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Intact Reversed Language-dominance but not Cognate Effects in Reading aloud of Language Switches in Bilingual Alzheimer's Disease

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Abstract

Objective: The current study investigated how Alzheimer's disease (AD) affects production of speech errors in reading-aloud of mixed-language passages with language switches on cognates (e.g., *family/familia*), noncognates (e.g., *people/gente*), and function words (*the/la*).

Method: Twelve Spanish-English bilinguals with AD and 22 controls read-aloud 8 paragraphs in four conditions (a) English-default content switches, (b) English-default function switches, (c) Spanish-default content switches, and (d) Spanish-default function switches.

Results: Reading elicited *language intrusions* (e.g., saying *la* instead of *the*), and several types of *within-language* errors (e.g., saying *their* instead of *the*). Reversed language-dominance effects were intact in AD; both patients and controls produced many intrusions on dominant language targets, and relatively fewer intrusions on nondominant language targets. The opposite held for within-language errors, which were more common with nondominant than dominant targets. Patients produced the most intrusion errors with cognate switch words (which best distinguished patients from controls in ROC curves of all speech error types), while controls had equal difficulty switching on cognate and function word targets.

Conclusions: Reversed language-dominance effects appear to illustrate automatic inhibitory control over the dominant language, but could instead reflect limited resources available for monitoring when completing a task in the nondominant language. The greater sensitivity of intrusion errors with cognate than with function word targets for distinguishing patients from

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controls implies that language control may be aided by relatively intact knowledge of grammatical constraints over code-switching in bilinguals with AD.

Keywords

bilingualism; language switching; speech errors; Alzheimer's disease; cognates

Although deficits in explicit memory are the hallmark of Alzheimer's disease (AD), deficits in executive functions (Baudic et al., 2006; Lafleche & Albert, 1995; Perry & Hodges, 1999), and changes in aspects of language processing are also common (for reviews see Mueller, Hermann, Mecollari & Turkstra, 2018; Slegers, Filiou, Montembeault, & Brambati, 2018; Szatloczki, Hoffmann, Vincze, Kalman, & Pakaski, 2015). These include word finding difficulty (e.g., Bayles, 1993), reduced verbal (especially semantic) fluency (e.g., Salmon, Butters, & Chan, 1999), reduced grammatical complexity and propositional content (e.g., Kemper, Thompson, & Marquis, 2001), longer hesitations and slower spontaneous speech (e.g., Hoffmann, Nemeth, Dye, Pákasaki, Irinyi, & Kálmán, 2010). Highly practiced and more automatic linguistic processing tasks, such as reading, are thought to be relatively preserved (Cummings et al., 1986; Friedman, Ferguson, Robinson, & Sunderland, 1992; Sasanuma, Sakuma, & Kitano, 1992). However, in moderate stages of cognitive impairment patients exhibit increased difficulty reading low-frequency words with irregular spelling-to-sound correspondences (e.g., Strain, Patterson, Graham, & Hodges, 1998, possibly reflecting semantic impairments, Glosser, Grugan, & Friedman, 1999), and articulation rate is decreased while proportion of pauses is increased in connected speech elicited via reading aloud (Martínez-Sánchez, Meilán, García-Sevilla, Carro, & Arana, 2013; see review in Glosser & Grossman, 2004).

To the extent that executive control abilities normally support language processing, some apparent deficits in language processing tasks might instead reflect primary deficits in executive control (e.g., left branching sentences require greater working memory; Almor, Kempler, MacDonald, Andersen, & Tyler, 1999; Kemper et al., 2001¹), or detection and resolution of conflict. For example, error rates on incongruent trials of the Stroop task (e.g., needing to say *red* in response to the word *green* printed in red ink) discriminated patients with early AD from healthy controls better than 18 commonly administered measures in a neuropsychological test battery (Hutchison, Balota, & Duchek, 2010). In bilinguals, speech itself might present a stronger than typical challenge for executive control, because bilinguals must choose between translation equivalent alternatives with virtually every word they produce, a selection challenge monolinguals face only occasionally when choosing between synonyms (e.g., *sofa* and *couch*; Jescheniak & Schriefers, 1998; Peterson & Savoy, 1998). This increased competition for selection challenge in bilinguals should be particularly strong when they speak in the nondominant language, which requires controlling the more automatic tendency to speak in the dominant language, possibly relying on domain general inhibition (Abutalebi & Green, 2007; Branzi, Della Rosa, Canini, Costa,

¹For example, from Kemper et al., (2001), older adults and especially patients with AD, favored right-branching constructions (e.g., "She's awfully young to be running a nursery school for our church") over left-branching constructions (e.g., "The gal who runs a nursery school for our church is awfully young")

& Abutalebi, 2016; Green, 1998; Guo, Liu, Misra, & Guo, 2011; Phillip & Koch, 2009; for review see Bialystok, 2017).

Consistent with this hypothesis, as AD progresses bilinguals increasingly avoid speaking their nondominant language (Mendez, Perryman, Pontón, & Cummings, 1999). Although cross-sectional comparisons sometimes reveal greater differences between patients and controls in the dominant language (Gollan, Salmon, Montoya, & da Pena, 2010), longitudinal comparisons reveal greater decline in the ability to name pictures in the nondominant than in the dominant languages with disease progression (Ivanova, Salmon, & Gollan, 2014²). Recently, we reported striking evidence that bilinguals with AD have more difficulty controlling activation of two languages in the form of speech errors produced during a reading aloud task (Gollan, Stasenko, Li & Salmon, 2017). When bilinguals read aloud mixed-language paragraphs they sometimes spontaneously translate written switch words to avoid switching in their speech; for example, producing *of* instead of its translation equivalent *de* when reading aloud a sentence like *The next day the group de people left for the capital of Guatemala*. Bilinguals with AD produce significantly more such intrusion errors compared to age-, education-, and proficiency-matched healthy bilingual controls (even though intrusions require rapid and automatic translation of written target words). Importantly, bilinguals with AD produced more intrusions only when reading aloud mixed-language paragraphs, not when reading paragraphs written in a single language. Thus, the ability to rapidly switch back and forth between languages was impaired, while selection of a single language for production was intact during reading aloud (and by contrast, in picture naming bilinguals with AD produced more intrusions than controls even without the requirement to switch languages; Costa et al., 2012).

Surprisingly, bilinguals with AD were also significantly more likely to replace dominant language targets with their nondominant language translation equivalents than the opposite – an apparent *reversed language-dominance* effect. This is surprising because bilinguals should produce words in the dominant language more automatically than words in the nondominant language. In previous work we suggested that reversed dominance effects reflect successful application of inhibitory control to the dominant language when bilinguals plan to switch languages (Fadlon, Li, Prior & Gollan, in press; Gollan, Schotter, Gomez, Murillo, & Rayner, 2014; Gollan & Ferreira, 2009; Gollan & Goldrick, 2018; Li & Gollan, 2018a; Schotter, Li, & Gollan, in press). On this view, and assuming inhibition of the dominant language in the read aloud task relies on domain general inhibitory control (Ratnu & Azuma, 2017), we should have found weaker dominance reversal for bilinguals with impairments to inhibitory control. However, both aging bilinguals (Gollan & Goldrick, 2016), and bilinguals with AD (Gollan et al., 2017), exhibited equally sized reversed language dominance effects relative to their comparison groups (young bilinguals and healthy aging controls respectively in these two studies). Thus, an alternative explanation may be needed to explain reversed dominance effects.

²Note that relatively balanced bilinguals (who do not have one strongly dominant language) exhibit parallel decline of the two languages in AD (Calabria et al., 2017).

While reversed dominance effects have been reported both in single picture naming (Costa & Santesteban, 2004; Gollan & Ferreira, 2009) and in the read aloud task (Gollan et al., 2014; Gollan & Goldrick, 2016, 2018; Gollan et al., 2017; Li & Gollan, 2018a), it is possible that different cognitive mechanisms underlie dominance effects in the two tasks. In paragraph reading it could even be questioned if the greater incidence of intrusion errors with dominant language targets in fact reflects dominance reversal because all dominant language switches appeared in paragraphs that were written primarily in the nondominant language. Thus, while dominance was reversed on the switch words themselves, at a more global task level, the rate of intrusions was higher when bilinguals were completing the more difficult task (i.e., reading in the nondominant language). As such, bilinguals might have had fewer cognitive resources to devote to monitoring and correcting planned speech errors prior to producing them overtly. A problem with this alternative explanation is that it predicts the opposite pattern; that is, if bilinguals with AD have reduced monitoring abilities, then they should have produced significantly *greater* dominance reversal effects than controls. Possibly consistent with this view, within each participant group alone, bilinguals with AD, but not controls, exhibited significantly reversed dominance effects in Gollan et al., (2017). However, the interaction between language dominance and participant group was not significant (possibly reflecting limited power in that study for observing interaction effects). This left open questions as to the mechanism underlying dominance reversal effects, and the higher rate of intrusions in bilinguals with AD.

