J. Child Lang. **43** (2016), 687–706. © Cambridge University Press 2016
doi:10.1017/S0305000915000811

Effects of Age of English Exposure, Current Input/Output, and grade on bilingual language performance*

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(*Received* 5 *January* 2015 – *Revised* 7 *October* 2015 – *Accepted* 6 *December* 2015 – *First published online 26 February 2016*)

ABSTRACT

This study evaluates the effects of Age of Exposure to English (AoEE) and Current Input/Output on language performance in a cross-sectional sample of Spanish–English bilingual children. First- ($N = 586$) and third-graders ($N = 298$) who spanned a wide range of bilingual language experience participated. Parents and teachers provided information about English and Spanish language use. Short tests of semantic and morphosyntactic development in Spanish and English were used to quantify children's knowledge of each language. There were significant interactions between AoEE and Current Input/Output for children at third grade in English and in both grades for Spanish. In English, the relationship between AoEE and language scores were linear for first- and third-graders. In Spanish a nonlinear relationship was observed. We discuss how much of the variance was accounted for by AoEE and Current Input/Output.

INTRODUCTION

Time and opportunity to hear and use each of their languages impact the performance of bilingual learners. Age of acquisition (AoA) effects have been isolated in work with adult bilinguals but fewer studies of children have focused specifically on AoA effects. These studies have generally considered outcomes relative to AoA and the question of how long it takes learners to acquire monolingual-like skills. Results offer conflicting findings relative to the assumption that earlier exposure will result in higher levels of

[*] This work was supported by the grant R01DC010366 from the National Institute on Deafness and Other Communication Disorders (NIDCD). We are grateful to the families that participated in the study. This report does not necessarily reflect the views or policy of the NIDCD. Address for correspondence: Lisa M. Bedore, Department of Communication Sciences and Disorders, Moody College of Communication, The University of Texas at Austin, Austin, Texas 78712. e-mail: lisa.bedore@austin.utexas.edu

knowledge or that children will reach the range of their monolingual peers in a shorter time frame (Jia, Aaronson & Wu, 2002; Meisel, 2009; Montrul, 2009). Some research suggests decreased L2 language knowledge as a function of AoA while in other work it appears that there are potential advantages to later acquisition. Less attention has been paid to the question of how the AoA of the L2 impacts L1 outcomes. Individuals who continue to use their L1 as their primary language will have different outcomes relative to those who shift to the use of the L2 as their primary language, as in heritage language contexts (Montrul, 2008; Muñoz, 2011).

These are important topics because understanding differences in L1 and L2 language outcomes as a function of L2 AoA would inform our understanding of the mechanisms at play in bilingual acquisition in childhood. By considering how AoA influences what children know during the early elementary years, we can give parents and educators a better understanding of how bilingual experiences affect the language skills that are available for academic learning. In this study we compare the effects of current language use and AoA, quantified as Age of first English exposure (AoEE), on the Spanish and English knowledge of first- and third-grade children growing up in a US bilingual community. We begin by briefly reviewing the role of experiential variables and then focus in greater depth on the ways that age of L2 acquisition relates to children's L2 and L1 language knowledge.

EXPERIENTIAL FACTORS

Bilingualism emerges because of the learner's need for more than one language to communicate (Grosjean, 2010). As such, a number of experiential factors contribute to bilingual development. These include opportunities to hear and use language (Bohman, Bedore, Peña, Mendez-Perez & Gillam, 2010), mother's education and self-rated English language proficiency (Hammer, Komaroff, Rodriguez, Lopez, Scarpino & Goldstein, 2012), language(s) of the home (De Houwer, 2007), and opportunities for literacy development in each language (Paradis, Emmerzael & Sorenson Duncan, 2010). Questionnaires focusing on bilingual language experience can be used to reliably predict language performance (e.g. Bedore, Peña, Joyner & Macken, 2011; Gutiérrez-Clellen & Kreiter, 2003; Paradis *et al.*, 2010). Current Input/Output estimates can account for up to 65% of the variance in children's language scores in the early school years (Bedore *et al.*, 2012; Unsworth, Argyri, Cornips, Hulk, Sorace & Tsimpli, 2014).

Age of acquisition

Much of the work focusing on AoA is guided by studies of adults who have acquired English as a L2 with the goal of understanding if there is a critical period for L2 acquisition. One example of this line of inquiry is Hakuta and

colleagues' (Hakuta, Bialystok & Wiley, 2003) study in which they hypothesized three possible patterns of language proficiency related to critical period: discontinuity resulting in a drop in learning around the critical period; change in slope around the critical period; or a combination with a drop in performance and a change in slope. Testing this relationship with US census data, which included self-ratings of proficiency for 2,016,317 Spanish-speakers and 324,444 Chinese-speakers, they found a strongly linear trend for individuals who started to acquire their L2 later to report lower proficiency. There was no evidence of discontinuities in trajectory associated with a critical period. In studies that treat AoA as a continuous variable, meta-analysis shows that about 65% of the variance in the long-term attainment in pronunciation, vocabulary, and grammar can be attributed to AoA (Birdsong, 2005). While self-ratings such as the judgments employed in the Hakuta *et al.,* study are a reliable source of information (e.g. Gollan, Weissberger, Runnqvist, Montoya & Cera, 2012), ratings of general proficiency may not allow for finely grained assessments of knowledge.

