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The Language Exposure Assessment Tool: Quantifying language exposure in infants and children

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Abstract

Purpose: The aim of the study was to develop the Language Exposure Assessment Tool (LEAT) and to examine its cross-linguistic validity, reliability, and utility. The LEAT is a computerized interview-style assessment that requests parents to estimate language exposure. The LEAT yields an automatic calculation of relative language exposure and captures qualitative aspects of early language experience.

Method: Relative language exposure as reported on the LEAT and vocabulary size at 17 months of age were measured in a group of bilingual language learners with varying levels of exposure to French and English or Spanish and English.

Results: The LEAT demonstrates high internal consistency and criterion validity. In addition, the LEAT's calculation of relative language exposure explains variability in vocabulary size above a single overall parent estimate.

Conclusions: The LEAT is a valid and efficient tool for characterizing early language experience across cultural settings and levels of language exposure. The LEAT could be a useful tool in clinical contexts to aid in determining whether assessment and intervention should be conducted in one or more languages.

Around the world, children growing up in bilingual homes are the norm rather than the exception (UNESCO, 2003). Indeed, even in the U.S., where the majority of the population speaks a single language, the proportion of U.S. residents who report speaking a language other than English has risen to one in five (U.S. Census Bureau, 2011). The rapid growth of this population in the United States, as well as the growing awareness that multilingualism is a common phenomenon around the world have prompted an increase in bilingual research. One particular source of difficulty in conducting bilingual research, however, is assessing language exposure and obtaining reliable estimates of daily/weekly and overall distribution of the input languages in heterogeneous groups of dual language-learners (for an overview see Byers-Heinlein, 2015). The focus of the present study is to provide a reliable tool for assessing relative language exposure in infants and young children based on a detailed parental interview. Relative language exposure generally refers to the proportion of input in each language (Grüter, Hurtado, Marchman, & Fernald, 2014). For example, bilingual children may receive relatively balanced (50 – 50%) or unbalanced exposure (75 – 25%) to each of their languages.

The extant literature provides robust evidence that relative language exposure is an important source of variability for bilingual language proficiency (Bedore, Peña, Summers, Boerger, Resendiz, Greene, Bohman, & Gillam, 2012; De Houwer, 2007; Pearson, Fernandez, Lewedeg, & Oller, 1997; Eilers, Pearson, & Cobo-Lewis, 2006; David & Wei, 2008; Place & Hoff, 2011; Poulin-Dubois, Bialystok, Blaye, Polonia & Yott, 2013). However, assessment of relative language exposure in bilingual infants and children who are unable to report on their language experience presents a unique problem for researchers and clinicians. Thus, the majority of extant measures of language exposure are based on parent report (Place & Hoff, 2011; Bosch & Sebastián-Gallés, 2001; Gutierrez-Clellen & Kreiter, 2003; Conboy & Mills, 2006; David &

Wei, 2008; Pearson et al., 1997). Whereas a number of researchers have developed valid and reliable self-report assessments of language experience to be used in adult populations (e.g., Li, Sepanski, & Zhao, 2006; Marian, Blumenfeld, & Kaushanskaya, 2007), the research on *early* dual language acquisition continues to suffer from inconsistency in the assessment of exposure. The present study seeks to provide an efficient and valid measure to reach an accurate estimate of relative language exposure for young children that can be used across research and clinical settings.

Prior Approaches to Measures of Language Exposure

Assessment of relative language exposure varies greatly across studies in early child language research. For example, language exposure has been measured by recording direct language input to a child in the home over the course of a day and calculating the amount of exposure in each language (Grüter, Hurtado, Marchman, & Fernald, 2014). A more common and efficient approach is to measure language exposure based on parent report. This can be in the form of a daily diary over the course of several days (e.g., De Houwer & Bornstein, 2003; Place & Hoff, 2011) or through a questionnaire assessing exposure over the lifespan (e.g., Bosch & Sebastian-Galles, 2001; Gutierrez-Clellen & Kreiter, 2003). Other assessments include amount of language exposure reported from each conversational partner as rated on a scale (Conboy & Mills, 2006; De Houwer, 2007), and others simply ask parents to estimate the percent of exposure to each language (David & Wei, 2008; Pearson et al., 1997). Thus, language exposure assessments vary in terms of the time period they assess (e.g., one day, several days, or the entire lifespan), the tools they use to assess it (e.g., direct language input or parent report), and in their administration time.

Effects of Quantity and Quality of Language Exposure in Bilinguals

Parent reports of language exposure have been shown to relate to various aspects of early bilingual first language acquisition thereby providing preliminary support for their reliability. These findings highlight the effects of several quantitative and qualitative aspects of exposure on language acquisition. In the monolingual literature, the seminal work by Hart and Risley (1995) demonstrated that the quantity of language input correlated with vocabulary size in English speakers. This finding is supported by more recent work documenting a relation between the amount of child-directed speech and speed of real-time language processing in Spanish speakers (Weisleder & Fernald, 2013). Similar results have been extended to bilingual language acquisition. For example, parent reports of relative language exposure across the lifespan correlate with size of vocabulary in young dual language learners, such that greater exposure to a language relates to a larger vocabulary size (David & Wei, 2008; Eilers, Pearson, & Cobo-Lewis, 2006; Hoff, Core, Place, Rumiche, Señor, & Parra, 2012; Pearson et al., 1997; Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013). In addition, classification of participants into bilingual and monolingual groups derived from parent reports of relative language exposure also predicts performance on executive function and memory tasks (Brito & Barr, 2012; Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). Byers-Heinlein and Werker (2009) found differences in the application of disambiguation, a word-learning heuristic, in monolingual, bilingual, and trilingual infants as classified by parent-reported relative language exposure. Using a similar tool, Garcia-Sierra et al. (2011) showed differences in electrophysiological responses between groups of infants also classified by parent reports of language exposure. Other quantitative variables such as parent reports of age of initial exposure to a second language have implications for language mastery in the context of reading, lexical development, and fast mapping in young children (e.g., Jia, Kohnert, Collardo, & Aquino-Garcia, 2006; Kan & Kohnert, 2008; Kovelman, Baker, &

