Sensitivity of Negative Subsequent Memory and Task-Negative Effects to Age and Associative Memory Performance. *Brain Research*, **1612**, 16–29. https://doi.org/10.1016/j.brainres.2014.09.045

De Chastelaine M, Mattson JT, Wang TH, Donley BE and Rugg MD (2016) The neural correlates of recollection and retrieval monitoring: relationships with age and recollection performance. *NeuroImage*, **138**, 164–175. https://doi.org/10.1016/j.neuroimage.2016.04.071.The

DeKeyser RM (2005) What Makes Learning Second-Language Grammar Difficult? A Review of Issues. *Language Learning*, **55**, 1–25.

Diaz MT, Rizio AA and Zhuang J (2016) The neural language systems that support healthy aging: Integrating function, structure, and behavior. *Language and Linguistics Compass*, **10**, 314–334. https://doi.org/10.1586/14737175.2015.1028369

Diependaele K, Lemhöfer K and Brysbaert M (2013) The word frequency effect in first- and second-language word recognition: A lexical entrenchment account. *The Quarterly Journal of Experimental Psychology*, **66**, 843–863. https://doi.org/10.1080/17470218.2012.720994

Dobbs AR and Rule BG (1989) Adult age differences in working memory. *Psychology and Aging*, **4**, 500–503. https://doi.org/10.1037/0882-7974.4.4.500

du Boisgueheneuc F, Levy R, Volle E, Seassau M, Duffau H, Kinkingnehun S and Dubois B (2006) Functions of the left superior frontal gyrus in humans: A lesion study. *Brain*, **129**, 3315–3328. https://doi.org/10.1093/brain/awl244

Duchek JM, Balota DA, Storandt M and Larsen R (2007) The Power of Personality in Discriminating Between Healthy Aging and Early-Stage Alzheimer's Disease. *Journal of Gerontology: Psychological Sciences*, **62B**, P353–P361.

Duff MC and Brown-Schmidt S (2012) The hippocampus and the flexible use and processing of language. *Frontiers in Human Neuroscience*, **6**, 89. https://doi.org/10.3389/fnhum.2012.00069

Duff MC and Brown-Schmidt S (2017) Hippocampal Contributions to Language Use and Processing Hippocampal Contributions to Language Use and Processing. In DE Hannula and MC Duff (eds), *The hippocampus from cells to systems*. Springer, pp. 503–536 https://doi.org/10.1007/978-3-319-50406-3.

Dussias PE, Valdés Kroff JR, Guzzardo Tamargo RE and Gerfen C (2013) When Gender and Looking Go Hand in Hand. *Studies in Second Language Acquisition*, **35**, 353–387. https://doi.org/10.1017/S0272263112000915

Eberhard KM (1997) The Marked Effect of Number on Subject–Verb Agreement. *Journal of Memory and Language*, **36**, 147–164.

Eberhard KM, Cutting JC and Bock K (2005) Making Syntax of Sense: Number Agreement in Sentence Production. *Psychological Review*, **112**, 531–559. https://doi.org/10.1037/0033-295X.112.3.000

Facal D, Juncos-Rabadán O, Rodríguez MS and Pereiro AX (2012) Tip-of-the-tongue in aging: influence of vocabulary, working memory and processing speed. *Aging Clinical and Experimental Research*, **24**, 647–656. https://doi.org/10.3275/8586

Federmeier KD, McLennan DB and De Ochoa E (2002) The impact of semantic memory organization and sentence context information on spoken language processing by younger and older adults: An ERP study. *Psychophysiology*, **39**, 133–146.

Felser C and Roberts L (2007) Processing wh-dependencies in a second language: a cross-modal priming study. *Second Language Research*, **23**, 9–36.

Felser C, Roberts L, Marinis T and Gross R (2003) The processing of ambiguous sentences by first and second language learners of English. *Applied Psycholinguistics*, **24**, 453–489.

Felser C, Sato M and Bertenshaw N (2009) The on-line application of binding Principle A in English as a second language. *Bilingualism: Language and Cognition*, **12**, 485–502. https://doi.org/10.1017/S1366728909990228

Feyereisen P (1997) A Meta-Analytic Procedure Shows an Age-Related Decline in Picture Naming. *Journal of Speech Language and Hearing Research*, **40**, 1328. https://doi.org/10.1044/jslhr.4006.1328

Feyereisen P, Demaeght N and Samson D (1998) Why Do Picture Naming Latencies Increase With Age: General Slowing, Greater Sensitivity to Interference, or Task-Specific Deficits? *Experimental Aging Research*, **24**, 21–51. https://doi.org/10.1080/036107398244346

Finkel D, Reynolds CA, Mcardle JJ and Pedersen NL (2007) Age Changes in Processing Speed as a Leading Indicator of Cognitive Aging. *Psychology and Aging*, **22**, 558–568. https://doi.org/10.1037/0882-7974.22.3.558

Fjell AM, Sneve MH, Grydeland H, Storsve AB and Walhovd KB (2017) The Disconnected Brain and Executive Function Decline in Aging. *Cerebral Cortex*, **27**, 2303–2317. https://doi.org/10.1093/cercor/bhw082

Flege JE, Yeni-Komshian GH and Liu S (1999) Age Constraints on Second-Language Acquisition. *Journal of Memory and Language*, **41**, 78–104. https://doi.org/10.1006/jmla.1999.2638

Foos PW (1989) Adult Age Differences in Working Memory. *Psychology and Aging*, **4**, 269–275.