When performance on the same measures of general language behavior (e.g. grammatical judgments, accent rating) is disaggregated (and treated as a categorical variable) the slope of the lines representing younger learners appears to differ from that of older learners (Birdsong, 2006). In studies that include learners across the lifespan the difference in performance of younger and older learners seems to shift at around fifteen years of age with a more gradual slope being associated with younger than older learners. These findings suggest that the role of AoA for children and adults might differ.

For child learners, a primary concern is the language knowledge available to support educational needs, so it is compelling to study AoA effects in school-age children. As for adults, age effects have been observed in studies that focus on general measures of language knowledge. For example, Jia *et al*. (2002) reported that age of English onset correlated with long-term attainment of English in Mandarin–English children as indicated by their performance on a grammaticality judgment task. Bedore *et al*. (2012) found that AoA of English accounted for about 35% of the variance in language dominance scores (in this case the difference between Spanish and English performance) in the morphosyntactic and semantic domains at kindergarten, but there were nonlinear relationships between AoA for English and performance in English and Spanish.

Researchers have proposed that there may be differences in younger and older bilingual children's learning. For example, Herschensohn (2007) analyzed how AoA impacted grammatical acquisition across a variety of language pairs and proposed that differences are likely to become evident after age four. She suggests that, up to this age, acquisition is similar enough across languages that knowledge of the L1 would compete minimally with the L2, and that there is greater likelihood of transfer for

syntax (e.g. word order, functional categories) than for grammatical elements such as verb inflection. In addition, learning strategies may begin to change around age four because of changes to memory and brain maturation (e.g. Meisel, 2009). Qualitative differences in acquisition patterns are observed between groups of bilingual children associated with their AoA. Unsworth *et al.* (2014), for example, studied monolingual learners versus their early and later sequential learning peers (divided around five years of age) acquiring gender agreement in Dutch or Greek as a L2. Dutch late L2 learners differed from their monolingual peers but neither group differed from the early sequential learners. For Greek learners, AoA interacted with knowledge of gender marking with early sequential learners being overall more similar to their monolingual peers than the late sequential learners. Davison and Hammer (2012) showed that children who acquired English and Spanish under comparable circumstances (i.e. SES, parental education levels), but started to learn English prior to entering preschool, were more likely to master English grammatical forms by first grade than children who did not start learning English until preschool entry.

In contrast to studies that show decreased scores for later age of first exposure to the L2, others have shown that that children who start to learn later catch up sooner. Golberg, Paradis, and Crago (2008) followed younger and older children's performance on the Peabody Picture Vocabulary Test III (Dunn & Dunn, 1997) for three years. Children who started to learn English after the age of six caught up with their monolingual peers in a shorter period of time than did the L2 learners who started acquiring English earlier. Golberg *et al.*, attribute these differences to the differences in strategies applied to vocabulary learning by more mature learners versus less mature learners. Herschensohn and colleagues (Herschensohn, Stevenson & Waltmunson, 2005) evaluated the acquisition of word order and grammatical markers of tense and number in first-graders who started to acquire Spanish at kindergarten age in an immersion program relative to their simultaneous bilingual peers from the same class. After a year's exposure, children accurately produced Spanish word order though they did not yet accurately produce past tense markers. Accelerated development in the morphosyntactic domain converges with the advantages in vocabulary observed for older learners in Golberg *et al.*,'s study discussed above.

Length of exposure

It is also important to consider length of exposure (i.e. the amount of time that an individual has been learning a language) in addition to AoA. Length of exposure is a significant predictor of language performance (Hammer *et al.*, 2012). However, for simultaneous bilingual children, length of exposure and AoA are inversely related and account for comparable amounts of the

variance in language performance (Unsworth *et al.*, 2014). For sequential bilinguals, greater length of exposure tends to be associated with greater age. That said, differences in patterns of acquisition across studies that delineate age as a predictor do not provide converging evidence of specific age effects. For young children of immigrant families it is common for English exposure to either start at birth or at school entry around four years of age (e.g. Bedore *et al.*, 2012; Chondrogianni & Marinis, 2011). Thus, for children, AoA and length of exposure tend to be correlated closely, while these variables can differ much more in adults. Furthermore, in studies of children age or grade is held constant so AoA and length of exposure effects cannot be differentiated.