Petitto, 2008), whereas recent language exposure is a better predictor of semantic and morphosyntactic language measures (Bedore et al., 2012).

Qualitative aspects of language exposure that contribute to variability in early language acquisition have been documented in monolingual acquisition. Early work demonstrated that word frequency, grammatical complexity, and gender differences in language input influence early vocabulary size and growth (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Snow, 1972). Similarly, several dimensions of maternal responsiveness predict children's acquisition of language milestones as early as 9 months of age (Tamis-LeMonda, Bornstein, & Baumwell, 2001) and even into the fourth year of life (Hudson, Levickis, Down, Nicholls, & Wake, 2015). Qualitative aspects of language exposure have been much less studied in the bilingual literature. Hoff and others (Place & Hoff, 2011; Hoff, Welsh, Place, & Ribot, 2014; see Hoff & Core, 2013 for a review) investigated various qualitative aspects of language exposure and how they related to children's vocabulary size and grammatical complexity. These qualitative variables were measured using a language diary in which parents documented exposure over the course of several days. Their findings showed that the number of different conversational speakers who interact with the child was a significant predictor of bilingual language proficiency at age 2. That is, increased variability in the input provides support for early language development. In addition, the proportion of input coming from native language speakers explained variability in vocabulary size. Importantly, these qualitative measures of exposure demonstrated significant effects on vocabulary after controlling for relative amount of exposure. That is, qualitative aspects of language exposure as reported by parents exert an additional influence over the quantity of exposure on acquisition. In terms of grammar, Place and Hoff (2011) found that the

number of exclusively English conversational partners and the amount of different sources of English exposure correlated with children's English grammatical complexity.

The Current Study

Although prior work demonstrates the value of parental reports of exposure, there remains a need to evaluate the reliability and validity of this approach. The present study aims to address current issues in measuring and quantifying relative language exposure by proposing an assessment protocol that can be used across languages and settings. The current study presents the Language Exposure Assessment Tool (LEAT), which captures aspects of language exposure by incorporating features from a number of existing instruments in an easy-to-use, systematic assessment format. Given that the literature demonstrates strong links between exposure and parent-reported vocabulary, the present study employs two measures of early vocabulary size (the MacArthur Communicative Development Inventory, MCDI, Fenson et al., 2006; and the Computerized Comprehension Task, CCT, Friend & Keplinger, 2008; Friend & Zesiger, 2011) to explore the criterion validity of the LEAT's measure of relative language exposure. The MCDI provides a parent report measure of early vocabulary size. However, because method bias could lead to a significant relation between parent-reported vocabulary and parent-reported language exposure, we employed a behavioral and laboratory-based measure of vocabulary comprehension (the CCT) as an additional test of the validity and reliability of parent-reported language exposure on the LEAT.

The LEAT provides a parent-report measure of relative language exposure through a systematic interview. For example, the LEAT acquires information on the number of communicative partners, the languages they speak, the amount of time the child interacts with each person in each language, and how this varies over time (Bosch & Sebastián-Gallés, 2001;

Bedore et al., 2012; Fennell, 2000; Conboy & Mills, 2006; Thordardottir, Rothenberg, Rivard, & Naves, 2006; Marchman, Martínez-Sussmann, & Dale, 2004; Parra, Hoff, & Core, 2011; Peña, Gutierrez-Clellen, Iglesias, Goldstein, & Bedore, 2014; Place & Hoff, 2011). The ability to extract these variables aids in identifying those aspects of language exposure that influence acquisition in young dual language learners. In addition, it can assist clinicians in clarifying the basis for dissociations in proficiency in the first and second language when assessing young dual language learners. The central motivation for investigating the detailed nature and computational power of the LEAT is to provide a standard measure that can be efficiently administered across settings to facilitate research on early language acquisition in dual language learners and assist in clinical assessment. Here, we describe three unique contributions of the LEAT to the measurement of early language exposure.

First, the LEAT is based in Excel software to facilitate data acquisition and language exposure calculation in the laboratory, clinic, or field. Because the LEAT consists of protected, fillable cells for calculation, data collection is easily captured across contexts and sites. In the past, researchers have characteristically completed the language assessments in a paper format. Calculating exposure to multiple languages manually can be tedious and may increase the possibility of error. In the LEAT, parents' responses to queries automatically generate relative language exposure calculations through built-in formulas. This fillable electronic format allows researchers and clinicians to quickly calculate relative language exposure in a systematic way and to conduct the assessment easily in person or over the phone. It also provides the benefit of facilitating export to analysis software through the use of built-in macros. Finally, electronic documents facilitate data sharing and data backup.