The present study provided a more in depth investigation of how AD affects bilinguals' ability to switch languages in the read aloud task with manipulations we hypothesized could increase power for distinguishing patients from controls. In Gollan et al., (2017) all switches out of the default language were on content words even though the vast majority of intrusion errors produced in the read aloud task involve function word targets – a highly robust *part-of-speech* effect (Kolers, 1966; Fadlon, et al., in press; Gollan et al., 2014; Gollan & Goldrick, 2016, 2018; Schotter, et al., in press). The exclusion of function words in our first study was purposeful – as controls rarely produce intrusion errors with content words targets we hypothesized that errors with such targets might be pathognomonic of AD. However, this same manipulation might have limited power for observing interactions between language dominance and participant group, because controls produced very few intrusion errors (9/19 controls produced none, 5/19 produced just 1, and only 4 produced more than 1).

To increase the rate of intrusion errors in the present study, half the paragraphs had language switches on content words and half on function words. In addition, within paragraphs with content word switches, half of those switches were on cognate targets. Cognates are translation equivalents that overlap in form; for example the translation equivalents of *group* is *grupo* in Spanish. Cognates often facilitate responses relative to noncognates (e.g., *people* is *gente* in Spanish; for review see Costa, Santesteban, & Caño, 2005) in various language measures including speeded responding in lexical decision (e.g., Caramazza & Brones, 1979; Van Hell & Dijkstra, 2002) and picture naming (Costa, Caramazza, & Sebastian-Galles, 2000; Hoshino & Kroll, 2008), higher scores on standardized tests of picture naming (Gollan, Fennema-Notestine, Morris, & Jernigan, 2007; Roberts & Deslauriers, 1999), fewer tip-of-the-tongue states (Gollan & Acenas, 2004), and smaller language switching costs (Declerck, Koch, & Philipp, 2012; Li & Gollan, 2018b).

However, cognate effects vary by task (e.g., Dijkstra, Miwa, Brummelhuis, Sappelli, & Baayen, 2010) and stimulus list composition, Poort & Rodd, 2017), and sometimes elicit interference including larger switch costs (Christoffels, Firk, & Schiller, 2007; Li & Gollan, 2018b), more accented speech in picture naming (Amengual 2012; Goldrick, Runnqvist, & Costa, 2014), faster response onset but slower total typing time and increased errors in translation (Muscalu & Smiley, in press), and greater apparent response conflict (as measured by error-related negativity or ERN, Acheson et al., 2012; and slower subsequent responding, Broersma, Carter, & Acheson, 2016). Most relevant in the present study, cognates elicit more intrusion errors in the read aloud task (Gollan et al., 2014; Li & Gollan, 2018a). Though this effect might seem to reflect competition between alternative pronunciations of orthographically similar words in reading aloud (Schwartz, Kroll, & Diaz, 2007) – Chinese-English bilinguals also produce more intrusions on cognate switches in the read aloud task (Li & Gollan, 2018a), implicating response selection in planning of speech (not recognition of words) in this cognate interference effect.

While our main goal was to increase intrusion rate to provide greater power for detecting possible effects of AD on language dominance in the read aloud task, a secondary aim was to ask which type of target best distinguishes patients from controls. On the one hand, our inclusion of more difficult switch targets (i.e., function words and cognates) could make the task more sensitive to between group differences (relative to Gollan et al., 2017). On the other hand, including targets that would increase error rates even in cognitively healthy aging bilingual controls could blur the distinction between patients and controls in this task and reduce the extent to which intrusion errors could be used as a tool for identifying AD. Either outcome would also inform models of bilingual language control and cognitive impairment in AD.

Methods

Participants

Twelve Spanish-English bilinguals diagnosed with probable AD (1 with Lewy Body variant), and 22 cognitively healthy controls participated in the study as part of their annual evaluation at University of California San Diego's (UCSD) Shiley-Marcos Alzheimer's Disease Research Center (ADRC). At the time of testing, 5 patients were mildly impaired (Dementia Rating Scale scores between 121 and 127; Mattis, 1988), 5 were moderately impaired (DRS scores between 97 and 109), and 2 were severely impaired (DRS scores of 74 and 92). Three of the bilinguals with AD (25%) and 12 of the cognitively healthy controls (55%) were also tested in Gollan et al. (2017). Diagnoses were determined using criteria developed by the National Institute of Neurological and Communicative Disorders and Stroke (NINCDS) and the Alzheimer's Disease and Related Disorders Association (ADRDA; McKhann et al., 1984). Participants with a history of alcoholism, drug abuse, severe psychiatric disturbances, severe head injury, and learning disabilities are excluded from participation in the ADRC study. Participant demographics, performance on annual neuropsychological test battery measures (see Weissberger, Salmon, Bondi & Gollan; 2013), and self-reported language history questionnaire responses are summarized in Table 1. Bilinguals with AD were older and less educated than controls. Note that to the extent that

older age and lower education level are associated with weaker executive control these demographic differences might merely strengthen some of the critical predictions regarding which conditions should elicit the greatest difference between groups. We controlled for these demographic differences between groups in the statistical analyses below, and report the results in detail only when this changed the pattern of significance.

Objective proficiency was determined by picture naming ability on the Multilingual Naming Test (MINT; Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012; Ivanova, Salmon, & Gollan, 2013) which consists of 68 black-and-white line drawings, administered in order of increasing difficulty (e.g., item #1 is *hand*, and item # 68 is *axle*). Bilinguals with AD and controls did not differ in degree of bilingualism as measured by the Bilingual Index Score which is calculated by dividing the Multilingual Naming Test score in the nondominant language by the dominant language score (e.g., a person who named 30 pictures in the nondominant language and 60 pictures in the dominant language would be classified as 50% bilingual; Gollan et al., 2010; 2012). Participant demographics, performance on annual neuropsychological test battery measures (see Weissberger, et al., 2013), and self-reported language history questionnaire responses are summarized in Table 1.

All participants reported being exposed to Spanish from birth. Seven patients and 13 controls chose English as their dominant language, while 5 patients and 9 controls chose Spanish. In all cases, self-selected language dominance matched classification based on the MINT. There were 7 patients and 12 controls who reported Mexico as their country of origin, 3 patients and 8 controls who reported the USA as country of origin, 1 patient from Panama, 1 patient from Peru, 1 control from Cuba, and 1 control from Honduras. All participants were right-handed except for one left-handed patient, and one control who reported being ambidextrous. Informed consent was obtained from all individuals (or their caregivers when needed) prior to their participation in the research study. The UCSD Institutional Review Board approved the study procedures.

Materials

A list of all switch out target words is presented in Appendix A, and an example of each type of paragraph and how it was modified between participants across conditions is presented in Appendix B. Switches on cognates with identical spelling were not included because it would be impossible to classify intrusion errors on such targets (e.g., the Spanish for *piano* is *piano*). Switches on content words that had previously already been language switched were also avoided with 1 exception on the cognate *family/familia*, and another on the noncognate *things/cosas*. Function word switches were repeated given more limited possibilities. On average, paragraphs had 129.8 words ($SD = 14.5$; range 104–153).

A native Spanish-English bilingual selected and adapted eight paragraphs from published English-Spanish translations of short stories (modified from Gollan & Goldrick, 2018). A second native Spanish-English bilingual read through the paragraphs to check for errors and confirm the intended manipulations. The mixed language paragraphs were written primarily in one language, henceforth the *default language* (similar to Matrix language; Myers-Scotton & Jake, 2009), and had 6 language switches. Each paragraph was adapted so that it could be presented in each of four conditions (between participants; see Procedure): (a) English-

default content switches, (b) English-default function switches, (c) Spanish-default content switches (d) Spanish-default function switches. The majority of Spanish and English function words are noncognates (with a few exceptions including just one in the present study, *other/otro*; see Appendix A). In paragraphs with switches on content words, half of the switches had cognate targets and half noncognate targets. Across adaptations of each paragraph, function word switches were either just before or just after content word switch locations in the same paragraphs in a different condition (e.g., one participant read *el money* in a Spanish-default paragraph with switches on content words while another read *the dinero* in a Spanish-default paragraph with switches on function words). These *Switch-out* of the default language points were distributed evenly throughout the paragraph and were immediately followed by *Switch-back* points (i.e., switches back into the default language). One paragraph had an extra switch on a cognate, and another paragraph had an extra switch on a noncognate, and a function word (in different versions of the same paragraph). These errors were corrected about half-way through data collection; thus, 14 controls and 5 patients read paragraphs with the planned number of switch out points (12 on cognates, 12 on noncognates, 24 on function words), while 6 controls and 3 patients read one extra switch on a noncognate, 1 control and 3 patients read one extra switch on a function word, and 1 control and 1 patient read one extra cognate switch and an extra function word switch. Statistical analysis controlled for these extra switches with logistic regression by examining the probability of error on switch out points.