Several researchers have explored the extent to which AoA and length of exposure effects contribute to performance. Ågren, Granfeldt, and Thomas (2014) estimated quantity of exposure, as indexed by length and age of exposure, as well as quantified opportunities children have to hear and use their languages based on quality of input in those contexts. They predicted that children who are exposed to two languages from birth would pattern with their monolingual peers on frequent and transparent grammatical forms (e.g. present tense verb forms), and that children with later exposure would score lower than their simultaneous bilingual peers on these forms. Quality of input based on opportunities to hear and use each language are thought to predict differences in performance between monolingual and simultaneous bilinguals for lower-frequency forms with complex form–function mappings (e.g. subject–verb agreement for number). To evaluate these claims they documented grammatical performance in three monolingual, three simultaneous, and three sequential learners. Children were tested at three- to five-month intervals up to the time that the sequential learners had about 30 months of exposure. At the early testing points, monolingual and simultaneous bilinguals did not differ on production of finite verbs forms, but the sequential learners produced errors. They overcame these errors by the final testing points when all children were over 90% accurate. For the less transparent number agreement forms, all of the children were accurate on the regular forms but were challenged on their production of agreement on forms requiring irregular stems when marking number agreement. This study is small in scale but offers insights into the ways in which differences in acquisition might emerge. Chondrogianni and Marinis (2011) evaluated the effects of age of exposure and length of exposure on L2 learners' English language performance on standardized measures of vocabulary and grammar. AoA accounted for about 30% of the variance in receptive vocabulary, production of third person singular present tense, and passive forms. Length of exposure contributed 30% of the variance to all of the measures of vocabulary under consideration. AoA and length of exposure were significantly correlated.

Age of L2 acquisition and L1 outcomes

For children who are acquiring heritage languages, such as Spanish in the US context, L1 development potentially supports L2 development (Portes & Hao, 2002). A challenge for learning in such contexts is that, as input becomes divided across languages, children may be less likely to acquire new grammatical constructions in their L1 (Montrul, 2008). Thus Spanish-speaking heritage speakers who start to learn English at age six would be more likely to know later-acquired verbs forms in Spanish (e.g. subjunctive, conditional) than those children who start to learn English at three or four years of age. Under this scenario we might expect trade-offs in English and Spanish knowledge. If the goal is that learners have maximal knowledge of both of their languages, early exposure to L2 might result in sub-optimal trade-offs, whereas later exposure to the L2 could potentially maximize outcomes for both languages. For example, Hammer *et al*. (2012) found that Spanish language performance was negatively associated with the age at which bilingual five-year-olds started to acquire English and how much English they spoke with parents and teachers. Austin, Blume, and Sanchéz (2013) tested eight children who spoke Spanish at home and learned English at school at 6-month intervals starting at age 5;6. Focusing on two forms that compete in English and Spanish (interrogatives and negative polarity), the investigators observed early errors in children's Spanish productions at the time the children entered kindergarten. Children showed steady increases in accuracy of Spanish and English between five–six and seven–eight years of age. By age seven–eight years children's performance on interrogatives and negative polarity decreased in Spanish relative to increases on English performance on these forms. These findings help illustrate how outcomes in the two languages trade off.

Summary and questions

In sum, the work reviewed here shows that AoA accounts for a significant percentage of variance in L2 performance, but there is conflicting evidence regarding the linearity of age effects. There are several key differences between studies that support linear vs. discontinuous effects. First, studies showing a linear relationship between AoA and performance have often relied on global measures of ability that do not allow for fine-grained analysis of language performance, while many of the studies showing discontinuity have focused on specific late-acquired skills. Another difference is whether the data are treated as continuous or categorical. Many of the studies that show categorical effects have pre-established categories based on predictions that shifts in learning style will occur around four or six years of age (e.g. Agren *et al*., 2014; Meisel, 2009). From a statistical perspective, categorization implies an assumption of a flat relationship between predictor and outcome,

yet we know there is developmental change in language knowledge over time. Dividing the developmental trajectory at cut-points associated with AoA results in score differences that may be interpreted as nonlinearity. At the same time, the age at which children acquire their L2 may impact the likelihood that they will continue to acquire their L1 in heritage language learning contexts.

In this study we considered how the age of acquisition as quantified by age of first English exposure influences children's English and Spanish knowledge at grades 1 and 3. All of the participants has Spanish as their L1 and varied in whether they were also first exposed to English at birth or subsequently. We also considered the role of current experience in the target language using averaged measures of input and output in conjunction with AoEE. We addressed the following specific questions:

1. What is the nature of the relationship between AoEE, Current English Input/Output, grade, and English knowledge? How much of the variance in English language performance can be accounted for by AoEE and Current English Input/Output?
2. What is the nature of the relationship between AoEE, Current Spanish Input/Output, grade of testing, and Spanish knowledge? How much of the variance in Spanish performance can be accounted for by AoEE and Current Spanish Input/Output?

METHOD

Participants

Data for the current study were collected as part of a larger research program on the patterns of long-term and short-term learning in Spanish–English bilingual elementary school children with differing levels of language experience ranging from Spanish dominant to English dominant and with varying levels of language ability (i.e. language impaired and typically developing). The participants were a cross-sectional sample of Latino children who spoke Spanish, English, or both, and who were enrolled in first or third grade in two school districts serving large numbers of Latino children in the metropolitan area of Austin, Texas. These school districts provide a variety of educational programs including bilingual education, ELL support, and English only. The first grade group included 568 students with an average age of 81·8 months ($SD = 5{\cdot}5$). The majority of the children received free (63·2%) or reduced (8·8%) lunch. Forty-nine percent of the children were female. The average Hollingshead score for mother education for this group was 3·79 ($SD = 1{\cdot}70$), which corresponds to a partial high school (3) or high school (4) education. The third grade group consisted of a different set of 287 students with an average age of

105·7 months (*SD* = 5·79). More than half of the children received free (57·1%) or reduced (9·8%) lunch. Forty-six percent of the children were female. For the third grade group the average Hollingshead score for mother education was 4·04 (*SD* = 1·76).