Second, we present a user manual that documents a method of administration for the LEAT (see Supplementary Materials). For many years, researchers and clinicians have relied upon orally transmitted instructions and informal, unpublished user guidelines (but see Peña, Gutierrez-Clellen, Iglesias, Goldstein, & Bedore, 2014 for children 4;0 to 6;11). This paper provides the documentation for assessing early language exposure in infants, toddlers, and young children prior to 4 years of age in an effort to standardize measurement of language exposure across laboratories.

Finally, we present data from 98 bilingual toddlers to establish the internal consistency, utility, and criterion validity of the LEAT across languages, cultures, and laboratories. Whereas the LEAT has high face validity, and similar paper-and-pencil assessments have been used in many studies, to our knowledge, this is the first time that the validity of parent report of language exposure in infants and toddlers has been directly assessed and documented. In addition, a goal of the present study was to provide an efficient and reliable tool to assess language exposure. As such, it was important to ensure that the detailed questioning on the LEAT explained variance beyond that provided by an overall parent estimate of relative language exposure. Specifically, the research questions were:

1. What is the internal consistency of the LEAT?
2. Does the LEAT's relative language exposure calculation demonstrate criterion validity, such that it explains significant variance in language outcomes?
3. What is the utility of the LEAT? That is, does it explain variance in vocabulary measures beyond that provided from an overall parent estimate of relative language exposure?

Method

Participants

Participants in the current study formed part of a larger longitudinal study aimed at documenting relations between early language acquisition and subsequent development. For the purposes of the present study, we selected participants with no more than 80% exposure to one of the input languages so that exposure to the other language was at least 20%. This 80-20% distribution is often the limit for inclusion of bilingual participants in a sample (Pearson et al., 1997; Byers-Heinlein, 2015). This provided the opportunity to evaluate the LEAT's validity across a wide range of second language exposure.

The present sample consisted of 98 17-month-old *(M* = 17;14, *SD* = 1.01, range = 14;22 to 19;24, 41 females, 57 males) toddlers. Children were either exposed to Spanish and English or French and English. An additional three children were tested but not included in the sample due to experimenter error (N = 1) or failure to complete the behavioral task (N = 2). Children and their families were recruited through flyer postings, mailings, and child-oriented events. In addition, birth record information was acquired from local health agencies. Letters and response cards were sent to 17-month-old children within a 10-mile radius of the laboratory. Response cards were then reviewed to ensure children met inclusionary criteria and parents were then contacted to participate in the study.

Participants resided in one of two geographical locations: Children exposed to French and English resided in Montréal, Canada (N = 54) and those exposed to Spanish and English resided in San Diego, U.S. (N = 44). The language exposure contexts across these locations vary greatly and allow us to test the LEAT's psychometric properties cross-linguistically. In Montréal, although the official language is French over half of residents speak both French and English (Canadian Census, 2011). In San Diego, the majority language is English but Spanish is a

significant minority language, such that 27% of California residents report speaking Spanish (American Community Survey, 2010).

All participants were typically developing and had normal hearing and vision. The average maternal and paternal education was at a college level (maternal: M = 15.20 years of education, SD = 2.60; paternal: M = 14.71 years of education, SD = 2.75). Note that there was no difference in maternal and paternal education based on language of exposure ($F(2, 89) = .66$, p = .52). The majority of children (N = 87) received exposure to two languages (French and English or Spanish and English, average exposure to the dominant language = 61%, SD = 7.35, range = 50 to 79%). The other 11 children received exposure to a third language in addition to French and English or Spanish and English (average exposure to the dominant language = 56%, SD = 8.52, range = 40 to 70%), but exposure to a third language was minimal (≤ 20%). All but four children resided in 2-parent homes. On average, children lived with approximately four family members (M = 3.84, SD = 1.3, range = 2 – 8 people), which most often included a combination of parents, grandparents, and siblings. All children in the current study received early, simultaneous exposure to their dominant and non-dominant language (i.e. simultaneous exposure to French and English or Spanish and English). For the purposes of the present study, we define the dominant language in terms of the LEAT's calculation of relative exposure (i.e., the dominant language is that with the highest level of exposure; Grosjean, 2010) which does not necessarily reflect proficiency. Indeed, a central question of the present study is whether exposure as calculated by the LEAT maps on to proficiency to evaluate its utility and criterion validity.

Measures

The Language Exposure Assessment Tool (LEAT).

The LEAT is an Excel-based interview assessment that relies on parent reports of exposure to measure both quantitative and qualitative aspects of language exposure (see Supplementary Materials online). The LEAT was designed in a manner that would allow parents to easily and systematically report on features of their child's language exposure without compromising validity. For this reason, the LEAT is separated into two major sections that together allow for the calculation of relative language exposure. In the first section, parents are asked to list the people who interact with the child at least once a week, the language(s) they speak, and whether they are native speakers of the language(s) (e.g., "Who interacts with your child on a regular basis?" "What is their primary/secondary language?"). This list automatically populates the second section, which inventories the amount of time that the child spends hearing each conversational partner in each language. This information is broken down by day of the week and by age, thereby capturing exposure that happens on specific days of the week and at specific ages in the child's life (e.g., "At what age did the child start receiving language input from person A?" "Has person A's interaction with your child been consistent in the past or were there times when he/she spent more or less time with your child, such as maternity leave, moved, etc.?" "During the week, what days is person A interacting with your child?"). Next, parents are asked to estimate the amount of input children receive on average for each conversational partner given the ages and days of the week during which they interacted ("On an average day, how many hours is your child exposed to person A speaking in language A?"). A detailed list of queries as well as information about exposure calculations can be found in the LEAT user manual (see Supplementary Materials online). This conceptual organization allowed parents to report on the timing, frequency, and amount of language exposure in a step-wise fashion from who interacts with the child, to the languages they speak with the child to ever more specific

information regarding time of exposure (i.e., child's age, days per week, and hours per day). In this way, parents are able to easily provide estimates for each aspect of language exposure, rather than asking for an overall estimate that may conflate important sources of variability.