Foote R (2010) Age of acquisition and proficiency as factors in language production: Agreement in bilinguals. *Bilingualism: Language and Cognition*, **13**, 99–118. https://doi.org/10.1017/S136672890999040X

Foote R (2011) Integrated knowledge of agreement in early and late English–Spanish bilinguals. *Applied Psycholinguistics*, **32**, 187–220. https://doi.org/10.1017/S0142716410000342

Frensch P and Miner CS (1994) Effects of presentation rate and individual differences in short-term memory capacity on an indirect measure of serial learning. *Memory & Cognition*, **22**, 95–110. https://doi.org/10.3758/BF03202765

Friederici AD, Steinhauer K and Pfeifer E (2002) Brain signatures of artificial language processing: Evidence challenging the critical period hypothesis. *Proceedings of the National Academy of Sciences*, **99**, 529–534.

Gathercole VCM, Thomas EM, Kennedy I, Prys C, Young N, Viñas Guasch N and Jones L (2014) Does language dominance affect cognitive performance in bilinguals? Lifespan evidence from preschoolers through older adults on card sorting, Simon, and metalinguistic tasks. *Frontiers in Psychology*, **5**, 11. https://doi.org/10.3389/fpsyg.2014.00011

Gilhooly KJ (1984) Word Age-of-Acquisition and Residence Time in Lexical Memory as Factors in Word Naming. *Current Psychological Research & Reviews*, **3**, 24–31.

Gold BT, Kim C, Johnson NF, Kryscio RJ and Smith CD (2013) Lifelong bilingualism maintains neural efficiency for cognitive control in aging.

Journal of Neuroscience, **33**, 387–396. https://doi.org/10.1523/JNEUROSCI.3837-12.2013

Gollan TH, Montoya RI, Cera C and Sandoval TC (2008) More use almost always a means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language*, **58**, 787–814. https://doi.org/10.1016/j.jml.2007.07.001

Gollan TH, Weissberger GH, Runnqvist E, Montoya RI and Cera CM (2012) Self-ratings of spoken language dominance: A Multilingual Naming Test (MINT) and preliminary norms for young and aging Spanish–English bilinguals. *Bilingualism: Language and Cognition*, **15**, 594–615. https://doi.org/10.1017/S1366728911000332

Gomez R (2002) Word Frequency Effects in Priming Performance in Young and Older Adults. *Journal of Gerontology: Psychological Sciences*, **57B**, 233–240.

Goral M (2004) First-language decline in healthy aging: implications for attrition in bilingualism. *Journal of Neurolinguistics*, **17**, 31–52. https://doi.org/10.1016/S0911-6044(03)00052-6

Goral M, Libben G, Obler LK, Jarema G and Ohayon K (2008) Lexical attrition in younger and older bilingual adults. *Clinical Linguistics & Phonetics*, **22**, 509–522. https://doi.org/10.1080/02699200801912237

Green DW (2003) Neural basis of lexicon and grammar in L2 acquisition: The convergence hypothesis. In Rv Hout, A Hulk, F Kuiken and R Towell (eds), *The interface between syntax and the lexicon in second language acquisition*. Amsterdam: John Benjamins, pp. 197–208.

Green DW and Abutalebi J (2013) Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology*, **25**, 515–530. https://doi.org/10.1080/20445911.2013.796377

Grognet AG (1997) Elderly refugees and language learning. *Aging*, **359**, 8–11.

Grosjean F (2010) *Bilingual: Life and Reality*. Cambridge, MA: Harvard University Press.

Grüter T, Lew-Williams C and Fernald A (2012) Grammatical gender in L2: A production or a real-time processing problem? *Second Language Research*, **28**, 191–215. https://doi.org/10.1177/0267658312437990

Hamrick P, Lum JAG and Ullman MT (2018) Child first language and adult second language are both tied to general-purpose learning systems. *Proceedings of the National Academy of Sciences*, **115**, 1487–1492. https://doi.org/10.1073/pnas.1713975115

Han Y and Ellis R (1998) Implicit knowledge, explicit knowledge and general language proficiency. *Language Teaching Research*, **2**, 1–23. https://doi.org/10.1177/136216889800200102

Harris RJ and Nelson McGhee EM (1992) Bilingualism: Not the Exception Any More. In RJ Harris (ed), *Advances in Psychology* (Volume 83). Amsterdam: Elsevier, pp. 3–14.

Hasher L and Zacks RT (1988) Working Memory, Comprehension, and Aging: A review and a new view. In GH Bower (ed), *The Psychology of Learning and Motivation* (Vol. 22). San Diego, CA: Academic Press, pp. 193–225.

Haskell TR and MacDonald MC (2005) Constituent Structure and Linear Order in Language Production: Evidence From Subject–Verb Agreement. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **31**, 891–904. https://doi.org/10.1037/0278-7393.31.5.891

Hedden T, Lautenschlager G and Park DC (2005) Contributions of processing ability and knowledge to verbal memory tasks across the adult life-span. *The Quarterly Journal of Experimental Psychology*, **58A**, 169–190. https://doi.org/10.1080/02724980443000179

Hedden T and Park DC (2001) Aging and Interference in Verbal Working Memory. *Psychology and Aging*, **16**, 666–681. https://doi.org/10.1037//0882-7974.16.4.666

Herbay AC, Gonnerman LM and Baum SR (2018) How Do French–English Bilinguals Pull Verb Particle Constructions Off? Factors Influencing Second Language Processing of Unfamiliar Structures at the Syntax-Semantics Interface. *Frontiers in Psychology*, **9**, 1885. https://doi.org/10.3389/fpsyg.2018.01885

Hertzog C, Raskind CL and Cannon CJ (1986) Age-Related Slowing in Semantic Information Processing Speed: An Individual Differences Analysis. *Journal of Gerontology*, **41**, 500–502.