Procedure

Participants were tested individually in a quiet, well-illuminated room by a Spanish-English bilingual psychometrist. Paragraphs were presented on paper with words printed in Times New Roman font, size 20, double spaced. Each paragraph was presented on a single page. Participants were instructed in their dominant language to read the paragraph aloud as accurately as possible at a comfortable pace, and were audio-recorded and timed with a stopwatch. Each participant read aloud 8 paragraphs with 2 paragraphs in each of 4 conditions presented in counterbalanced order between participants. Prior to reading the first paragraph of each condition, participants completed a shorter practice paragraph. The experimenter corrected participants if they produced any errors during these practice trials. In total 19 participants (7 patients, 12 controls) read paragraphs aloud in their dominant language first, and 15 participants (5 patients, and 10 controls) read aloud in their nondominant language first.

Counterbalancing assured that each paragraph appeared in every condition between participants. To this end, paragraphs were paired into groups of two and then rotated across the four conditions using a Latin Square design. Paragraphs were then presented in one of 4 different fixed-order lists with 2 paragraphs of each type appearing consecutively within each list. Thus, across the 4 different lists paragraphs of each type (crossing default-language and content versus function switches) were presented in each list position (1st through 4th) an equal number of times. Each bilingual was presented with just one of these lists. Errors were marked on a coding sheet during testing and were later checked against audio recordings. Errors were defined as any word produced differently from what was written on the page. Examples of error types are shown in Table 2.

Results

Following the methods of Gollan et al. (2017), a native Spanish-English bilingual research assistant transcribed errors and classified them into error types (see Table 3). Inter-rater reliability for intrusion errors in previous work was 100% and 95.5% of all other words produced in the read-aloud task (Gollan et al., 2017; error classifications were completed by the same research assistant in the present study). Eleven intrusion errors, 5 function word substitution errors, and small numbers of other different types of errors (1 accent, 2 content word substitutions, 1 inflection, 2 nonword errors, and 3 omissions) were initially produced correctly and then as an error; these cases were counted as errors. Errors that were repeated twice were counted as a single error, and in cases where bilinguals produced more than one error type on a single target word preference was given to classifying the production as the more common error type. For example, if a single target word induced both a partial intrusion and an intrusion error then a single intrusion error was coded; e.g., if instead of saying "...*there was nothing more difcil than tricking grandma...*" a participant said "...*there was nothing more diffi...difficult than tricking grandma*" this would get coded as a single intrusion error (not as both a partial intrusion and a full intrusion error).

Reading times

Though speech errors were our primary measure of interest, we first examined if paragraph reading times varied by group and condition to ensure that there were no speed-accuracy trade-offs using a linear mixed effects regression with the R package lme4 (Bates, Maechler, Bolker, & Walker, 2015) with switch word type (content vs. function), default language (dominant vs. nondominant), group (patients vs. controls), and all the two-way and three-way interactions as fixed effects, with participants and paragraphs entered as random intercepts, and all the relevant random slopes. Correlations between random effects were removed due to the failure to converge. We log-transformed reading times so that regression coefficients would express proportional changes in reading times, but Table 4 shows unadjusted mean reading times. Bilinguals read paragraphs written mostly in the dominant language faster than those written mostly in the nondominant language ($M = 58.65$ s vs. 77.70 s; $\beta = -0.30$; $SE\beta = 0.03$; $\chi^2(1) = 35.117$, $p < .001$), and paragraphs with content switches faster than those with function switches ($M = 66.66$ s vs. 69.68 s; $\beta = -0.04$; $SE\beta = 0.01$; $\chi^2(1) = 8.96$, $p = .003$). Patients read more slowly than controls ($M = 77.27$ s vs. 63.21 s; $\beta = 0.20$; $SE\beta = 0.06$; $\chi^2(1) = 8.69$, $p = .003$), and none of the interactions were significant (p s $> .63$)³.

³In our analyses controlling for age and education, we included both centered age and centered years of education as factors and following Gollan and Goldrick (2016), we avoided running overly complex models (the full model would have included 5 main effects and every possible interaction crossing all 5 factors), by adding two main effects (i.e., age and education) and interactions between these and originally significant terms. Thus, the final model used in this case was: $\text{Intrusion} \sim \text{Group} * \text{POS} * \text{Language} + \text{Age} + \text{Education} + \text{Group:Age} + \text{Group:Education} + \text{POS:Age} + \text{POS:Education} + \text{Language:Age} + \text{Language:Education} + (1|\text{Participant}) + (1|\text{Paragraph})$. Unless noted, we adopted the same method to control for age and education for all other models. The main effect of group was not significant after controlling for age and years of education ($\beta = 0.11$; $SE\beta = 0.08$; $\chi^2(1) = 2.11$, $p = .146$), while other results remained unchanged.

Intrusion errors

Of greatest interest was to determine if patients exhibited reversed dominance effects, and if differences between patients and controls varied with target type. Because cognates and noncognates were intermixed in the same paragraphs, we began with a 2*2*2 analysis that included all of our data with contrast-coded fixed effects of group (patients with AD vs. controls), language of the target word (dominant vs. non-dominant), part-of-speech (POS: content vs. function), and all interactions between these factors focusing on switch-out words using logistic mixed-effects regressions (Dixon, 2008; Jaeger, 2008) with the R package lme4 (Bates et al., 2015). This model collapsed cognates and noncognates (given that there were three cognates and three noncognates in each content paragraph). To compare target types, we then ran three additional 2*2*2 models with a similar structure, but this time comparing cognates vs. function words, cognates vs. noncognates, and function word vs. noncognates. In all the models, participants and individual words were entered as random intercepts (some models with random slopes failed to converge so we removed random slopes from all the models). The significance of each fixed effect was assessed via likelihood ratio tests (Barr, Levy, Scheepers, & Tily, 2013).

Table 5 shows the mean intrusion rate for each group (patients vs. controls), language of the target switch word (dominant vs. nondominant), and part-of-speech (content vs. function). Overall bilinguals produced more intrusions with dominant than nondominant language switch word targets, a significant reversed dominance effect ($M = 22.42\%$ vs. 11.28% ; $\beta = 1.03$; $SE \beta = 0.18$; $\chi^2(1) = 35.43$, $p < .001$). They also tended to produce more intrusions with function than content switch words, a marginally significant main effect of part-of-speech ($M = 19.83\%$ vs. 13.91% ; $\beta = 0.75$; $SE \beta = 0.41$; $\chi^2(1) = 3.51$, $p = .061$). Patients produced significantly more intrusions on switch out words than controls ($M = 27.05\%$ vs. 11.27% ; $\beta = 1.66$; $SE \beta = 0.34$; $\chi^2(1) = 18.73$, $p < .001$), and there was also a significant interaction between group and part-of-speech ($\beta = -0.87$; $SE \beta = 0.37$; $\chi^2(1) = 5.78$, $p = .016$), such that function and content switch words elicited intrusion errors about equally often in patients ($M = 29.11\%$ vs. 25.00% , $\beta = 0.16$; $SE \beta = 0.45$; $\chi^2 < 1$), while function words elicited more intrusions than content words in controls ($M = 14.72\%$ vs. 7.85% , $\beta = 0.99$; $SE \beta = 0.42$; $\chi^2(1) = 6.03$, $p = .014$). Stated differently, the higher intrusion rate in patients than controls was larger with content ($M = 25.00\%$ vs. 7.85% , $\beta = 2.31$; $SE \beta = 0.50$; $\chi^2(1) = 18.48$, $p < .001$) than with function switches ($M = 29.11\%$ vs. 14.72% , $\beta = 1.17$; $SE \beta = 0.35$; $\chi^2(1) = 9.73$, $p = .002$). No other interactions were significant ($p > .43$).

To better understand part-of-speech effects and to consider the effects of cognate status, we conducted three planned analyses comparing cognates vs. noncognates (within the content switch paragraphs only), cognates to function words, and noncognates to function words (across content and function switch paragraphs). Though we had twice as many switches on function words as on each of the two types of content words, note that (unlike ANOVA) mixed effects models are well suited for handling unbalanced data sets (Baayen, Davidson, & Bates, 2008). Controls produced no intrusion errors with noncognate switch words in the nondominant language (i.e., there was no variance for this condition); thus when comparing 1) cognates to noncognates, and 2) function words to noncognates, the models with all the three independent variables (i.e., group, switch word type, and language) only converged

after we excluded the three-way interaction (between word type, language, and group). Figure 1 shows intrusion rates separately for cognates, noncognates, and function words in the dominant and nondominant languages in each participant group.