The detailed responses provided on the LEAT yield several variables. Relative language exposure is calculated by weighting the hours of exposure according to the duration of exposure to each source of input relative to the child's age. That is, if a 12-month-old infant heard 4 hours of French per day from her grandmother in the first six months of her life, these hours of French would receive a weight of one half to reflect the fact that this exposure did not continue for the first full year. In contrast, if the same infant heard 6 hours of English per day from her mother for the entire first year, these hours would receive a weight of one. From these weighted estimates for each language, the LEAT calculates relative language exposure (total weighted hours of exposure to language A divided by total weighted hours of exposure to language A and language B). As we reviewed in the introduction, various qualitative variables have been found to exert a significant effect on early vocabulary development (e.g., Place & Hoff, 2011) and these are also captured on the LEAT. Given that parents are asked to enumerate conversational partners, the languages they speak, and whether they are native speakers, the LEAT is able to document the following qualitative variables: the number of sources of input the child is exposed to, the number of speakers who speak more than one language to the child, the amount of native and non-native language exposure, and the absolute hours of language input.

Trained interviewers were taught to use specific questions to probe parents about the child's language exposure outlined in a detailed manual (see Supplementary Materials online). These questions use parent-friendly terminology to allow respondents to easily provide responses. To maintain consistency across administrations, each specific question is overlaid

onto the electronic version of the LEAT. Interviewers are able to hover over each section and view the required dialogue to probe parents for responses. All parents in the present sample were able to respond to the interviewer's trained line of questioning with ease and completed the LEAT within about 15 minutes. In addition, parents demonstrated remarkable understanding of the constructs in question, as their estimates of language exposure across speakers fell within the expected range of waking hours (M = 4.3 hours; range = 1.74 – 9.38).

MacArthur Communicative Development Inventory: Words and Gestures (MCDI).

The MCDI is a widely used parent report measure of early language. The Words and Gestures inventory, intended for children between 8 and 18 months of age, is a checklist allowing parents to mark the words their child understands and says. The inventory provides researchers with an indirect account of the child's vocabulary comprehension. The MCDI, originally developed in English, has good reliability and validity and has been adapted for use in over 50 languages and dialects, including Spanish and Canadian French (Fenson et al., 2006; Jackson-Maldonado, Thal, Fenson, Marchman, Newton, & Conboy, 2003; Kern, 1999; Trudeau, Frank, & Poulin-Dubois, 1999). These adaptations were used in the present study for the Spanish- and French-learning children.

The MCDI yields a measure of vocabulary size based on the number of words identified by parents on the checklist. Since children were evaluated in both languages, two separate measures of vocabulary size were calculated for each participant. From these measures, relative vocabulary size in the child's dominant language of exposure was computed for each participant (vocabulary size in language A divided by the sum of vocabulary size across language A and B). This allowed us to compare the LEAT's relative exposure calculations to a relative measure of vocabulary and assess criterion validity.

Computerized Comprehension Task (CCT).

The CCT contains 41 pairs of images presented on a touch sensitive screen following Friend et al. (Friend & Keplinger, 2003; Friend, Schmitt, & Simpson, 2012). Children are prompted to touch the target by an experimenter ("Where is the shoe? Touch shoe."). The task begins with 4 training trials followed by a test phase consisting of nouns, verbs, and adjectives of varying difficulty. During the test phase, the experimenter presents the pairs of images immediately following the first mention of the target word in the prompt. After seven seconds elapse, if no response has been made, the trial ends and the pair of images disappears. The CCT yields a total vocabulary score based on the number of correctly identified words (defined as a first touch to the target item).

The CCT has shown significant immediate test-retest reliability across English, Spanish, and French adaptations, thus demonstrating that performance is systematic in children as young as 16 months of age. The CCT also demonstrates convergent validity with MCDI reports of vocabulary comprehension and 4-month test-retest reliability (Friend & Keplinger, 2008; Friend & Zesiger, 2011) and accounts for significant variance in subsequent vocabulary production (Friend, Schmitt, & Simpson, 2012).

Once again, relative vocabulary size in the child's dominant language of exposure was computed for each participant based on the number of correctly identified words on the CCT in each language (vocabulary size in language A divided by the sum of vocabulary size across language A and B).

Procedure

Approximately one week before the children's visit to the lab, the LEAT was administered over the phone with the primary caregiver. The interviewers administering the

assessment were fluent bilingual speakers of English and Spanish or English and French and were trained to follow the LEAT manual outlining specific questions to be asked to elicit the caregiver's responses. The LEAT was administered in English, Spanish, or French depending on the parents' language preference. During the visits to the lab, vocabulary size was assessed using the MCDI and CCT in both of the bilingual children's languages (Pearson et al., 1997).