Data-collection procedures

Participants' parents completed the Bilingual Input Output Survey (BIOS) as a phone interview in their preferred language (BESOS; Peña, Gutiérrez-Clellen, Iglesias, Goldstein & Bedore, 2014). The survey includes questions about history of language use year by year and a report of Current Input/Output (Bedore *et al.*, 2011; Gutiérrez-Clellen & Krieter, 2003). The year-by-year report provided information about the language(s) children were exposed to from birth to their current age and were used to calculate the Age of first Exposure to English. AoEE was quantified by year (e.g. 0–1 years, 1–2 years) in the survey and simplified to the midpoint (e.g. 0·5, 1·5) in the calculations of AoEE. The report of Current Input/Output asked parents to report how much English and Spanish children hear and use hour-by-hour for a typical weekday and a weekend day. This information was projected to a 7-day week and is reported here as the averaged percentage of input and output in English or Spanish. The variables derived from this data are Current English Input/Output and Current Spanish Input/Output, and they are inversely related.

To assess children's knowledge of Spanish and English we administered one of two versions of the Bilingual English Spanish Oral Screener (BESOS 1st grade or BESOS 3rd grade) depending on their grade. This experimental screener (Peña, Bedore, Gutiérrez-Clellen, Iglesias, & Goldstein, 2010a) includes English and Spanish subtests in morphosyntax and semantics. The majority of targets include forms that are developmentally appropriate for monolingual children in the same age range. The items are drawn from the upward extension of the Bilingual English Spanish Assessment–Middle Elementary version currently in development (Peña, Bedore, Iglesias, Gutiérrez-Clellen & Goldstein, 2010b). Targets in Spanish include articles, irregular past, prepositional phrases, subjunctive, conditional, direct object clitics, relative clauses, imperfect, and adjective agreement. English targets include third person singular, regular and irregular past, copula, prepositional phrases, passives, negatives, and question inversion. Semantic items include both receptive and expressive items. Children are asked to point to a picture or pictures for receptive items, and to respond to questions in the expressive mode.

Children were tested individually by trained bilingual research associates presenting each subtest in random order. Responses to each item were written verbatim and scored as correct or incorrect. Individual testing took approximately 20 minutes per child total for both languages. Testing on a

TABLE 1. *Descriptive values for language experience and language knowledge scores*

	Grade 1		Grade 3		Overall	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age months	81·86	(5·53)	105·69	(5·79)	89·86	(12·58)
AoEE	1·96	(1·92)	1·78	(1·96)	1·90	(1·93)
Current English Input/Output	67	(29)	73	(24)	69	(27)
Current Spanish Input/Output	33	(29)	27	(24)	31	(27)
BESA Semantics English	95·58	(18·62)	94·81	(23·33)	95·32	(20·31)
BESA MS English	92·04	(25·17)	103·35	(18·86)	95·83	(23·84)
BESA Composite English	93·81	(19·96)	99·08	(16·76)	95·58	(19·10)
BESA Semantics Spanish	76·19	(24·35)	45·87	(48·43)	66·01	(37·21)
BESA MS Spanish	70·14	(29·75)	52·45	(33·80)	64·20	(32·25)
BESA Composite Spanish	73·17	(25·98)	49·16	(39·06)	65·11	(32·98)

NOTE: AoEE = Age of English Exposure; Current English Input/Output and Current Spanish Input/Output are the average percentages of input and output and are inversely related; BESA scores are standard scores with a mean (*M*) of 100 and standard deviation (*SD*) of 15.

given subtest in a given language was discontinued if the child gave no response to the question or indicated that they did not speak/understand the language to five items in a row. This procedure minimized frustration from being tested in a language they did not know. Total scores for each language were converted to standard scores ($M = 100$ and $SD = 15$) according to age and entered into the analysis.

Cronbach's alpha, a test of internal consistency, was calculated for each subtest for each grade (see Table 1). Results indicated that alpha was acceptable for all subtests. Specifically morphosyntax subtests were in the good range (over ·8 for both languages and grades) but alpha was marginally acceptable for semantics (between ·597 and ·816) (DeVellis, 1991; George & Mallery, 2003).

Statistical modeling

Our interest was in modeling performance as reflected in the composite score on the BESOS in each language as a function of AoEE and Current English or Spanish Input/Output. All participants were exposed to Spanish from birth, so age of acquisition for Spanish was not a variable we could examine in this dataset. Previous research has provided evidence of nonlinearity in the relationship between AoA and L2 performance (e.g. Birdsong, 2005, 2006). Rather than use polynomial regression, we elected to incorporate these nonlinearities in our modeling via smoothing regression splines. Smoothing regression splines are more flexible than polynomial regression and afford a number of other advantages as well. They require no prespecification of a

functional form (e.g. specifying a quadratic versus a cubic versus a quartic polynomial), achieve optimal fit under a wide range of circumstances, and need little-to-no intervention by the analyst. Smoothing splines allow for the modeling of nonlinear relationships between predictor variables and a dependent variable when the nature of those relationships do not or cannot be assumed to follow a prespecified functional form and were therefore an ideal choice for examining the interplay of language use and AoA on performance.