Hopp H (2006) Syntactic features and reanalysis in near-native processing. *Second Language Research*, **22**, 369–397. https://doi.org/10.1191/0267658306sr272oa

Hopp H (2010) Ultimate attainment in L2 inflection: Performance similarities between non-native and native speakers. *Lingua*, **120**, 901–931. https://doi.org/10.1016/j.lingua.2009.06.004

Hopp H (2014) Working Memory Effects in the L2 Processing of Ambiguous Relative Clauses. *Language Acquisition*, **21**, 250–278. https://doi.org/10.1080/10489223.2014.892943

Howard JH, Dennis NA, Howard DV, Yankovich H and Vaidya CJ (2004) Implicit Spatial Contextual Learning in Healthy Aging. *Neuropsychology*, **18**, 124–134. https://doi.org/10.1097/OPX.0b013e3182540562.The

Howard DV and Howard JH (1989) Age differences in learning serial patterns: direct versus indirect measures. *Psychology and Aging*, **4**, 357–364. https://doi.org/10.1037/0882-7974.4.3.357

Howard DV and Howard JH (1992) Adult Age Differences in the Rate of Learning Serial Patterns: Evidence From Direct and Indirect Tests. *Psychology and Aging*, **7**, 232–241.

Howieson DB, Dame A, Camicioli R, Sexton G, Payami H and Kaye JA (1997) Cognitive Markers Preceding Alzheimer's Dementia in the Healthy Oldest Old. *Journal of the American Geriatrics Society*, **45**, 584–589.

Ingvalson E, Nowicki C, Zong A and Wong PCM (2017) Non-native speech learning in older adults. *Frontiers in Psychology*, **8**, 148. https://doi.org/10.3389/fpsyg.2017.00148

Jackson CN and Bobb SC (2009) The processing and comprehension of wh-questions among second language speakers of German. *Applied Psycholinguistics*, **30**, 603–636.

Jacob G, Fleischhauer E and Clahsen H (2013) Allomorphy and affixation in morphological processing: A cross-modal priming study with late bilinguals. *Bilingualism: Language and Cognition*, **16**, 924–933. https://doi.org/10.1017/S1366728913000291

Jacob G, Heyer V and Veríssimo J (2017) Aiming at the same target: A masked priming study directly comparing derivation and inflection in the second language. *International Journal of Bilingualism*, **22**, 619–637. https://doi.org/10.1177/1367006916688333

Jardim de Paula J, de Souza Costa D, Laiss B, de Miranda D and Malloy-Diniz LF (2013) Verbal fluency in older adults with low educational level: what is the role of executive functions and processing speed? *Brazilian Journal of Psychiatry*, **35**, 440–442.

Johns BT, Sheppard CL, Jones MN and Taler V (2016) The role of semantic diversity in word recognition across aging and bilingualism. *Frontiers in Psychology*, **7**, 703. https://doi.org/10.3389/fpsyg.2016.00703

Juncos-Rabadán O (1994) The assessment of bilingualism in normal aging with the bilingual aphasia test. *Journal of Neurolinguistics*, **8**, 67–73. https://doi.org/10.1016/0911-6044(94)90008-6

Kaan E, Ballantyne JC and Wijnen F (2015) Effects of reading speed on second-language sentence processing. *Applied Psycholinguistics*, **36**, 799–830. https://doi.org/10.1017/S0142716413000519

Kachlicka M, Saito K and Tierney A (2019) Successful second language learning is tied to robust domain-general auditory processing and stable neural representation of sound. *Brain and Language*, **192**, 15–24. https://doi.org/10.1016/j.bandl.2019.02.004

Kail RV and Salthouse TA (1994) Processing speed as a mental capacity. *Acta Psychologica*, **86**, 199–225.

Kaplan E, Goodglass H and Weintraub S (1983) *Boston Naming Test*. Philadelphia: Lea & Febiger.

Kasparian K and Steinhauer K (2017) When the second language takes the lead: Neurocognitive processing changes in the first language of adult attriters. *Frontiers in Psychology*, **8**, 389. https://doi.org/10.3389/fpsyg.2017.00389

Keating GD (2009) Sensitivity to violations of gender agreement in native and nonnative Spanish: An eye-movement investigation. *Language Learning*, **59**, 503–535.

Keijzer M (2013) Working Memory Capacity, Inhibitory Control and the Role of L2 Proficiency in Aging L1 Dutch Speakers of Near-Native L2 English. *Brain Sciences*, **3**, 1261–1281. https://doi.org/10.3390/brainsci3031261

Kelly LP (1993) Recall of English Function Words and Inflections by Skilled and Average deaf Readers. *American Annals of the Deaf*, **138**, 288–296.

Kelly LP (1996) The Interaction of Syntactic Competence and Vocabulary During Reading by Deaf Students. *Journal of Deaf Studies and Deaf Education*, **1**, 75–90.

Kemtes KA and Kemper S (1997) Younger and Older Adults' On-Line Processing of Syntactically Ambiguous Sentences. *Psychology and Aging*, **12**, 362–371. https://doi.org/10.1037//0882-7974.12.2.362

Kilborn K (1992) On-line Integration of Grammatical Information in a Second Language. In RJ Harris (ed), *Cognitive Processing in Bilinguals* (pp. 337–350). Amsterdam: Elsevier.