When comparing cognates to noncognates, only three main effects were significant. Bilinguals produced more intrusions with dominant than nondominant language switch targets ($M = 18.69\%$ vs. 9.16% ; $\beta = 1.68$; $SE \beta = 0.46$; $\chi^2(1) = 19.60$, $p < .001$), more intrusions with cognate than noncognate switches ($M = 23.66\%$ vs. 4.32% ; $\beta = 3.36$; $SE \beta = 0.65$; $\chi^2(1) = 35.81$, $p < .001$), patients produced more intrusions than controls ($M = 25.0\%$ vs. 7.85% ; $\beta = 2.20$; $SE \beta = 0.55$; $\chi^2(1) = 15.17$, $p < .001$), and none of the interactions were significant ($ps > .14$).

When comparing cognates to function words, bilinguals produced significantly more intrusions with dominant than nondominant language switch targets ($M = 27.39\%$ vs. 14.80% ; $\beta = 0.95$; $SE \beta = 0.19$; $\chi^2(1) = 26.61$, $p < .001$). Patients produced more intrusions than controls ($M = 33.18\%$ vs. 14.46% ; $\beta = 1.69$; $SE \beta = 0.34$; $\chi^2(1) = 19.27$, $p < .001$), and there was a significant interaction between group and switch word type ($\beta = 1.02$; $SE \beta = 0.39$; $\chi^2(1) = 7.07$, $p = .008$). Follow-up comparisons revealed that the increased rate of intrusions in patients relative to controls was larger with cognate ($M = 41.38\%$ vs. 13.96% ; $\beta = 2.41$; $SE \beta = 0.56$; $\chi^2(1) = 16.64$, $p < .001$) than with function word targets ($M = 29.11\%$ vs. 14.72% ; $\beta = 1.17$; $SE \beta = 0.35$, $\chi^2(1) = 9.73$, $p = .002$). Stated differently, while patients produced more intrusions with cognate than with function word switches ($M = 41.38\%$ vs. 29.11% ; $\beta = 1.05$; $SE \beta = 0.44$; $\chi^2(1) = 6.22$, $p = .013$), controls produced similar rates of intrusions for cognate and function word switches ($M = 13.96\%$ vs. 14.72% ; $\beta = -0.06$; $SE \beta = 0.38$; $\chi^2 < 1$). All other fixed effects were not significant ($ps > .20$)⁴.

Comparing function words to noncognates, bilinguals produced significantly more intrusions with dominant than nondominant language targets ($M = 19.97\%$ vs. 9.22% ; $\beta = 1.64$; $SE \beta = 0.43$; $\chi^2(1) = 21.75$, $p < .001$), and more intrusions with function words than with noncognate targets ($M = 19.83\%$ vs. 4.32% ; $\beta = 2.70$; $SE \beta = 0.58$; $\chi^2(1) = 28.57$, $p < .001$). Patients produced more intrusions than controls ($M = 22.32\%$ vs. 10.38% ; $\beta = 1.61$; $SE \beta = 0.45$; $\chi^2(1) = 12.10$, $p < .001$). None of the interactions were significant ($ps > .10$)⁵.

Self-corrected rates of intrusions

To consider if patients spontaneously self-corrected their own full intrusion errors less often than controls, we conducted a 2*2*2 analysis with contrast-coded fixed effects of group (patients vs. controls), language of the target word (dominant vs. non-dominant), part-of-speech (POS: content vs. function), and all interactions between these factors. Participants and target words were entered as two random intercepts. Bilinguals self-corrected full

⁴The model that attempted to jointly control for age and education failed to converge. However, we ran two separate models with centered age or years of education, and all the above results held. Most critically, the interaction between group and word type (function vs. cognate) remained significant in both models ($ps < .01$). The final models were: 1) Intrusion ~ Group*WordType*Language + Age + Group:Age + Language:Age + Group:WordType:Age + (1|Participant)+(1|Word); 2) Intrusion ~ Group*WordType*Language + Education + Group:Education + Language:Education + Group:WordType:Education + (1|Participant)+(1|Word).

⁵A model with both age and years of education as covariates failed to converge. Thus, we controlled for these two factors in two separate models, and found the same pattern of results.

intrusions with content word targets significantly less often than with function word targets ($M = 12.17\%$ vs. 25.77% ; $\beta = -1.11$; $SE \beta = 0.49$; $\chi^2(1) = 5.74$, $p = .017$), and controls tended to correct themselves more often than patients, a marginally significant difference ($M = 28.50\%$ vs. 14.56% ; $\beta = -0.98$; $SE \beta = 0.59$; $\chi^2(1) = 2.88$, $p = .090$). None of the other effects were significant ($ps \geq .54$)⁶.

Within-language errors

Though our manipulations were not intended to elicit within-language errors, as in previous studies with the read-aloud task, bilinguals produced many within-language errors as well and these provide an interesting point of comparison (see Table 3). We analyzed within-language errors in a model with the same structure as our initial analysis of intrusion errors, but without restricting the analyses to switch targets (since switch and non-switch words are equally prone to within language errors; Gollan & Goldrick, 2016; 2018). In this analysis, we collapsed across all different subtypes of within-language errors (see Table 3), but then we conducted separate analyses of each subtype of within-language errors for which we had at least 100 data points. Thus, the first analysis included group (patients vs. controls), language (dominant vs. nondominant), and part-of-speech (content vs. function) as independent variables, but subtype analyses only included group and language, as some subtypes only applied to content (e.g., content word substitutions) or function words (e.g., function word substitutions). Figure 2 shows the average percentage of words that elicited within-language errors broken down by paragraph type, language, and group, and Figure 3 presents the results separately for each error subtype. While not critically important for testing our primary hypotheses of interest, language dominance effects patterned differently across subtypes (implying that different accounts will be needed to explain different types of speech errors).

Collapsing across all within-language error subtypes, there was a significant main effect of language in the opposite direction of that reported for intrusion errors; that is, bilinguals produced more within-language errors for nondominant than for dominant language targets ($M = 4.74\%$ vs. 2.20% ; $\beta = -0.96$; $SE \beta = 0.07$; $\chi^2(1) = 200.6$, $p < .001$), part-of-speech effects were marginally significant, with more errors on content than on function word targets ($M = 3.55\%$ vs. 3.42% ; $\beta = 0.21$; $SE \beta = 0.12$; $\chi^2(1) = 3.01$, $p = .083$), and there was a significant effect of group such that patients produced more errors than controls, ($M = 5.56\%$ vs. 2.33% ; $\beta = 0.83$; $SE \beta = 0.26$; $\chi^2(1) = 8.97$, $p < .001$). However, unlike for intrusions, in this case the difference between patients and controls was larger with function than with content word targets, a significant interaction between part-of-speech and group, (M difference = 3.76% vs. 2.43% ; $\beta = 0.34$; $SE \beta = 0.13$; $\chi^2(1) = 5.87$, $p = .015$), while the difference between dominant and nondominant languages was smaller with function than with content word targets (M difference = 1.84% vs. 3.61% ; $\beta = 0.70$; $SE \beta = 0.13$; $\chi^2(1) = 24.63$, $p < .001$; see also Gollan & Goldrick, 2016), as would be expected given that function

⁶The results remained unchanged after controlling for age and education, except that the main effect of group was no longer significant ($\beta = -0.47$; $SE \beta = 0.55$; $\chi^2 < 1$). Noncognates elicited very few intrusions ($n=18$; see Table 6) and just 1 self-correction. However, bilinguals self-corrected intrusions with cognates significantly less often than with function words ($M = 13.40\%$ vs. 25.77% ; $\beta = -1.04$; $SE \beta = 0.51$; $\chi^2(1) = 4.53$, $p = .033$), and controls tended to correct themselves more often than patients, a marginally significant difference ($M = 28.70\%$ vs. 15.18% ; $\beta = -1.13$; $SE \beta = 0.63$; $\chi^2(1) = 3.37$, $p = .067$) that was not significant after controlling for education level ($\beta = -0.47$; $SE \beta = 0.59$; $\chi^2 < 1$).

words are highly frequent in both languages, and language dominance effects are larger for low frequency words (Gollan, Montoya, Cera, & Sandoval, 2008; Gollan, Slattery et al., 2011; Duyck, Vanderelst, & Hartsuiker, 2008). None of the other interactions were significant (all $ps > .146$). The main effect of group and the interaction between group and part-of-speech were not significant after controlling for age and education; details regarding this modulation are reported below in the analyses of within-language error subtypes (in which we collapsed across cognate status to maximize power).