We used the smoothing spline implementation in the mgcv package (mixed GAM computation vehicle within the R statistical software environment (R Core Team, 2014)). For further information on the mgcv package and on smoothing splines, see Wood (2006, 2011).

RESULTS

Children's language experience and performance on the BESOS is summarized in Table 1. The first-grade children had an average AoEE of 1·96 years. At the time of testing, they used English 67% of the time and Spanish 33%. Earlier exposure to English was associated with higher proportion of Current English Input/Output ($r = -0{\cdot}76$, $p < .00001$). Children obtained an average composite BESOS score (averaged semantics and morphosyntax standard scores) of 93 in English and 73 in Spanish. Semantics and Morphosyntax scores from which the composite score is derived are reported in Table 1. Recall that the scores for the BESOS are standardized to allow for direct comparison across languages and grades. The third-grade children had an average AoEE of 1·78 years ($SD = 1{\cdot}96$). Although the AoEE was similar for the two grades they differed in length of exposure to English, which is confounded with effects of Grade. That is, the children in grade 3 were exposed to English for two years longer than the children in grade 1. At the time of testing, the third-graders used English 73% of the time and Spanish 27% of the time on average. As with grade 1, earlier exposure to English was associated with higher proportions of Current English Use ($r = -0{\cdot}71$, $p < {\cdot}00001$) in grade 3. Children in grade 3 obtained an average BESOS score of 99 in English but 49 in Spanish.

We assessed each of the two testing languages separately, using proportion Current English Input/Output in analyses of performance in English and its inverse, proportion Current Spanish Input/Output for performance in Spanish. For each language, we examined whether Grade interacted with our predictors (AoEE and Current Input/Output). The interactions with Grade were highly significant for both languages (English $X^2(5{\cdot}88) = 51{\cdot}89$, $p < {\cdot}001$; Spanish $X^2(12{\cdot}46) = 483{\cdot}34$, $p < {\cdot}001$). (Fractional *df* are common in GAM modeling.) In English, there was greater nonlinearity in the effects of AoEE and Current Input/Output on performance in grade 3 than in grade 1 (estimated $df = 4{\cdot}88$ vs. 2·00, respectively). These

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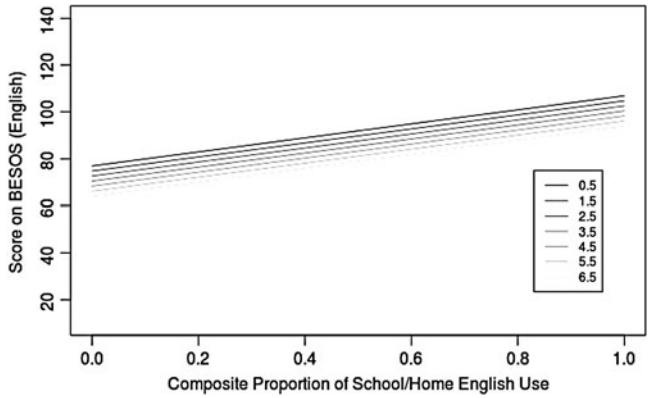

Fig. 1. First-grade performance on BESOS English as a function of Current English Input/Output. Lines represent performance by age of exposure to English in years.

differences by grade may reflect maturation or greater length of exposure to English (the pattern of the effects and nonlinearity are detailed below). The overall nonlinearity was greater in Spanish than English and, again, it was greater for grade 3 than Grade 1 (estimated $df = 12{\cdot}62$ vs. 10·26, respectively). Accordingly, we assessed the impact of AoEE and Current Input/Output separately for each of the four combinations of Testing Language (English, Spanish) and Grade (1, 3).

Within each of the four combinations of Testing Language and Grade, the simple main effects of AoEE and Current Input/Output were assessed by comparing a model consisting of each term to a null model, and the complex interaction of the two terms was assessed by comparing a model with both simple linear main effect terms to a nonlinear GAM model where both terms contribute jointly. All significance tests were standard likelihood ratio chi-squared tests.

English grade 1

The final model solution for English grade 1 is shown in Figure 1. As expected, the earlier children were initially exposed to English, the higher their performance in English. This was reflected in the significant main effect of Age of English Exposure ($X^2(1) = 297{\cdot}88$, $p < {\cdot}001$). On its own, AoEE accounted for 23·1% of the variance. Also as expected, children whose current language use was primarily English scored higher on English tests than children who spent proportionately more time using Spanish, as reflected in the significant main effect of Current English Input/Output ($X^2(1) = 372{\cdot}40$, $p < {\cdot}001$). On its own, Current English Input/Output accounted for 28·0% of the variance in English scores.