Kirk NW, Fiala L, Scott-Brown KC and Kempe V (2014) No evidence for reduced Simon cost in elderly bilinguals and bidialectals. *Journal of Cognitive Psychology*, **26**(6), 640–648. https://doi.org/10.1080/20445911.2014.929580

Köpke B and Schmid MS (2004) Language Attrition: The next phase. In MS Schmid, B Köpke, M Keijzer and L Weilemar (eds), *First Language Attrition: Interdisciplinary perspectives on methodological issues*. Amsterdam: John Benjamins, pp. 1–43.

Kousaie S and Phillips NA (2012) Ageing and bilingualism: Absence of a "bilingual advantage" in Stroop interference in a nonimmigrant sample. *The Quarterly Journal of Experimental Psychology*, **65**, 356–369. https://doi.org/10.1080/17470218.2011.604788https://doi.org/10.1080/20445911.2014.929580https://doi.org/10.1037//0882-7974.12.2.362

Kousaie S, Sheppard C, Lemieux M, Monetta L and Taler V (2014) Executive function and bilingualism in young and older adults. *Frontiers in Behavioral Neuroscience*, **8**, 250. https://doi.org/10.3389/fnbeh.2014.00250

Kramer AF and Kray J (2006) Aging and Attention. In FIM Craik and E Bialystok (eds), *Lifespan cognition: Mechanisms of change*. New York, NY: Oxford University Press, pp. 57–69 https://doi.org/10.1093/acprof:oso/9780195169539.003.0005.

Kürten J, De Vries MH, Kowal K, Zwitserlood P and Flöel A (2012) Age affects chunk-based, but not rule-based learning in artificial grammar acquisition. *Neurobiology of Aging*, **33**, 1311–1317. https://doi.org/10.1016/j.neurobiolaging.2010.10.008

Kwong See ST and Bouchard Ryan E (1995) Cognitive Mediation of Adult Age Differences in Language Performance. *Psychology and Aging*, **10**, 458–468.

LaBarge E, Edwards D and Knesevich JW (1986) Performance of Normal Elderly on the Boston Naming Test. *Brain and Language*, **384**, 380–384.

Lardiere D (1998) Dissociating syntax from morphology in a divergent L2 end-state grammar. *Second Language Research*, **14**, 359–375. https://doi.org/10.1191/026765898672500216

Lawrence B, Myerson J and Hale S (1998) Differential Decline of Verbal and Visuospatial Processing Speed Across the Adult Life Span. *Aging, Neuropsychology, and Cognition*, **5**, 129–146.

Leal T, Slabakova R and Farmer TA (2016) The fine-tuning of linguistic expectations over the course of L2 learning. *Studies in Second Language Acquisition*, **39**, 493–525. https://doi.org/10.1017/S0272263116000164

Lenet AE, Sanz C, Lado B, Howard JH and Howard DV (2011) Aging, Pedagogical Conditions, and Differential Success in SLA: An Empirical Study. In C Sanz and RP Leow (eds), *Implicit and explicit language learning: Conditions, processes, and knowledge in SLA and bilingualism*. Washington, DC: Georgetown University Press, pp. 73–84.

Light LL and Anderson PA (1985) Working-Memory Capacity, Age, and Memory for Discourse. *Journal of Gerontology*, **40**, 737–747. https://doi.org/10.1093/geronj/40.6.737

Linck JA, Osthus P, Koeth JT and Bunting MF (2014) Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review*, **21**, 861–883. https://doi.org/10.3758/s13423-013-0565-2

Lindenberger U and Baltes PB (1994) Sensory Functioning and Intelligence in Old Age: A Strong Connection. *Psychology and Aging*, **9**, 339–355.

MacWhinney B (2001) The competition model: The input, the context, and the brain. In P Robinson (ed), *Cognition and Second Language Instruction*. Cambridge: Cambridge University Press, pp. 69–90.

Madden DJ (1992) Four to Ten Milliseconds Per Year: Age-Related Slowing of Visual Word Identification. *Journal of Gerontology: Psychological Sciences*, **47**, 59–68.

Madden DJ and Whiting WL (2004) Age-related changes in visual attention. In PT Costa and IC Siegler (eds), *Recent advances in psychology and aging*. Amsterdam: Elsevier, pp. 41–88

Mainz N, Shao Z, Brysbaert M and Meyer AS (2017) Vocabulary Knowledge Predicts Lexical Processing: Evidence from a Group of Participants with Diverse Educational Backgrounds. *Frontiers in Psychology*, **8**, 1164. https://doi.org/10.3389/fpsyg.2017.01164

Marinis T, Roberts L, Felser C and Clahsen H (2005) Gaps in second language sentence processing. *Studies in Second Language Acquisition*, **27**, 53–78.

Mather M and Harley CW (2016) The Locus Coeruleus: Essential for Maintaining Cognitive Function and the Aging Brain. *Trends in Cognitive Sciences*, **20**, 214–226. https://doi.org/10.1016/j.tics.2016.01.001

Mathers CD, Stevens GA, Boerma T, White RA and Tobias MI (2015) Causes of international increases in older age life expectancy. *The Lancet*, **385**, 540–548. https://doi.org/10.1016/S0140-6736(14)60569-9

McDonald JL (2000) Grammaticality judgments in a second language: Influences of age of acquisition and native language. *Applied Psycholinguistics*, **21**, 395–423. https://doi.org/10.1017/S0142716400003064

McDonald JL (2006) Beyond the critical period: Processing-based explanations for poor grammaticality judgment performance by late second language learners. *Journal of Memory and Language*, **55**, 381–401. https://doi.org/10.1016/j.jml.2006.06.006

McDonald JL and Roussel CC (2010) Past tense grammaticality judgment and production in non-native and stressed native English speakers. *Bilingualism: Language and Cognition*, **13**, 429–448. https://doi.org/10.1017/S1366728909990599

McDonough IM, Wood MM and Miller WS (2019) A Review on the Trajectory of Attentional Mechanisms in Aging and the Alzheimer's Disease Continuum through the Attention Network Test. *Yale Journal of Biology and Medicine*, **92**, 37–51.