To check if our manipulation of cognate status (which elicited a robust effect on intrusion errors as reported above) reflected a general property of cognates for eliciting all types of speech errors, we compared cognates to noncognates on switch words within the content switch paragraphs alone in a logistic regression with the same structure as in the analogous planned comparison reported above for intrusion errors. Cognates and noncognates elicited within-language errors equally often, and if anything cognates tended to produce fewer within-language errors than noncognates ($M = 2.44\%$ vs. 3.12% respectively; $\beta = -0.09$; $SE \beta = 0.55$; $\chi^2 < 1$). In this same analysis bilinguals also tended to produce more errors in the nondominant than in the dominant language, though this effect was just marginally significant ($M = 3.86\%$ vs. 1.70% ; $\beta = -0.83$; $SE \beta = 0.50$; $\chi^2(1) = 2.93$, $p = .087$), and patients did not produce more errors than controls ($M = 3.08\%$ vs. 2.62% ; $\beta = 0.18$; $SE \beta = 0.59$; $\chi^2 < 1$). None of the interactions were significant (all $ps > .263$).

Sub-types analyses

Function word substitution errors were the most frequent within-language error subtype. Analysis of these errors revealed that bilinguals produced more errors in the nondominant than in the dominant language ($M = 1.34\%$ vs. 0.74% ; $\beta = -0.69$; $SE \beta = 0.12$; $\chi^2(1) = 34.18$, $p < .001$), and patients produced more errors than controls ($M = 1.94\%$ vs. 0.55% ; $\beta = 1.25$; $SE \beta = 0.55$; $\chi^2(1) = 25.26$, $p < .001$). There was no interaction between group and language ($\beta = 0.28$; $SE \beta = 0.24$; $\chi^2(1) = 1.36$, $p = .24$).

Analysis of omission errors revealed that patients omitted words significantly more often than controls ($M = 0.84\%$ vs. 0.38% ; $\beta = 0.79$; $SE \beta = 0.24$; $\chi^2(1) = 8.98$, $p = .003$). Neither language nor the interaction between group and language were significant ($ps > .18$).

Analysis of content word substitutions revealed that bilinguals produced more errors with nondominant than dominant targets ($M = 0.74\%$ vs. 0.24% ; $\beta = -1.30$; $SE \beta = 0.19$; $\chi^2(1) = 52.30$, $p < .001$), patients produced more errors than controls ($M = 0.78\%$ vs. 0.33% ; $\beta = 0.77$; $SE \beta = 0.32$; $\chi^2(1) = 5.48$, $p = .019$), and the interaction was not significant ($\beta = -0.63$; $SE \beta = 0.38$; $\chi^2(1) = 2.69$, $p = .101$). The difference between patients and controls was no longer significant after controlling for age and education ($\beta = 0.32$; $SE \beta = 0.36$; $\chi^2(1) = 1.62$, $p = .203$).

Analysis of inflection errors revealed bilinguals produced more errors with nondominant than dominant targets ($M = 0.81\%$ vs. 0.30% ; $\beta = -1.19$; $SE \beta = 0.18$; $\chi^2(1) = 50.23$, $p < .001$), and patients produced more errors than controls ($M = 0.78\%$ vs. 0.44% ; $\beta = 0.90$; $SE \beta = 0.31$; $\chi^2(1) = 8.07$, $p = .004$). However, the difference between patients and controls was significant only in the dominant language, a significant interaction between group and

language dominance ($\beta = 0.85$; $SE \beta = 0.36$; $\chi^2(1) = 5.82$, $p = .016$). With dominant language targets, patients produced significantly more inflection errors than controls ($M = 0.55\%$ vs. 0.17% ; $\beta = 1.30$; $SE \beta = 0.50$; $\chi^2(1) = 6.25$, $p = .012$), but this difference was not significant with nondominant targets ($M = 1.01\%$ vs. 0.71% ; $\beta = 0.59$; $SE \beta = 0.39$; $\chi^2(1) = 2.39$, $p = .12$). However, neither the group difference nor the interaction remained significant after controlling for age and education ($ps \geq .25$).

Lastly, analysis of nonword errors revealed that bilinguals produced these more often with nondominant than with dominant language targets ($M = 0.77\%$ vs. 0.11% ; $\beta = -2.35$; $SE \beta = 0.28$; $\chi^2(1) = 106.77$, $p < .001$). None of the other effects were significant (all $ps \geq .414$).

Self-correction rates of within-language errors

As shown in Table 8, collapsing all the within-language errors, controls spontaneously corrected their own speech errors significantly more often than patients ($M = 31.33\%$ vs. 17.17% ; $\beta = -1.06$; $SE \beta = 0.31$; $\chi^2(1) = 9.94$, $p < .001$), and corrected function word errors more frequently than content word errors ($M = 26.00\%$ vs. 19.44% ; $\beta = 0.36$; $SE \beta = 0.18$; $\chi^2(1) = 4.20$, $p = .040$), while neither language nor the interaction between participant group and language were significant ($ps \geq .24$). Analyses of subtypes revealed that controls corrected themselves significantly more often than patients with function word substitutions ($M = 38.09\%$ vs. 25.62%), omissions ($M = 45.35\%$ vs. 10.48%), and content word substitutions ($M = 35.53\%$ vs. 18.56% ; $ps < .036$), but not with inflection ($M = 18.00\%$ vs. 11.34%), or nonword errors ($M = 22.99\%$ vs. 11.59% ; $ps \geq .10$).

Receiver Operating Characteristic (ROC) curves

Following Gollan et al. (2017), we submitted all error types that revealed a significant difference between patients and controls (i.e., a significant group main effect) in the mixed effects models to ROC curve analyses to consider the potential diagnostic utility of speech errors, which included intrusion errors on cognates and function word switch targets, as well as two subtypes of within-language errors—function word substitutions and omissions (the two subtypes that revealed a significant effect of participant group in error rate that survived control for age and education). The area under the curve (AUC), sensitivity, specificity, and ideal hypothetical cut-off scores for predicting group membership were calculated using ROC analyses in SPSS version 24. The AUC measure provides an overall indication of the diagnostic accuracy for each measure; generally classifying AUC values of 0.9 or higher as excellent and above 0.8 as good (values closer to 0.50 are at chance for discriminating between groups). Sensitivity (i.e., the true positive rate or hit) and specificity (i.e., the true negative rate or correct rejection) were calculated and sensitivity was plotted as a function of specificity. Thus, the ROC curves illustrate diagnostic accuracy for all possible cut-off scores (from which an optimal cut-off can then be determined). Table 9 shows the results of these analyses and Figure 4 shows ROC curves.

Intrusions.—Intrusions for cognate switches, collapsing across dominant and non-dominant languages, provided good-to-excellent diagnostic accuracy ($AUC = 0.87$, $p = 0.001$; see Fig. 4A). Actual scores ranged from 0 to 5 in controls, and 0 to 9 in patients, with an optimal cut-off at 3.5 intrusion or more giving 75% sensitivity and 86% specificity.

Intrusions for function word switches (AUC = 0.71) and noncognate switches (AUC = 0.74) fell below desirable diagnostic accuracy (see Table 9).

Within-language errors.—Function word substitution errors provided good diagnostic accuracy (AUC = 0.81, $p < .01$). Actual scores for this measure ranged from 1 to 12 in controls, and 1 to 44 in patients, with an optimal cut-off at 8.5 substitution errors or more giving 75% sensitivity and 73% specificity. All other subtypes of errors, including omission errors, failed to provide acceptable diagnostic accuracy (see Table 9).

Discussion

The current study replicated and extended our previous observation that AD increases the rate of intrusion errors produced on switch word targets when reading aloud mixed-language paragraphs (despite the fact that patients with AD read more slowly, or after controlling for age and education effects equally fast, as controls). Of great interest, bilinguals produced more intrusion errors when attempting to read targets written in the dominant language that appeared in paragraphs written primarily in the nondominant language (see Figure 1), while they produced within-language errors more often with targets in the nondominant language (see Figure 2). Importantly, language dominance effects were not significantly smaller in patients relative to controls for intrusion errors, and this was also true for nearly all within-language error subtypes – with the only exception being inflection errors in which the difference between patients and controls was significant only in the dominant language (see Figure 3). Part-of-speech and cognate effects patterned differently in intrusion errors compared to within-language errors; there were more intrusions on function than on content words (the opposite was true for within-language errors), dominance effects were stronger with function than with content words (the opposite was true for within-language errors), cognates were more prone to intrusions than noncognates (but not for within-language errors, in which if anything cognates tended to be less error prone), and patients produced more intrusions than controls particularly with content words, which include cognates (but patients produced more within-language errors than controls especially with function words). Finally, patients self-corrected their speech errors less often than controls (though this effect was just marginally significant for intrusion errors), and ROC curves revealed that intrusion errors for cognate targets, and function-word substitution errors within-language provided excellent and good discrimination between patients and controls, respectively.