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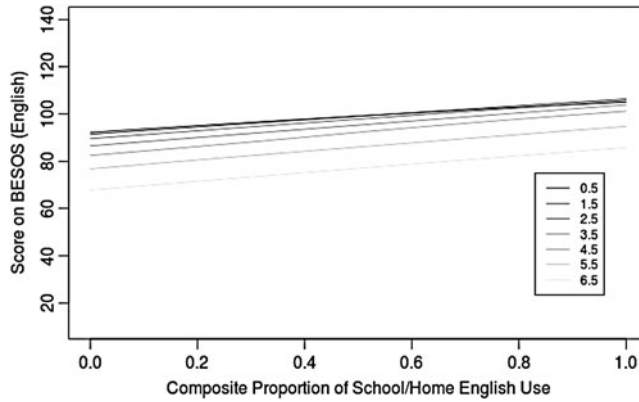

Fig. 2. Third-grade performance on BESOS English as a function of Current English Input/Output. Lines represent performance by age of exposure to English in years up to age 6·5.

Differences in proportion Current English Input/Output had the same impact across different Ages of English Exposure, as reflected in the lack of an interaction between the predictors ($X^2(1) = 0$, n.s.). Although both AoEE and Current English Input/Output were significant predictors of performance, as they were highly correlated, together the variables accounted for only 29·4% of the variance in scores. Although the GAM approach was chosen to detect any sort of nonlinearity in the predictors, there was no significant nonlinearity in the relationships between AoEE and Current English Input/Output performance in the English grade 1 data.

English grade 3

As shown in Figure 2, children in grade 3 showed a wider range of performance in English than children in grade 1 did. As with grade 1, the earlier that children were initially exposed to English, the higher their performance in English ($X^2(1) = 65{\cdot}12$, $p < {\cdot}001$), with little difference in performance among children exposed to English before the age of three. Again, the higher their proportion Current English Input/Output, the higher their performance ($X^2(1) = 48{\cdot}60$, $p < {\cdot}001$). Unlike grade 1, these two predictors showed significant nonlinearity and interaction ($X^2(2{\cdot}54) = 16{\cdot}85$, $p < {\cdot}001$). The nonlinear impact of AoEE was apparent in the unequal spacing between the lines in Figure 2. Specifically, AoEE had little effect on performance for children who were first exposed to English before the age of three, whereas children first exposed to English at six–seven years of age scored 10 points lower than those exposed at five–six years. Amount of Current English Input/Output was most strongly

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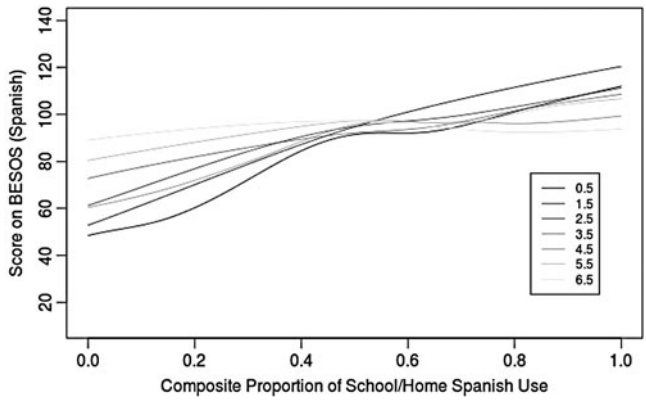

Fig. 3. Third-grade performance on BESOS English as a function of Current Spanish Input/Output. Lines represent performance by age of exposure to English in years.

associated with performance for children with late rather than early AoEE. Additionally contributing is the greater impact of each additional later year of exposure when Current English Input/Output is low among children with relatively early AoEE (~2–3 years). The main effect of AoEE accounted for 10·7% of variance on its own, while Current English Input/Output accounted for 8·1% alone. Together these variables accounted for 11·3% of the variance, and their interaction an additional 2·6%.

Spanish grade 1

As shown in Figure 3, the relationship between Age of English Exposure and Current Spanish Input/Output was much more complex for grade 1 Spanish performance than it was for English (Figure 1). The greater the proportion of Current Spanish Input/Output, the higher children scored on tests in Spanish, but the effect of Current Spanish Input/Output was much larger for children who were first exposed to English at early rather than later ages. So, the significant main effects of age of English exposure ($X^2(1) = 537{\cdot}42$, $p < {\cdot}001$) and Current Spanish Input/Output ($X^2(1) = 1015{\cdot}26$, $p < {\cdot}001$) were qualified by a highly significant cross-over interaction ($X^2(15{\cdot}96) = 113{\cdot}89$, $p < {\cdot}001$). AoEE accounted for 37·7% of the variance when entered into the model alone, while Current Spanish Input/Output accounted for 59·1% alone. Both variables in combination accounted for 59·3% of the variance, while their interaction explained an additional 3·9%.