Meinzer M, Flaisch T, Seeds L, Harnish S, Antonenko D, Witte AV and Crosson B (2012) Same modulation but different starting points: Performance modulates age differences in inferior frontal cortex activity during word-retrieval. *PLoS ONE*, **7**, e33631. https://doi.org/10.1371/journal.pone.0033631

Meinzer M, Seeds L, Flaisch T, Harnish S, Cohen ML, McGregor KM and Crosson B (2012) Impact of changed positive and negative task-related brain activity on word-retrieval in aging. *Neurobiology of Aging*, **33**, 656–669. https://doi.org/10.1016/j.neurobiolaging.2010.06.020

Meinzer M, Wilser L, Flaisch T, Eulitz C, Rockstroh B, Conway T and Crosson B (2009) Neural signatures of semantic and phonemic fluency in young and old adults. *Journal of Cognitive Neuroscience*, **21**, 2007–2018. https://doi.org/10.1162/jocn.2009.21219.Neural

Meir N, Walters J and Armon-Lotem S (2016) Disentangling SLI and bilingualism using sentence repetition tasks: the impact of L1 and L2 properties. *International Journal of Bilingualism*, **20**, 421–452. https://doi.org/10.1177/1367006915609240

Montrul S (2011) Morphological Errors in Spanish Second Language Learners and Heritage Speakers. *Studies in Second Language Acquisition*, **33**, 163–192.

Morgan-Short K, Finger I, Grey S and Ullman MT (2012) Second language processing shows increased native-like neural responses after months of no exposure. *PLoS ONE*, **7**, e32974. https://doi.org/10.1371/journal.pone.0032974

Morgan-Short K, Sanz C, Steinhauer K and Ullman MT (2010) Second Language Acquisition of Gender Agreement in Explicit and Implicit Training Conditions: An Event-Related Potential Study. *Language Learning*, **60**, 154–193.

Morgan-Short K, Steinhauer K, Sanz C and Ullman MT (2012) Explicit and implicit second language training differentially affect the achievement of native-like brain activation patterns. *Journal of Cognitive Neuroscience*, **24**, 933–947. https://doi.org/10.1162/jocn_a_00119

Morrison CM, Hirsh KW and Duggan GB (2002) Age of acquisition, ageing and verb production: Normative and experimental data. *The Quarterly Journal of Experimental Psychology: Section A*, **56**, 705–730.

Mortensen L, Meyer AS and Humphreys GW (2006) Age-related effects on speech production: A review. *Language and Cognitive Processes*, **21**, 238–290. https://doi.org/10.1080/01690960444000278

Myerson J, Ferraro FR, Hale S and Lima SD (1992) General Slowing in Semantic Priming and Word Recognition. *Psychology and Aging*, **7**, 257–270.

Nichols ES, Wild CJ, Stojanoski B, Battista ME and Owen AM (2020) Bilingualism affords no general cognitive advantages: a population study of executive function in 11,000 people. *Psychological Science*. https://doi.org/10.1177/0956797620903113

Noble KG, Houston SM, Kan E and Sowell ER (2012) Neural correlates of socioeconomic status in the developing human brain. *Developmental Science*, **15**, 516–527. https://doi.org/10.1111/j.1467-7687.2012.01147.x

Nyberg L, Lövdén M, Riklund K, Lindenberger U and Bäckman L (2012) Memory aging and brain maintenance. *Trends in Cognitive Sciences*, **16**, 292–305. https://doi.org/10.1016/j.tics.2012.04.005

O'Regan JK, Lévy-Schoen A, Pynte J and Brugaillère B (1984) Convenient Fixation Location Within Isolated Words of Different Length and Structure. *Journal of Experimental Psychology: Human Perception and Performance*, **10**, 250–257.

Olsen RK, Pangelinan MM, Bogulski C, Chakravarty MM, Luk G, Grady CL and Bialystok E (2015) The effect of lifelong bilingualism on regional grey and white matter volume. *Brain Research*, **1612**, 128–139. https://doi.org/10.1016/j.brainres.2015.02.034

Papadopoulou D and Clahsen H (2003) Parsing Strategies in L1 and L2 Sentence Processing: A Study of Relative Clause Attachment in Greek. *Studies in Second Language Acquisition*, **25**, 501–528.

Paradis M (1987) *The assessment of bilingual aphasia*. New York, NY: Lawrence Erlbaum Associates, Inc.

Paradis M (2009) *Declarative and procedural determinants of second languages* (Vol. 40). Amsterdam: John Benjamins Publishing Company.

Park DC, Lautenschlager G, Hedden T, Davidson NS, Smith AD and Smith PK (2002) Models of Visuospatial and Verbal Memory Across the Adult Life Span. *Psychology and Aging*, **17**, 299–320. https://doi.org/10.1037//0882-7974.17.2.299

Pearlmutter NJ, Garnsey SM and Bock K (1999) Agreement Processes in Sentence Comprehension. *Journal of Memory and Language*, **41**, 427–456. https://doi.org/10.1006/jmla.1999.2653

Peelle JE, Troiani V, Wingfield A and Grossman M (2010) Neural processing during older adults' comprehension of spoken sentences: Age differences in resource allocation and connectivity. *Cerebral Cortex*, **20**, 773–782. https://doi.org/10.1093/cercor/bhp142

Perani D, Paulesu E, Galles NS, Dupoux E, Dehaene S, Bettinardi V and Mehler J (1998) The bilingual brain: Proficiency and age of acquisition of the second language. *Brain*, **121**, 1841–1852.