Reversed Dominance – Language Specific Inhibition, or Monitoring?

The starting point for the present study was to re-test the hypothesis that bilinguals with AD might exhibit impaired inhibition, and therefore weaker or absent reversed dominance effects in the read-aloud task. Our experimental manipulations of switch target type were successful in raising the rate of intrusions relative to our previous study (Gollan et al., 2017), reducing concerns over possible floor effects influencing the results in the present study. Though it is always difficult to interpret null effects especially given a small number of participants, we observed robust interactions between part-of-speech effects and participant group, suggesting we had sufficient power in the present study to observe such interactions. Previously we suggested that the failure to find reduced dominance reversal effects in

been significantly *greater* in patients than in controls in the present study (but they were not). This in turn suggests that the non-significance of the trend we observed in that direction in Gollan et al., (2017) could have been driven by the exclusion of function words switches, and the absence of sufficient intrusion errors to detect significant dominance effects in controls in that study.

To further test this task difficulty hypothesis we conducted two additional analyses. First, we combined the data from the 2017 paper with those reported in the present study to maximize power in the analysis of intrusion errors. The results are shown in Figure 5; though the interaction remained nonsignificant⁷ even in the combined data set, the means illustrate that dominance effects are, if anything, larger (not smaller) in patients than in controls. Second, we asked if *within-language errors* produced on switch words in mixed-language paragraphs exhibited reversed dominance effects in the present study. The above reported analyses of within-language errors included both switch and nonswitch targets because previously we showed that within-language errors are equally probable on switch vs. non-switch words. However, if error monitoring is more difficult when reading paragraphs written primarily in the nondominant language, then within-language errors might also exhibit reversed dominance effects when focusing exclusively on switch words (all switch words in nondominant-default paragraphs were in the dominant language, while switch words in dominant-default paragraphs were in the nondominant language). Supporting this hypothesis, bilinguals produced significantly more within-language errors on function switch words in the dominant, than in the nondominant, language ($M = 3.15\%$ vs. 1.22% , $p = .050$). However, they produced more within-language errors on content switch words in the nondominant, than the dominant, language ($M = 1.70\%$ vs. 3.86% , $p = .070$), a significant interaction between target language dominance and part-of-speech ($p = .021$). Additionally, this interaction appeared to be mainly driven by patients, but none of the interactions between participant group and other fixed effects in the model were significant ($ps > .17$). Thus, the task difficulty hypothesis appears to apply only to within-language errors on function word targets. A speculative interpretation of this result is that because function words are relatively high frequency in both languages, only these can exhibit reversed dominance effects. By contrast, content words primarily exhibit the effects of being much lower frequency in the nondominant relative to the dominant language (which leads to normal dominance effects even in mixed-language paragraphs), but this possibility will require further investigation.

Ultimately, it will be necessary to develop a more detailed account of how code-switches are planned in reading aloud. In the present study, switches might be most analogous to insertions (Muysken, 2000) in which a single word from one language is inserted into an utterance in the other language, possibly reflecting a “coupled control” process (Green & Wei, 2014; Green, 2018) in which access to the speech plan is only temporarily ceded to the

⁷In this analysis, we included Group (patients, controls), Language (dominant, nondominant), and their interaction as contrast coded fixed effects, and controlled Education and Age as follows [Intrusion~Group*Language+Age +Education + Group:Age + Group:Education + Language:Age + Language:Education + (1|Participant)+(1|Word)]. There were significant main effects of Group (patients produced more intrusions, $p < .001$), Language (more intrusions with targets in the dominant language, $p < .001$), and Age (older participants produced more intrusions, $p = .039$). However, all other effects were not significant ($ps > .25$), including the Group * Language interaction ($p = .71$).

other language. This proposal seems most consistent with the finding that switches back to the default language rarely elicit intrusion errors (Gollan & Goldrick, 2016; 2018), however, such control might also enable more automatic temporary increases of activation of the switched to language, that is different from the type of inhibitory control that is required when disengaging more completely from the previously used language (i.e., competitive control; Green & Wei, 2014), and thus remains intact in AD. Testing this possibility would require development of read-aloud paragraphs with switches that simulate the hypothesized modes of control, and also clarifying more specifically how inhibition differs across control modes.

Broader forms of evidence might also be needed. Although intrusion errors provide striking clues as to the mechanisms that enable control, even patients produced intrusion errors only on a minority of trials, which limits power. In turn, this highlights the relative automaticity of reading aloud even when it requires production of relatively unnatural code-switches – if this is not a highly automatic process, error rates should have been much higher in the present study, especially in patients. Finally, considering the broader literature on bilingual speech production, it is worth noting that reversed dominance effects appear to be more robust in the read-aloud task than in picture naming. The read-aloud task consistently produced reversed dominance effects with bilinguals who speak different language combinations (including Hebrew-English and Chinese-English bilinguals; Fadlon et al., in press; Li & Gollan, 2018a; Schotter et al., in press), and with different types of switches and switch targets (Gollan et al., 2014, 2017; Gollan & Goldrick, 2016, 2018). In other paradigms reversed dominance effects are sometimes but not always found (for recent review see Kleinman & Gollan, 2018). Moreover, it is not clear why dominance sometimes reverses fully even in tasks which (unlike the read aloud task) lack a clear default language; if the goal is to make both languages about equally accessible to enable switching back and forth, then response times should be equal in the two languages (not slower in the dominant language; for additional discussion see Gollan & Ferreira, 2009). Thus, although dominance reversal appears to be a robust phenomenon (that appears in different speech production tasks), additional work is needed to reveal why it occurs. Though the patterns can be described in the same way across paradigms (i.e., as dominance reversal), this does not necessarily mean that the same underlying cognitive mechanisms are involved.

Part-of-Speech and Cognate Effects

Bilinguals with AD exhibited significantly smaller part-of-speech effects than controls on intrusion errors (*M* function vs. content intrusions = 29.11% vs. 25.00% for patients, and 14.72 vs. 7.85% for controls), likely because patients had particular difficulty with switches on cognates (which are content words). By contrast, bilinguals with AD exhibited significantly *larger* part-of-speech effects on within-language errors, an effect that could reflect impaired monitoring of planned speech. Function words are particularly difficult to monitor even for young adults. For example, function word repetitions (e.g., *the the*) are difficult to detect even when eye-movements show fixations, which imply attention, on both instances of the word (Staub, Dodge, & Cohen, in press), whereas repeated nouns are detected most of the time (90%, and regardless of eye movement patterns; Staub et al., in press). Similarly, we recently showed that young bilinguals were more likely to self-correct

intrusion errors for content word targets when eye movements showed a regression back to the target word (Schotter et al., in press), whereas they did not correct function word intrusions even when their eyes had regressed back to the intended target word, thereby exhibiting failed monitoring processes for function words even in the presence of explicit evidence of an attempt to pay attention and monitor accuracy. Finally, aging also increases the rate of function word substitution errors in the read aloud task (Gollan & Goldrick, 2019), which when combined with the results of the present study could imply a common mechanism underlying the effects of aging and AD on reading aloud.

Monitoring deficits might also explain why cognates were more vulnerable than noncognates to intrusion errors, and why cognates exhibited greatest sensitivity for distinguishing patients from controls. The latter was supported by ROC curve analyses, and by our comparison of the two types of targets that produced the greatest number of intrusion errors, i.e., cognates and function word switches. This showed bilinguals with AD had particular difficulty with cognates, which for them were most error prone, while controls were equally likely to produce intrusions with cognate and function word switches. Although our comparison of cognates to noncognates did not reveal similar results (i.e., there was no interaction between target type and participant type), this analysis might have been underpowered because of the very low rate of intrusions for noncognate switches. On a monitoring account, the reason why patients had significantly more difficulty switching on cognates is an inability to distinguish between translation equivalent alternatives when one did, while the other did not, match the intended target. For cognates this would require both remembering which language was intended, and discriminating small differences in phonological form between lexical representations (whereas noncognates are more obviously different in form). Above we argued against the possibility that cognate effects arise during visual word recognition because Chinese-English bilinguals, whose writing systems are visually distinct, also exhibited cognate effects in the read-aloud task (Li & Gollan, 2018a), and because word recognition is highly automatic and relatively easy. However, it is possible that both orthographic and phonological form influenced the extent of difference between patients and controls in the present study.