In addition, the relationships between AoEE, Current Spanish Input/Output, and performance in Spanish contained nonlinearities. AoEE had little impact on performance for children with relatively balanced current exposure to Spanish and English (40–60%). For children currently using

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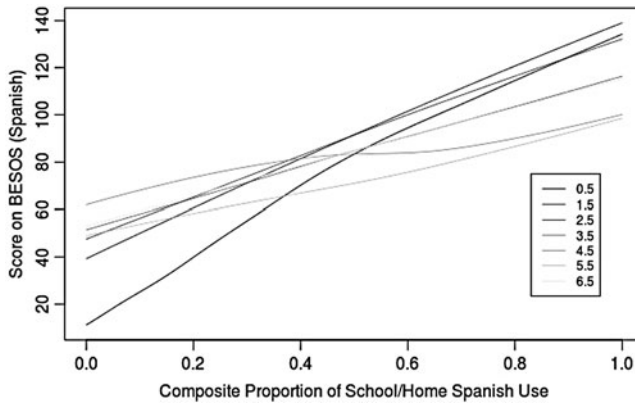

Fig. 4. Third-grade performance on BESOS Spanish as a function of Current Spanish Input/Output. Lines represent performance by age of exposure to English in years up to age 6·5.

Spanish over 70% of the time, early age of exposure to English was associated with high performance on Spanish, while later exposure was associated with lower Spanish performance. In contrast, for children with less than 40% Current Spanish Input/Output, early exposure to English was associated with lower performance in Spanish.

Spanish grade 3

The performance of children tested in Spanish in grade 3 also varied as a function of both AoEE and Current Spanish Input/Output (Figure 4). Again, performance in Spanish was highest for children who were exposed to English early and who currently used Spanish the majority of the time, and lowest for children who were exposed English early but use Spanish less than 40% daily. Whereas the children in grade 1 who were only recently exposed to English (i.e. AoEE = 6·5 years) showed minimal effects of Current Spanish Input/Output on their BESOS performance, the third-graders who stated to acquire English at 6·5 years had more Current Spanish Input/Output, such that English Input/Output modulated their BESOS scores to a greater degree than it did for the first-graders. There were significant main effects of Current Spanish Input/Output ($X^2(1) = 460{\cdot}05$, $p < {\cdot}001$) and AoEE ($X^2(1) = 179{\cdot}01$, $p < {\cdot}001$), as well as a highly significant interaction ($X^2(8{\cdot}95) = 66{\cdot}61$, $p < {\cdot}001$). Age of English Exposure accounted for 26·8% of variance alone, while Current Spanish Input/Output accounted for 55·1%. Both main effects combined accounted for 55·1%, and their interaction an additional 5·0%.

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DISCUSSION

The goal of this paper was to explore influences of AoEE, and Current English and Spanish Input/Output on children's performance on brief tests of English and Spanish semantic and morphosyntactic knowledge. We employed a large group of first- and third-graders who encompass a wide range of bilingual experience both in regard to age of first exposure to English as well as Current Input/Output of their two languages. We will focus our discussion on how these factors influence children's knowledge of English and Spanish. A key question of interest in this study is the presence or absence of nonlinearity associated with age of first exposure to English. If there are differences in ability to learn the L2 as a function of AoA then nonlinearity may be observed. In the case of L1, learning changes may be associated with children's ability to maintain or to continue to develop in their L1 once L2 learning has begun.

We chose to model our data with a smoothing spline model to evaluate nonlinear changes in ability associated with age of first exposure to English. This analysis is highly sensitive to nonlinearity. Grade at the time of testing interacted significantly in the model, so we modeled performance at grades 1 and 3 separately. Performance in English – children's L2 – increased relatively linearly with earlier age of English exposure for both grades. In contrast, performance in Spanish – the children's L1 – demonstrated nonlinearity, especially when children's current language use was not balanced.

In evaluating English performance, Figures 1 and 2 illustrate linear trajectories in L2 performance for children who had their first age of English exposure between birth and 5·5 years of age. There are differences in performance as a function of grade, with children in first grade scoring lower than in third grade, and children with lower ages of first English exposure scoring higher. The model based on Age of Exposure to English and Current English Input/Output explains more of the variance at grade 1 (29·4%) than at grade 3 (11·3%), suggesting that, as length of exposure increases, English AoA decreases in importance.

Based on these findings, the evidence for linear relationships in English acquisition is robust for young school-age children. Limitations of past studies have included small numbers of participants and/or small range of age of exposure to the L2. Here the number of participants is large and the participants span the full range, so the linear findings seem highly reliable. The amount of variance in the model accounted for by our AoA variable – AoEE – accounted for a comparable amount of the variance in language knowledge at first grade, as has been reported in previous work. By third grade, current Spanish Input/Output accounts for a large amount of the variance in the model. This speaks to the importance of continued use to support learning of the L1 over time.

In contrast, for Spanish there is a robust cross-over interaction between AoEE and Current Spanish Input/Output, as seen in Figures 3 and 4. The best-fitting models for grades 1 and 3 accounted for a significant proportion of the variance in Spanish scores (59·3% and 55·1%, respectively). For Spanish, AoEE by itself accounted for a significant proportion of the variance in scores (37·7% and 26% of the variance at first and third grades, respectively), but Current Input/Output accounted for a greater proportion of the variance (at 59·3% and 55·1% respectively), with the interaction between AoEE and Current Spanish Input/Output adding significantly to predict children's performance. In viewing Figures 3 and especially 4, it is apparent that the greatest nonlinearity was observed for children who started to acquire English at ages 5·5 and 6·5. Children with composite use of Spanish between ·3 and ·7 score within 15 points (1 standard deviation) of each other across widely differing AoEE. Recall that the BESOS scores are standard scores with a mean of 100 and standard deviation of 15. In contrast, for children who start to acquire English the earliest and have little Current Spanish Input/Output there is a significant cross-over interaction, and their predicted Spanish BESOS scores suggest they have low knowledge of Spanish.