During the visit to the lab, children were first given a few minutes to warm up to the lab environment and the experimenter. Children and their parents were then escorted to a dimly-lit room to administer the CCT. Parents wore blacked-out sunglasses and noise-cancelling headphones while their children sat on their lap and completed the CCT. Following the CCT, parents filled out the MCDI. The MCDI was given to the expert reporter for each language (see Table 1).

Planned Analyses

Internal consistency refers to the homogeneity of a test, or the degree to which all items on a test measure the same construct. That is, the items on a test should correlate if they indeed represent the construct of interest. High internal consistency suggests that the construct of interest has been consistently measured, and that the derived scores are reliable (Henson, 2001). Thus, to answer our first question regarding the internal consistency of the LEAT, we assessed its four quantitative measures of language exposure: the overall parent estimate, the LEAT's calculation of hours per week, hours per day, and relative language exposure. The overall parent report estimate is obtained by asking parents to provide overall percentages of relative exposure for each language that the child has been exposed to since birth, whereas the other three measures are derived from the detailed day-to-day hourly exposure reported throughout the assessment. Although all of the measures are based on parent report, the LEAT calculations are

based on careful questioning about the timeline of exposure on a day-by-day basis. This is in contrast to the overall parent estimate, for which parents provide a single estimate of relative language exposure over their child's lifespan. We conducted an analysis of the internal consistency of these estimates to assess their reliability in measuring language exposure (Tavakol & Dennick, 2011).

The second research question concerned the LEAT's criterion validity. Criterion validity refers to the relation between a test and performance on another theoretically related measure (DeVon et al., 2007; Woehr & Arthur, 2003; Waltz, 2005). Following the approach of similar adult assessments (Marian, Blumenfeld, & Kaushanskaya, 2007), we evaluated the criterion validity of the LEAT by asking whether the relative language exposure calculation predicts language outcomes. In the case of young toddlers, we expected that relative language exposure would predict scores on our vocabulary measures (David & Wei, 2008; Eilers, Pearson, & Cobo-Lewis, 2006; Hoff et al., 2012; Hurtado, Grüter, Marchman, & Fernald, 2014; Pearson et al., 1997; Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013). According to Grüter, Hurtado, Marchman, and Fernald (2014) analyses between exposure and language outcomes should be conducted in the same terms (either absolute or relative). For example, Hurtado et al. (2014) demonstrate a strengthened correlation between exposure and proficiency in Spanish- and English-speaking 30- and 36-month-olds when both measures were assessed in relative terms (e.g. relative exposure and L1:L2 ratios). Thus in the present analyses, relative language exposure served as our independent measure of interest and *relative* vocabulary size in L1 and L2 (rather than a raw vocabulary score) served as our dependent measure. Recall that the LEAT's estimate of relative language exposure was calculated by weighting the hours of exposure per day according to the duration of exposure to each source of input relative to the

child's age (see LEAT under Method and Supplementary Materials online for more detail). From these weighted hour estimates the LEAT calculates relative language exposure (e.g. hours of exposure to language A divided by sum of hours of exposure to language A and language B).

The final question of the present study was aimed at investigating the utility of the LEAT. Specifically, does it provide more explanatory power than simply asking parents to give an overall estimate of exposure? To this end, we investigated whether the detailed nature of the LEAT explained more variance than the single parent report estimate of relative language exposure.

To answer our research questions concerning the utility and criterion validity of the LEAT, we ran two hierarchical linear regressions with relative vocabulary size as the dependent variable. The predictor variables for these two models were identical. In the first model, we assessed the utility and criterion validity of the LEAT using CCT scores as the dependent measure. Because there are established effects of age and SES on raw vocabulary size, we included these in our models as control variables. However, it is important to note that there is no *a priori* reason to expect age or SES to influence children's *relative* vocabulary across their two languages. On the first step of the model, we included maternal education as a proxy for SES (e.g. Hoff, 2003; Hoff & Tian, 2005) and age to examine whether LEAT variables explained additional variance in language proficiency (vocabulary) above these two factors. On the second step, we included language (either English, Spanish, or French) to evaluate language-specific effects on relative vocabulary size. On the third step, we included the overall parent estimate of relative language exposure to the dominant language. Recall that this was a separate parent estimate that was *not* derived from the LEAT's calculations, in which parents were asked to provide an overall estimate of percent language exposure from birth. On the final step, we

entered the LEAT's calculation of relative exposure to the dominant language, derived from the detailed parent report estimates provided throughout the assessment. The second model assessed the utility and criterion validity of the LEAT using MCDI scores as the dependent measure. All predictors were identical across the two models. Thus, these models evaluate the LEAT's utility by examining whether the LEAT's calculation of exposure, derived from a detailed parent report of day-by-day language input, explains significant variance in relative vocabulary size (as measured by the MCDI and CCT) above simply asking parents to provide an overall estimate. In addition, the analyses evaluate the LEAT's criterion validity by asking whether the LEAT's relative language exposure calculation is a significant predictor of a theoretically related measure (vocabulary).

We expected that, consistent with previous research, an increase in relative language exposure would be associated with a larger proportion of known words in that language. Further, the regression analyses evaluate language-specific effects between subjects by holding language of exposure and vocabulary size constant within subjects and asking whether the relation between the LEAT and vocabulary varies with language. That is, English exposure is considered in relation to English vocabulary for a single participant, Spanish exposure to Spanish vocabulary, and French exposure to French vocabulary. We opted for this single model approach rather than evaluating separate models for each language. In this way, we avoid reducing power by breaking up the sample and decrease the possibility of capitalizing on chance by running separate analyses for each language.