As explained above, cognates facilitate processing in some tasks and interfere in others. In some cases, both facilitation and interference are observed even within the same study across different outcome measures (e.g., Broersma et al., 2016; Li & Gollan, 2018b; Muscalu & Smiley, 2018). In a cued language switching paradigm with a small set of repeatedly presented pictures, the first time bilinguals saw each picture they named cognates more quickly than noncognates especially on switch trials, which resulted in smaller switch costs for cognates than noncognates. However, with repetition, bilinguals named pictures more quickly except for cognates on switch trials, which slowed with repetition (Li & Gollan, 2018b). To explain this pattern we suggested that the initial facilitation arises at the sublexical phonological level (following Costa et al., 2000, due to automatic flow of activation from the picture to translation equivalent lexical representations to phonology, which overlaps for cognates but not noncognates), but that this facilitation is then offset by the emergence of increased competition for selection at the lexical level with repetition (which increases feedback from phonology back up to the lexical level, Rapp & Goldrick, 2000; for a similar interpretation of a different set of findings see Broersma et al., 2016). In

the read aloud task, intrusions can be produced only when translation equivalents are readily accessible, and cognates are easier to translate. In this respect, it might seem that the patients' particular difficulty with cognates must reflect reduced ability to resolve competition for selection. However, function words are also very easy to translate (indeed for this reason these targets exhibited weak language dominance effects both in the present study, and in Gollan & Goldrick, 2016). Thus, a monitoring account seems more plausible.

A question that remains is why the ability to produce function word switches, which in controls was as difficult as producing switches on cognates, remained relatively intact in patients when compared to switching on cognates. This result is relatively easy to explain by assuming that grammatical constraints on switching are highly automatic, and driven by syntactic processing, which remains relatively intact in AD. On this view, default language selection (Gollan & Goldrick, 2018; Myers-Scotton & Jake, 2009) would automatically create resistance to switching on single function words because intended switches on single function words are rare in spontaneous speech (Muysken, 2000; Deuchar, 2005; while function words are frequent targets of intrusion errors in spontaneous speech, Poullisse & Bongaerts, 1994). Consistent with this view, cognitively intact aging bilinguals produced more intrusions, but exhibited similarly sized effects of grammaticality on switching when reading aloud (a set of paragraphs that experimentally manipulated grammaticality; Gollan & Goldrick, 2016). Additionally, in some tasks, syntactic processing appears to be relatively intact in AD (e.g., Kavé & Levy, 2003; Hoffman et al., 2010; Kempler, Curtiss, & Jackson, 1987). This interpretation also fits with the above discussed possibility that default language selection primarily involves activation of morphosyntactic rules in one language (Branzi et al., 2014; Gollan & Goldrick, 2018; Wu & Thierry, 2017), and might be easier to accommodate within the general constellation of cognitive deficits in AD (which includes deficits in executive control).

Conclusions

Further investigation will be needed to determine if both cognate intrusion errors across languages, and function word substitution errors within-language, should be attributed to monitoring deficits. However, the present results confirm the sensitivity of speech errors produced in reading aloud as a potentially useful, and easy to administer tool for identifying AD in bilinguals, and possibly also in monolinguals (since they too produce function word substitution errors in the read aloud task; Gollan & Goldrick, 2019). Though increased production of speech errors would seem to imply language deficits in AD, on some theories of monitoring (Nozari, Dell, & Schwartz, 2011; Nozari & Novick, 2017) this particular deficit could easily originate outside the language system.

A more broadly relevant implication of the greater sensitivity of cognate than function word intrusions to AD in the present study implies that the recipe for developing good tests for discriminating patients from controls is to combine a difficult task (i.e., not a task on which controls would perform at ceiling) with a manipulation that targets specifically the cognitive mechanisms most affected by the disease. Finally, the hypothesis that grammatical processing remains intact in AD was initially proposed (Kemper, LaBarge, Ferraro, Cheung, Cheung, & Storandt, 1993; Lyons, Kemper, LaBarge, Ferraro, Balota, & Storandt, 1994) and

then later revised as a possible over-simplification of the facts (Snowdon, Kemper, Mortimer, Greiner, Wekstein, & Markesbery, 1996; Kemper, et al., 2001; but see Caplan & Waters, 2002). Our interpretation of the relative sensitivity of cognate versus function word switches to AD in the read-aloud task implies that the original idea that grammatical processing remains relatively intact in AD might vary with the nature of the task demands (e.g., grammaticality of code-switches places low demands on working memory; Bickel, Pantel, Eysenbach, Schröder, 2000), and might have more merit than recently appreciated in the literature.

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Appendix A

Cognate, Noncognate, and Function Switch Words

	cognates		noncognates		function	
	English	Spanish	English	Spanish	English	Spanish
Paragraph 1	decided noticed family	decidio notó familia	stretched young odd	estiraba joven raro	his he that and her because	su él que y su porque
Paragraph 2	family escape difficult	familia escaparse difícil	faking courage cards	fingiendo valentía barajas	that the her and to than	que la su y de que
Paragraph 3	parents problems mom	padres problemas mama	kids evening things	Niños tarde cosas	their that the their when that	sus que los su cuando que
Paragraph 4	experienced passion visits	experimentaba pasión visitas	love book heart	amor libro corazon	every others and the his from	cada otros y el su de
Paragraph 5	group companions giant	grupo companioneros gigante	place road people	lugar camino gente	of where that his and because	de donde ese sus y porque

	cognates		noncognates		function	
	English	Spanish	English	Spanish	English	Spanish
Paragraph 6	time rest faith	tiempo resto fe	lived beans nightmare	vivían frijoles pesadilla	that that of and because their	ese que de y porque su
Paragraph 7	rich fortune day	ricos fortuna dia	things women drunkard	cosas mujeres borracho	and that with the his every but	y que con el su cada pero
Paragraph 8	servants passed intelligent	sirvientas pasó inteligente	test prove window	prueba comprobar ventana	the for that your among and	las para que tu entre y

Appendix B

Example paragraph with adapted versions across conditions (switch words underlined only in the examples; switch words were not underlined in the experimental materials).

English-default, Function word switches:

The next day the group de people left for the capital of Guatemala. They went walking because there were no cars or buses at that time. They came to a place donde they had to stay. They had dinner and slept on ese road in the forest. The boy, however, did not sleep because he was not sleepy. All of sus companions slept but he was awake. Around one in the morning, he heard the noise of a horse that was approaching. There was someone coming. It was the man who was going to kill the people y he was going to take them to a cave. Then the boy turned into a giant porque he was very intelligent. He turned into a giant!

English-default, Content word switches:

The next day the grupo of people left for the capital of Guatemala. They went walking because there were no cars or buses at that time. They came to a lugar where they had to stay. They had dinner and slept on that camino in the forest. The boy, however, did not sleep because he was not sleepy. All of his compañeros slept but he was awake. Around one in the morning, he heard the noise of a horse that was approaching. There was someone coming. It was the man who was going to kill the gente and he was going to take them to a cave. Then the boy turned into a gigante because he was very intelligent. He turned into a giant!

Spanish-default, Function word switches:

Al día siguiente el grupo of personas se fue para la capital de Guatemala. Se fueron caminando porque no había carros o camiones en ese tiempo. Llegaron a un lugar where ellos tenían que quedarse. Cenaron y durmieron en that camino en el bosque. El niño, sin

embargo, no durmió porque no tenía sueño. Todos his compañeros durmieron pero él estaba despierto. Como a la una de la mañana, escuchó el ruido de un caballo que se acercaba. Había alguien que venía. Era el hombre que iba a matar a la gente and se los iba a llevar a una cueva. Entonces el niño se volvió un gigante because él era muy inteligente. ¡Se volvió un gigante!

Spanish-default, Content word switches:

Al día siguiente el group de personas se fue para la capital de Guatemala. Se fueron caminando porque no había carros o camiones en ese tiempo. Llegaron a un place donde ellos tenían que quedarse. Cenaron y durmieron en ese road en el bosque. El niño, sin embargo, no durmió porque no tenía sueño. Todos sus companions durmieron pero él estaba despierto. Como a la una de la mañana, escuchó el ruido de un caballo que se acercaba. Había alguien que venía. Era el hombre que iba a matar a la people y se los iba a llevar a una cueva. Entonces el niño se volvió un giant porque él era muy inteligente. ¡Se volvió un gigante!

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Public Significance Statement:

When bilinguals read aloud mixed-language paragraphs, they produce speech errors that may be diagnostic of Alzheimer's disease. *Cognates* (e.g., *reason* is *razón* in Spanish), or words that are similar in form between languages, may be most useful for this purpose. Monitoring deficits may account for this phenomenon, while grammatical processing in connected speech appears to be relatively intact in AD.