Perpiñán S (2015) L2 Grammar and L2 Processing in the Acquisition of Spanish Prepositional Relative Clauses. *Bilingualism: Language and Cognition*, **18**, 577–596. https://doi.org/10.1017/S1366728914000583

Phillips C (2013) Some arguments and nonarguments for reductionist accounts of syntactic phenomena. *Language and Cognitive Processes*, **28**, 156–187. https://doi.org/10.1080/01690965.2010.530960

Pinker S (1999) *Words and rules: the ingredients of language*. New York: Harper Collins.

Pinker S and Ullman MT (2002) The past and future of the past tense. *Trends in Cognitive Sciences*, **6**, 456–463.

Pliatsikas C, Veríssimo J, Babcock L, Pullman MY, Glei DA, Weinstein M and Ullman MT (2018) Working memory in older adults declines with age, but is modulated by sex and education. *Quarterly Journal of Experimental Psychology*, **72**, 1308–1327.

Prehn K, Taud B, Reifegerste J, Clahsen H and Flöel A (2018) Neural correlates of grammatical inflection in older native and second-language speakers. *Bilingualism: Language and Cognition*, **21**, 1–12. https://doi.org/10.1017/S1366728916001206

Prull M, Gabrieli JDE and Bunge SA (2000) Age-related changes in memory: A cognitive neuroscience perspective. In FIM Craik and TA Salthouse (eds), *Handbook of Aging and Cognition*. Mahwah, NJ: Lawrence Erlbaum Associates, pp. 91–153.

Ramscar M, Hendrix P, Shaoul C, Milin P and Baayen RH (2014) The myth of cognitive decline: Non-linear dynamics of lifelong learning. *Topics in Cognitive Science*, **6**, 5–42. https://doi.org/10.1111/tops.12078

Ratcliff R, Thapar A, Gomez P and McKoon G (2004) A diffusion model analysis of the effects of aging in the Lexical Decision Task. *Psychology and Aging*, **19**, 278–289. https://doi.org/10.1037/0882-7974.19.2.278

Raz N, Ghisletta P, Rodrigue KM, Kennedy KM and Lindenberger U (2010) Trajectories of brain aging in middle-aged and older adults: Regional and individual differences. *NeuroImage*, **51**, 501–511. https://doi.org/10.1038/jid.2014.371

Reifegerste J, Elin K and Clahsen H (2019) Persistent differences between native speakers and late bilinguals: Evidence from inflectional and derivational processing in older speakers. *Bilingualism: Language and Cognition*, **22**, 425–440. https://doi.org/10.1017/S1366728918000615

Reifegerste J and Felser C (2017) Effects of aging on interference during pronoun resolution. *Journal of Speech, Language, and Hearing Research*, **60**, 3573–3589. https://doi.org/10.1044/2017_JSLHR-L-17-0183

Reifegerste J, Hauer F and Felser C (2017) Agreement processing and attraction errors in aging: evidence from subject-verb agreement in German. *Aging, Neuropsychology, and Cognition*, **24**, 672–702. https://doi.org/10.1080/13825585.2016.1251550

Reifegerste J, Jarvis R and Felser C (2020b) Effects of chronological age on native and nonnative sentence processing: Evidence from subject-verb agreement in German. *Journal of Memory and Language*, **111**, 104083. https://doi.org/10.1016/j.jml.2019.104083

Reifegerste J, Meyer AS and Zwitserlood P (2017) Inflectional complexity and experience affect plural processing in younger and older readers of Dutch and German. *Language, Cognition and Neuroscience*, **32**, 471–487. https://doi.org/10.1080/23273798.2016.1247213

Reifegerste J, Russell LE, Balota DA, Luta G, Meinzer M, Rugg MD, Shattuck K, Turkeltaub PE, VanMeter JW, Veríssimo J and Ullman MT (2020a) *What's that word again? The contribution of the hippocampus to word-finding declines in aging.* Poster accepted for the 2020 Cognitive Aging Conference, Atlanta, GA.

Robert C and Mathey S (2007) Aging and Lexical Inhibition: The Effect of Orthographic Neighborhood Frequency in Young and Older Adults. *Journal of Gerontology*, **62**, 340–342.

Rodríguez-Aranda C and Jakobsen M (2011) Differential Contribution of Cognitive and Psychomotor Functions to the Age-Related Slowing of Speech Production. *Journal Of the International Neuropsychological Society*, **17**, 807–821. https://doi.org/10.1017/S1355617711000828

Rönnlund M, Nyberg L, Bäckman L and Nilsson L-G (2005) Stability, Growth, and Decline in Adult Life Span Development of Declarative Memory: Cross-Sectional and Longitudinal Data From a Population-Based Study. *Psychology and Aging*, **20**, 3–18. https://doi.org/10.1037/0882-7974.20.1.3

Ross TP, Lichtenberg PA and Christensen BK (1995) Normative data on the boston naming test for elderly adults in a demographically diverse medical sample. *The Clinical Neuropsychologist*, **9**, 321–325. https://doi.org/10.1080/13854049508400496

Rossi E and Diaz MT (2016) How aging and bilingualism influence language processing: Theoretical and neural models. *Linguistic Approaches to Bilingualism*, **6**, 9–42. https://doi.org/10.1075/lab.14029.ros

Ryskin R, Qi Z, Covington NV, Duff MC and Brown-Schmidt S (2018) Knowledge and learning of verb biases in amnesia. *Brain and Language*, **182**, 62–83. https://doi.org/10.1016/j.bandl.2018.04.003

Sagarra N and Herschensohn J (2010) The role of proficiency and working memory in gender and number agreement processing in L1 and L2 Spanish. *Lingua*, **120**, 2022–2039. https://doi.org/10.1016/j.lingua.2010.02.004

Sagarra N and Herschensohn J (2012) Processing of gender and number agreement in late Spanish bilinguals. *International Journal of Bilingualism*, **17**, 607–627. https://doi.org/10.1177/1367006912453810

Sagarra N, Sánchez L and Bel A (2019) Processing DOM in relative clauses Salience and optionality in early and late bilinguals. *Linguistic Approaches to Bilingualism*, **9**, 120–160.