Results

Internal Consistency

Cronbach's alpha was calculated for the overall parent estimate, the LEAT's calculation of hours per week, hours per day, and relative language exposure indicating strong internal consistency ($\alpha = .96$).

Utility and Criterion Validity

Relative Vocabulary Size as Measured on the CCT.

To answer our research questions concerning the utility and criterion validity of the LEAT, we first ran a hierarchical linear regression with CCT *relative* vocabulary size in the child's two languages as the dependent variable. On the first step of the model, we included maternal education and age. On the second step, we included language (English, Spanish, or French). The third step included the overall parent estimate of relative language exposure to the dominant language. On the final step, we entered the LEAT's calculation of relative language exposure to the dominant language. Variance inflation factors (VIF's) were between 1.0 and 1.09, indicating that the predictor variables were not multicollinear and therefore appropriate for the regression analyses (Mansfield & Helms, 1982).

The first, second, and third models with age, maternal education, language, and the overall parent estimate were not significant in explaining relative vocabulary size. Similarly, the fourth and overall model that included maternal education, age, overall parent estimate, and the LEAT calculation was not significant. However, the LEAT estimate explained significant additional variance in vocabulary ($R^{2\Delta} = .06$, $p = .02$) above maternal education, age, language, and the overall parent estimate. Indeed, removing these non significant predictors yielded a significant model, such that the LEAT calculation predicted significant variance in vocabulary size, evincing a moderate effect size ($F(1, 96) = 4.85$, $p = .03$, $R = .22$, see Table 2 for model fit statistics). The absence of a relation between vocabulary, age, and SES may seem somewhat

surprising, however recall that the dependent measure used in these analyses is relative vocabulary size rather than overall vocabulary. There is no *a priori* reason to expect that age or SES would influence vocabulary size in the dominant, *relative* to the non-dominant, language. Figure 1 presents a scatter plot of the LEAT calculation of relative exposure as a function of relative vocabulary size on the CCT across the three language groups. Note that the trend lines are relatively parallel across languages.

Relative Vocabulary Size as Measured on the MCDI.

A second hierarchical linear regression was performed but this time with MCDI relative vocabulary size as the dependent variable to parallel the analyses on the CCT. The predictor variables were identical to the ones in the previous regression analysis: The first step included maternal education and age, the second step included language (English, Spanish or French), the third step included the overall parent estimate of relative language exposure, and the fourth step included the LEAT's calculation of relative language exposure. Once again, the predictor variables were not multicollinear and therefore appropriate for the regression analyses (VIF range: 1.0 to 1.9; Mansfield & Helms, 1982).

Only the overall model that included maternal education, age, language, the overall parent estimate, and the LEAT's calculation was significant in predicting MCDI relative vocabulary size ($F(4, 78) = 2.81$, $p = .02$, $R^2 = .13$, see Table 2). All other previous models were not significant. Further, as before, only the LEAT calculation explained significant variance above the other predictor variables ($R^{2\,\Delta} = .07$, $p = .008$). Figure 2 presents a scatter plot of the LEAT calculation of relative exposure and relative vocabulary size on the MCDI across the three language groups. Note that, as for the CCT, the trend lines are relatively parallel across

languages. Table 3 provide the bivariate correlations among the outcome and predictor variables across MCDI and CCT analyses.

Discussion

The validity and reliability of parent report as a measure of relative language exposure have not been previously established despite its widespread use in early bilingual language acquisition research. Thus, the aim of the present study was to provide an efficient language exposure assessment that could be used across languages and contexts, and to examine the validity, reliability, and utility of the LEAT. Our results indicate that the LEAT demonstrates high internal consistency, criterion validity, and additional explanatory power above simply asking parents for an overall estimate of relative language exposure. Importantly these latter effects hold across parent-report and behavioral estimates of vocabulary knowledge.

Prior findings demonstrate that parent reports of relative language exposure correlate with word knowledge such that greater language exposure leads to larger vocabulary (David & Wei, 2008; Eilers, Pearson, & Cobo-Lewis, 2006; Pearson et al., 1997; Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013; Hoff, Core, Place, Rumiche, Senor, & Parra, 2012). Similarly, Place and Hoff (2011) showed that the number of different conversational speakers and amount of native language exposure as reported by parents explained significant variance in lexical knowledge above relative language exposure in children at age 2. Further, the number of language-exclusive sources of input predicted grammatical complexity in English. The link between exposure and language proficiency also held in the present study, as language exposure estimated on the LEAT converges with measures of vocabulary size across French, English, and Spanish in young children indicating strong criterion validity. Indeed, in the current sample of

children, exposure to two languages was relatively balanced on average, and this balance is reflected in children's vocabulary sizes as a group (see Table 1).

We also assessed the utility of the LEAT by comparing its calculations to the overall parent report measure of relative language exposure. That is, what is the utility of a detailed assessment, and what does it provide above the overall estimate a parent could provide? Across both measures of vocabulary, the calculation of relative language exposure based on detailed questioning explained significant additional variance above the overall parent estimate, age, and maternal education. Thus the comprehensive calculation generated by the LEAT based on detailed parent report provides a more robust and reliable measure of language exposure than the overall parent estimate. Together, these results support the idea that the LEAT indeed captures aspects of language exposure underlying early vocabulary growth consistent with prior research. Given the widespread variability in parent reports of early language exposure, the LEAT introduces a valid, reliable, and systematic approach to assessing language exposure across studies.