Figure. 1.

Mean percentage of switch-out words with intrusions for each condition and group. The error bars represent 95% Confidence Intervals. Dominant vs. non-dominant refers to the language of the target word.

Figure 2.

Mean percentage of content vs. function words with within-language errors for each language and group. The error bars represent 95% Confidence Intervals.

Figure 3.

Mean percentage of words that elicited each within-language error type (see Table 3). The error bars represent 95% Confidence Intervals.

Figure 4.

Receiver Operating Characteristic (ROC) curves comparing sensitivity and specificity for discriminating cognitively healthy bilinguals from those with probable AD. Panel A plots intrusion errors produced for cognate targets and Panel B plots intrusion errors produced for function word targets (for switch targets only, and collapsed across target language). Panel C plots function-word substitution errors and Panel D plots omission errors (collapsed across target language and across all target types). Table 9 shows detailed results of the ROC curve analyses.

Figure 5. Mean percentage of switch-out words with intrusions in the dominant versus the nondominant languages in 20 patients and 29 controls combining data from the present study and Gollan et al., 2017. The error bars represent 95% Confidence Intervals.

Table 1.**Participant Characteristics**

Characteristic	Participant Group				<i>p value</i>
	Probable AD (<i>n</i> =12)		Controls (<i>n</i> =22)		
	M	SD	M	SD	
Age	82.0	9.0	75.1	7.4	0.02
Years of Education	11.9	4.9	15.9	3.8	0.01
%female	58%		59%		
current %English use	51.7	44.6	60.4	35.8	0.54
%Spanish (or both-languages) at home in childhood	50% (92%)		45% (95%)		
Age of Regular English Use	10.7	9.3	16.4	14.8	0.26
Age of Regular Spanish Use	3.5	9.7	3.5	7.1	0.99
%tested in English at ADRC	41%		42%		
MINT (Multilingual Naming Test) English	45.8	13.5	59.5	10.1	0.00
MINT Spanish	51.1	9.2	56.3	9.8	0.14
MINT dominant	56.3	4.6	64.5	3.4	0.00
MINT nondominant	40.6	11.2	51.3	10.0	0.00
Bilingual Index (nondominant MINT/dominant MINT)	0.72	0.19	0.80	0.15	0.22
Dementia Rating Scale (DRS)	108.6	16.1	136.6	5.0	0.00
Digit Span Forward	5.3	1.1	6.0	1.3	0.10
Digit Span Backward	2.8	1.1	4.3	0.9	0.00
Letter fluency (F, A, S)	20.8	6.4	42.8	11.7	0.00
Category fluency (Animals, Fruits, Vegetables)	21.3	9.5	46.1	14.0	0.00
Digit Symbol (Raw Scores)	20.7	7.4	41.5	8.9	0.00
Block Design	18.3	12.3	37.3	8.6	0.00
CERAD Trial 3 Immediate memory	3.9	2.6	8.0	1.0	0.00
CERAD Trial3 Delay	0.9	1.5	6.3	1.6	0.00

Table 2.

Switch word characteristics

Characteristic	Switch Word Type					
	Cognate		Noncognate		Function	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Celex Frequency per Million	12.8	21.8	15.2	19.2	952.2	1083.2
English length (in letters)	6.5	2.2	5.5	1.5	3.8	1.2
Spanish length (in letters)	6.7	2.6	6.4	1.6	2.8	1.4
Levenshtein distance	2.4	1.1	5.5	1.6	4	0.9
Overlapping onset letters	3.7	1.8	0.0	0.2	0	0

Table 3.

Between-language (in first three rows) and within-language error types (all rows below the third), counts, definition, and examples for all error types that bilinguals produced during the read aloud task.

Error type	Error rate (%)		Definition	Example(s)	Context Example
	Patients	Controls			
Intrusion ($n=278$)	27.05	11.27	Speaker produced the target in the wrong language	$y \rightarrow$ and	Otros claimed it went even further <u>y</u> love was what Brian was feeling.
Partial Intrusion ($n=24$)	1.37	1.50	Speaker began to produce the target in the wrong language but self-corrected before fully producing the error	day $\rightarrow$ <i>di.day</i>	...pidiendo cada <u>day</u> para los tragos
Accent ($n=34$)	2.40	1.88	Speaker produced the correct target but with an accent that matches the other language	young $\rightarrow$ <i>jong</i>	Ella era una mujer que no era <u>young</u> ni era...
Function Word Substitution ($n=368$)	1.94	0.55	Speaker substituted a function word target with a different function word	was $\rightarrow$ <i>were</i>	But among these there <u>was</u> one real flower
Content Word Substitution ($n=173$)	0.78	0.33	Speaker substituted a content word target with a different content word	unified $\rightarrow$ <i>united</i>	The lady and her children were a <u>unified</u> family
Omission ($n=191$)	0.84	0.38	Speaker skipped the target word	to $\rightarrow$	People would tell him <u>to</u> quit being a drunkard
Inflection ($n=197$)	0.78	0.44	Speaker produced a syntactic error, either adding or omitting an affix	showed $\rightarrow$ show	...grabbed the little flower and <u>showed</u> it to everyone...
Nonword ($n=156$)	0.55	0.38	Speaker produced a nonword	triplets $\rightarrow$ <i>tryples</i>	Many years went by and the <u>triplets</u> came to be young teens
Insert ($n=93$)	0.47	0.15	Speaker inserted a word not written on the page	left him $\rightarrow$ left <i>for</i> him	He wasted all the money that they had <u>left him</u>
Other ($n=48$)	0.20	0.10	All other words that do not belong to any of the above		

Note. Cross-language error (i.e., Intrusion, partial intrusion, and accent) percentages are out of all switch-out words, while other error percentages are out of all words.

Table 4.

Mean reading times in seconds and (standard errors) per paragraph

	Dominant Language		NonDominant Language	
	Content	Function	Content	Function
Patients	63.67 (3.57)	68.08 (3.09)	84.62 (3.56)	93.71 (4.65)
Controls	54.52 (2.15)	54.89 (1.97)	71.18 (2.61)	72.25 (2.70)

Table 5.

Mean intrusion error rates (%) and (standard error) on switches out of the default language

	Dominant Language		NonDominant Language	
	Content	Function	Content	Function
Patients	32.87 (3.90)	35.37 (3.96)	17.12 (3.13)	22.76 (3.49)
Controls	10.90 (1.91)	21.05 (2.50)	4.83 (1.31)	8.33 (1.70)

Table 6.

Mean self-correction rates (%) of intrusions and (standard error) on switches out of the default language

	Dominant Language			NonDominant Language		
	Cognate	Function	Noncognate	Cognate	Function	Noncognate
Patients	5.40 (5.40)	17.31 (5.30)	9.09 (9.09)	13.04 (7.18)	24.24 (7.58)	0 (0)
Controls	25.00 (9.03)	32.14 (6.30)	0 (0)	15.38 (10.41)	31.82 (10.16)	N/A

Note: N/A refers to the fact that controls did not produce any noncognate intrusion errors, thus no self-corrections were possible; there was 1 patient who self-corrected 1 noncognate intrusion error.

Table 7.

Mean partial intrusion rate (%) and (standard error) on switches out of the default in each condition and group

	Dominant Language			NonDominant Language		
	Cognate	Function	Noncognate	Cognate	Function	Noncognate
Patients	4.17 (2.37)	0.68 (0.68)	0 (0)	5.48 (2.68)	0 (0)	1.37 (1.37)
Controls	9.09 (2.51)	0.38 (0.38)	0 (0)	1.50 (1.06)	0 (0)	0.73 (0.73)

Table 8.

Mean self-correction rates (%) and (standard errors) of within-language errors

	Dominant Language		NonDominant Language	
	Content	Function	Content	Function
Patients	15.15 (4.45)	18.97 (2.98)	11.70 (2.35)	20.38 (2.48)
Controls	39.29 (6.59)	31.52 (4.87)	22.75 (3.06)	37.24 (3.46)

Table 9.

Results from ROC curve analyses showing area under curve (AUC), sensitivity, specificity, and cut-off values which evaluate the ability to distinguish patients from controls based on total number of intrusions (cognate and function targets) and within-language errors (function-word substitutions and omissions) produced

Speech Error	AUC	SE	<i>p</i>	Cut-off value	Sensitivity (%)	Specificity (%)
Cognate intrusions	0.87	0.08	0.001	3.5	75	86
Function word substitutions	0.81	0.09	0.003	8.5	75	73
Omissions	0.74	0.11	0.025	8.5	67	96
Noncognate intrusions	0.74	0.10	0.021	0.5	58	86
Function intrusions	0.71	0.10	0.043	4.5	67	67