Saito K, Sun H, Kachlicka M, Carvayal Alayo JR, Nakata T and Tierney A (under review) *Domain-General Auditory Processing Explains Multiple Dimensions of L2 Acquisition in Adulthood.*

Salthouse TA (1996) The processing-speed theory of adult age differences in cognition. *Psychological Review*, **103**, 403–428. https://doi.org/10.1037/0033-295X.103.3.403

Salthouse TA (1998) Independence of age-related influences on cognitive abilities across the life span. *Developmental Psychology*, **34**, 851–864. https://doi.org/10.1037/0012-1649.34.5.851

Salthouse TA and Kail RV (1983) Memory development throughout the life span: The role of processing rate. In PB Baltes and OG Brim (eds), *Life-span Development and Behavior*. New York: Academic Press, pp. 89–116

Salthouse TA, Pink JE and Tucker-Drob EM (2008) Contextual analysis of fluid intelligence. *Intelligence*, **36**, 464–486. https://doi.org/10.1016/j.intell.2007.10.003

Sato M and Felser C (2010) Sensitivity to Morphosyntactic Violations in English as a Second Language Sensitivity to Morphosyntactic Violations in English as a Second Language. *Second Language*, **9**, 101–118.

Schel MA, Kühn S, Brass M, Haggard P, Ridderinkhof KR and Crone EA (2014) Neural correlates of intentional and stimulus-driven inhibition: a comparison. *Frontiers in Human Neuroscience*, **8**, 27. https://doi.org/10.3389/fnhum.2014.00027

Schmitter-Edgecombe M, Vesneski M and Jones DWR (2000) Aging and Word-Finding: A Comparison of Spontaneous and Constrained Naming Tests. *Archives of Clinical Neuropsychology*, **15**, 479–493.

Schneider BA and Pichora-Fuller MK (2000) Implications of perceptual deterioration for cognitive aging research. In FIM Craik and TA Salthouse (eds), *The handbook of aging and cognition* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, pp. 155–219.

Scialfa CT (2002) The Role of Sensory Factors in Cognitive Aging Research. *Canadian Journal of Experimental Psychology*, **56**, 153–163.

Service E, Simola M, Metsänheimo O and Maury S (2010) Bilingual working memory span is affected by language skill. *European Journal of Cognitive Psychology*, **14**, 383–408. https://doi.org/10.1080/09541440143000140

Shao Z, Janse E, Visser K and Meyer AS (2014) What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Frontiers in Psychology*, **5**, 772. https://doi.org/10.3389/fpsyg.2014.00772

Shao Z, Meyer AS and Roelofs A (2013) Selective and nonselective inhibition of competitors in picture naming. *Memory & Cognition*, **41**, 1200–1211. https://doi.org/10.3758/s13421-013-0332-7

Shao Z, Roelofs A and Meyer AS (2012) Sources of individual differences in the speed of naming objects and actions: The contribution of executive control. *The Quarterly Journal of Experimental Psychology*, **65**, 1927–1944. https://doi.org/10.1080/17470218.2012.670252

Shibuya M and Wakabayashi S (2008) Why are L2 learners not always sensitive to subject-verb agreement? *EUROSLA Yearbook*, **8**, 235–258.

Sonnenstuhl I, Eisenbeiss S and Clahsen H (1999) Morphological priming in the German mental lexicon. *Cognition*, **72**, 203-236. https://doi.org/10.1016/S0010-0277(99)00033-5

Staub A (2009) On the interpretation of the number attraction effect: Response time evidence. *Journal of Memory and Language*, **60**, 308–327. https://doi.org/10.1016/j.jml.2008.11.002

Steinhauer K (2014) Event-related Potentials (ERPs) in Second Language Research: A Brief Introduction to the Technique, a Selected Review, and an Invitation to Reconsider Critical Periods in L2. *Applied Linguistics*, **35**, 393–417. https://doi.org/10.1093/applin/amu028

Steinhauer K, White EJ and Drury JE (2009) Temporal dynamics of late second language acquisition: evidence from event-related brain potentials. *Second Language Research*, **1**, 13–41. https://doi.org/10.1177/0267658308098995

Stine-Morrow EAL (2007) The Dumbledore Hypothesis of Cognitive Aging. *Current Directions in Psychological Science*, **16**, 295–299. https://doi.org/10.1111/j.1467-8721.2007.00524.x

Stine-Morrow EAL, Loveless MK and Soederberg LM (1996) Resource allocation in on-line reading by younger and older adults. *Psychology and Aging*, **11**, 475–486. https://doi.org/10.1037/0882-7974.11.3.475

Stine-Morrow EAL, Ryan S and Leonard JS (2000) Age differences in on-line syntactic processing. *Experimental Aging Research*, **26**, 315–322. https://doi.org/10.1080/036107300750015714

Tokowicz N and MacWhinney B (2005) Implicit and explicit measures of sensitivity to violations in second language grammar: An event-related potential investigation. *Studies in Second Language Acquisition*, **27**, 173–204.