The present findings also have implications for the assessment of exposure to better discern the sources of variability in early language acquisition research. Moreover, and from a clinical perspective, the LEAT provides speech and language pathologists with a relatively easy, quick, and reliable tool for evaluating relative language exposure and determining whether language assessments and subsequent intervention should be conducted in one or more of the child's languages. For example, if both languages are functionally relevant for the child, it is recommended that both languages be assessed (Hoff & Core, 2013; Kohnert, 2013). Qualitative information on the child's significant conversational partners also informs the clinician and the researcher about the relevant communication settings for the child. The LEAT can also be re-

administered longitudinally to document the changing nature of the child's language exposure, thereby informing the changing communicative needs of the child. In addition, the current study contributes to the systematic measurement of language exposure in young bilingual and multilingual infants, building on previous language assessments. The LEAT can be used with other measures to inform educational policy with regard to the design of pre-K programs aimed at school readiness and K-12 curriculum especially in communities with large immigrant populations. Finally, the LEAT may also be particularly useful for immigrant populations in conjunction with currently available assessments to aid in determining the proper educational setting for children with varying degrees of exposure to the majority language.

Limitations

We now turn to potential limitations of the LEAT in capturing language exposure. As with all forms of self-report, there is a risk of reporting bias in using the LEAT. Highlighting this point, preliminary research by Grüter, Hurtado, Marchman, and Fernald (2014) has shown that parental reports of exposure do not correlate with a home language sample during a single, typical day. It is important to note that this finding is based on a small sample of 10 children between the ages of 36 and 40 months. As children enter the period of early childhood, it is likely that they are exposed to multiple speakers. Thus a single overall parent report on language input may be insufficient to capture the richness of the language environment.

Relatedly, one caution in using the LEAT (or any parent-reported measure of exposure) is that estimates are likely to be most veridical for infants and toddlers for whom parents have substantial opportunity to observe sources of language input. This limitation could be mitigated by obtaining assessments from multiple sources (e.g., parents, teachers, other caregivers). For example, findings from Bornstein, Putnick, and De Houwer (2005) using parent report of

vocabulary on the MCDI demonstrate the importance of obtaining information from all possible sources of information to provide a broader estimate of early vocabulary.

An additional caution is that memory limitations should be taken into account when asking parents to estimate past language exposure. In the present study, we asked parents to estimate exposure over the course of the child's 17 months of life. Such retroactive estimates can become increasingly difficult as children get older, and may therefore diminish the reliability of the LEAT. In these cases, it is possible to record more recent exposure estimates on the LEAT to ensure more accurate estimates (Bedore et al., 2012).

It is also important to note that although the LEAT's calculation of relative language exposure is associated with language outcomes (size of the lexicon), it is not itself an estimate of language proficiency. The LEAT should therefore not replace assessments of language levels in both languages for children in dual language contexts. Instead, it can be a useful tool in clinical contexts for determining whether to examine proficiency in one or two languages. Similarly, the LEAT does not capture all aspects of language exposure, but measures a subset of important factors that together are associated with vocabulary. For example, it does not assess fine-grained measures of language input that also impact early acquisition, such as number of words, speech rate, and maternal responsiveness, as these are variables that cannot be obtained from parental reports but through direct observation usually in home settings (e.g., Hart & Risley, 1995; Tamis-LeMonda, Bornstein, & Baumwell, 2001).

Conclusion

The heterogeneity of bilingual populations requires a valid characterization of the linguistic environment. Introducing consistency in the way in which we measure early language exposure in young children is a step in the direction of providing consistent assessments. This

paper has introduced the LEAT, an electronic scoring tool, and a detailed user manual. Further, we have provided evidence for the utility, validity, and reliability of the LEAT with data from toddlers across English-French, and English-Spanish exposure contexts. Given that the majority of language exposure assessments in young children are parent-reported, the present adaptation of the LEAT provides a unified assessment of relative language exposure variables in research and clinical contexts, while also contributing ease and consistency in administration through its electronic interface.

Materials

The LEAT will be made available at the Child Language Data Exchange System (CHILDES) website in a downloadable excel format, (childes.psy.cmu.edu) as well as in the supplementary information available online for this publication. The LEAT also has an accompanying manual that provides instructions as well as suggested dialogue for the researcher to elicit appropriate responses from parents (see Supplementary Materials online). The manual also includes details on the calculations of exposure, and instructions for creating spreadsheets with summary variables for each participant that can be exported into data analysis software using macros built into the LEAT. These materials can also be obtained directly from the first and senior authors.

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Figure Captions

Figure 1. Scatter plot for CCT relative vocabulary measure as a function of LEAT relative language exposure by dominant language.

Figure 2. Scatter plot for MCDI relative vocabulary measure as a function of LEAT relative language exposure by dominant language.

Supplementary Material Descriptions

1. The LEAT manual describes administration. It includes specific questions used to probe caregiver responses and provides detail on each calculation. It also includes directions for using the macros for data export.
2. The LEAT is the excel-based tool that allows researchers and clinicians to directly enter language exposure data obtained from parental report into a fillable form. Built-in formulas allow for quick and efficient calculations of exposure to be documented in a digital format.
3. The LEAT merge file holds an excel VBA macro that allows data to be compiled across digital questionnaires to allow for easy data export to statistical analyses software.

Figure 1. Scatter plot for CCT relative vocabulary measure as a function of LEAT relative language exposure by dominant language.