One criticism of past studies of the role of AoA and language experience is that if there is insufficient variability in either the participant characteristics (e.g. narrow age or AoA range) or range of scores on the outcome measures, it may be difficult to fully evaluate these factors. In this study we addressed this concern by including participants in two age groups who had a wide range of language experience (measured in AoEE as well as Current English Input/Output). In addition, because the participants were tested as part of a larger study focusing on language impairment and bilingualism, children with a wide range of language abilities participated. The statistical procedure used in this study permitted us to include age of exposure to English, Current Input/Output, and grade in our examination of these effects.

The findings are in line with work demonstrating that both AoA and Current Input/Output play a role in the bilingual language knowledge of children. AoEE and input and output accounted for comparable amounts of variance in our models of English performance, and barely interacted. In contrast, Spanish-speaking children who started to learn English at ages 5·5 and 6·5 and continued to use Spanish more than 50–60% of the time had Spanish scores that were about a standard deviation below the mean of their peers. For these children, Spanish BESOS scores are low relative to the first-grade group, while the difference between first- and third-graders' English BESOS scores is minimal. Low English scores are unsurprising, but low Spanish scores suggest the possibility that Spanish is suppressed or neglected as children turn their attention to learning English. It would be interesting to follow children into later grades to see

if they are able to show increased Spanish performance at an age at which their English knowledge is stabilizing.

The relative difference in the variance accounted for by age of exposure to English and Current Spanish Input/Output third-graders relative to their first-grade peers may have several possible sources. One possibility is that the nonlinearity reflects instability due to the transition from Spanish to English. Nonlinearity is observed in performance of kindergarten-age bilingual children as they shift from Spanish to English dominance (see Bedore *et al*., 2012). Another consideration may be changes to the patterns of use and input that interact with AoEE by third grade. When children are learning English in the early grades they are likely to spend more time at home and they are more likely to be exposed to Spanish at school along with English. It has been shown that the number of speakers to whom learners are exposed increases the likelihood that speakers will retain bilingual language knowledge (Gollan, Starr & Ferreira, 2015). In addition, the quality of Spanish input that children hear supports the use of complex language in Spanish (Gamez & Levine, 2013).

Finally, one reason that the study of AoA effects has been of interest is to understand the extent to which there are advantages to earlier exposure to the L2 for bilingual children. It is evident in the figures for first- and third-grade performance on the BESOS in English that there is a linear relationship with Current Input/Output and AoA. Performance in Spanish decreases as English increases, so there is a trade-off in total bilingual language knowledge. This finding of stable performance in English across multiple ages of acquisition of English aligns with observations of prekindergarten children who showed flat performance in English when they started to learn English between two and four years of age (Bedore *et al*., 2012).

It is important to keep in mind that the primary variable of interest in this study is age of English acquisition, which we quantified as AoEE. However, for this group of children who were divided into first- and third-grade groups, reflecting the time at which they were recruited for testing, AoEE was highly correlated with length of exposure to English. Thus it is possible that what is observed here is a length of exposure effect rather than an effect of AoEE. Recall that length of exposure is often included as a variable in studies in which AoA is examined. A limitation, then, of these findings is that length of exposure might have explained the variability in findings, as well as AoEE. In a similar vein it is worth noting that AoEE and Current Input/Output were also highly related. These correlated variables seem to interact more with Spanish performance than English. On the one hand, the fact that the length of exposure and current Input/Output are highly related to age of acquisition can be viewed as a limitation of the study, but it is important to keep in mind that this is a characteristic of the population under consideration.

Similar relationships have been documented in other contexts in which children are acquiring and being educated in the majority language of the community. To better evaluate if it is age or length of exposure that most influences learning trajectories in future, work using longitudinal designs and/or using weighted measures of length of exposure would be informative.

The practical implications of the work reported here are that earlier exposure to the L2 comes at a cost to the knowledge of the L1, when L1 use is not maintained. Increases in English language knowledge for these groups of children were not matched by increases in Spanish for the group as a whole. The performance at first and especially third grade was lower and more variable than their English performance. From a practical perspective it may not make sense to recommend earlier exposure to the L2 since it may negatively affect children's overall language knowledge and any benefits of bilingualism accrued through continued opportunities to hear and use two languages.

It is likely that not all children showed equally low scores in Spanish by grade 3, given the large variation demonstrated here. Thus one important way to follow up on the findings presented here is to identify profiles of children who demonstrate high levels of knowledge in both of their languages and compare these children to those who have been successful in retaining only one of their languages. By comparing the language environments of these children it will be possible to understand if specific combinations of AoA and use of both languages contribute to differential outcomes.

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