Tombaugh TN, Kozak J and Rees L (1999) Normative Data Stratified by Age and Education for Two Measures of Verbal Fluency: FAS and Animal Naming. *Archives of Clinical Neuropsychology*, **14**, 167–177.

Tsimpli I, Sorace A, Heycock C and Filiaci F (2004) First language attrition and syntactic subjects: A study of Greek and Italian near-native speakers of English. *International Journal of Bilingualism*, **8**, 257–277. https://doi.org/10.1177/13670069040080030601

Tucker GR (1999) A Global Perspective on Bilingualism and Bilingual Education. Retrieved from http://www.cal.org/content/download/1803/19986/file/AGlobalPerspectiveonBilingualism.pdf

Ullman MT (2001a) A neurocognitive perspective on language: the declarative/procedural model. *Nature Reviews Neuroscience*, **2**, 717–727.

Ullman MT (2001b) The neural basis of lexicon and grammar in first and second language: the declarative/procedural model. *Bilingualism: Language and Cognition*, **4**, 105–122.

Ullman MT (2004) Contributions of memory circuits to language: the declarative/procedural model. *Cognition*, **92**, 231–270. https://doi.org/10.1016/j.cognition.2003.10.008

Ullman MT (2005) A Cognitive Neuroscience Perspective on Second Language Acquisition: The Declarative/Procedural Model. In C Sanz (ed), *Mind and Context in Adult Second Language Acquisition: Methods, Theory, and Practice*. Washington, DC: Georgetown University Press, pp. 141–178.

Ullman MT (2016) The Declarative/Procedural Model: A Neurobiological Model of Language Learning, Knowledge and Use. In G Hickok and S Small (eds), *The Neurobiology of Language*. Amsterdam: Elsevier, pp. 953–968.

Ullman MT (2020) The Declarative/Procedural Model: A Neurobiologically-Motivated Theory of First and Second Language. In B VanPatten, GD Keating and S Wulff (eds), *Theories in Second Language Acquisition* (3rd editio). New York: Routledge.

Unsworth N, Spillers GJ and Brewer GA (2011) Variation in verbal fluency: A latent variable analysis of clustering, switching, and overall performance. *The Quarterly Journal of Experimental Psychology*, **64**, 447–466. https://doi.org/10.1080/17470218.2010.505292

VanPatten B, Keating GD and Leeser MJ (2012) Missing verbal inflections as a representational problem: Evidence from self-paced reading. *Linguistic Approaches to Bilingualism*, **2**, 109–140. https://doi.org/10.1075/lab.2.2.01pat

Veríssimo J, Heyer V, Jacob G and Clahsen H (2018) Selective Effects of Age of Acquisition on Morphological Priming: Evidence for a Sensitive Period. *Language Acquisition*, **25**, 315–326. https://doi.org/10.1080/10489223.2017.1346104

Veríssimo J, Verhaeghen P, Goldman N, Weinstein M and Ullman MT (under review) *Evidence that aspects of attention and executive function improve in old age.*

Wagers MW, Lau EF and Phillips C (2009) Agreement attraction in comprehension: Representations and processes. *Journal of Memory and Language*, **61**, 206–237.

Warren DE, Rubin R, Shune S and Duff MC (2018) Memory and Language in Aging: How Their Shared Cognitive Processes, Neural Correlates, and Supporting Mechanisms Change with Age. In M Rizzo, S Anderson and B Fritzsch (eds), *The Wiley Handbook on the Aging Mind and Brain*. Hoboken, NJ: Wiley Blackwell, pp. 270–295.

Waters GS and Caplan D (2001) Age, Working Memory, and On-Line Syntactic Processing in Sentence Comprehension. *Psychology and Aging*, **16**, 128–144. https://doi.org/10.1037//0882-7974.16.1.128

Wauters LN, Van Bon WHJ and Tellings AEJM (2006) Reading comprehension of Dutch deaf children. *Reading and Writing*, **19**, 49–76. https://doi.org/10.1007/s11145-004-5894-0

White L, Valenzuela E, Kozlowska-MacGregor M and Leung Y-KI (2004) Gender and number agreement in nonnative Spanish. *Applied Psycholinguistics*, **25**, 105–133. https://doi.org/10.1017/S0142716404001067

Wilmoth JR (2000) Demography of longevity: past, present, and future trends. *Experimental Gerontology*, **35**, 1111–1129.

Wong PCM, Ettlinger M and Zheng J (2013) Linguistic Grammar Learning and DRD2-TAQ-IA Polymorphism. *PLoS ONE*, **8**, e64983. https://doi.org/10.1371/

Wong PCM, Morgan-Short K, Ettlinger M and Zheng J (2012) Linking neurogenetics and individual differences in language learning: The dopamine hypothesis. *Cortex*, **48**, 1091–1102. https://doi.org/10.1016/j.cortex.2012.03.017

Wong PCM, Vuong L and Liu K (2017) Personalized Learning: From Neurogenetics of Behaviors to Designing Optimal Language Training. *Neuropsychologia*, **98**, 192–2000. https://doi.org/10.1016/j.physbeh.2017.03.040

Yap MJ, Balota DA, Sibley DE and Ratcliff R (2012) Individual Differences in Visual Word Recognition: Insights From the English Lexicon Project. *Journal of Experimental Psychology: Human Perception and Performance*, **38**, 53–79. https://doi.org/10.1037/a0024n7