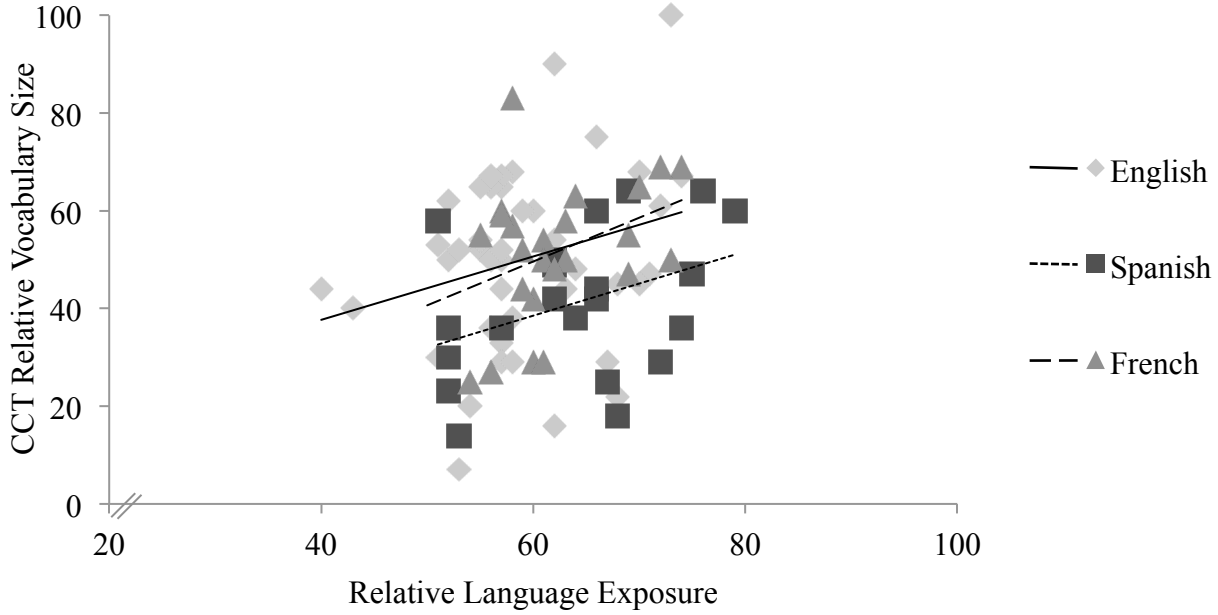

Figure 2. Scatter plot for MCDI relative vocabulary measure as a function of LEAT relative language exposure by dominant language.

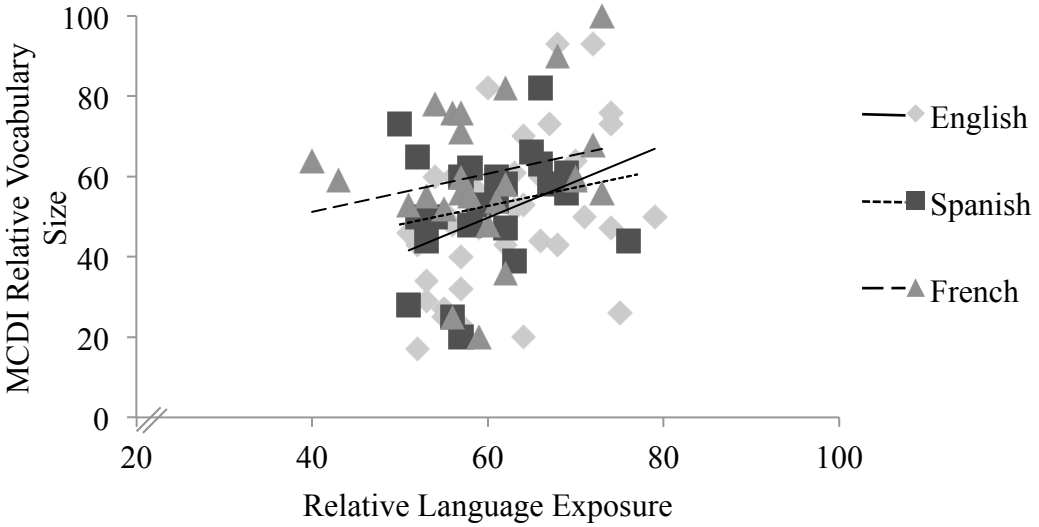

Table 1. Descriptive information for vocabulary size across measures.

	Average	SD
Dominant language		
CCT	9.18	6.1
MCDI	165.79	91.26
Non-dominant language		
CCT	9.35	5.79
MCDI	146.64	94.65

Table 2. Change statistics and model fit analyses for each step in the hierarchical linear regressions using CCT and MCDI vocabulary as the dependent variable (DV), respectively.

	Change Statistics		*Model Fit*			
	$R^{2\,\Delta}$	*p*	β	*F*	*R*	*p*
DV: CCT Relative Vocabulary Size						
1. Maternal education			.12			
Age	.01	.52	.01	.66	.12	.52
2. Language	.002	.63	.05	.51	.13	.67
3. Overall parent estimate of relative exposure	<.001	.97	.004	.38	.13	.82
4. LEAT calculation of relative exposure	.06	.02*	.24	1.42	.27	.22
DV: MCDI Relative Vocabulary Size						
1. Maternal education			.14			
Age	.03	.23	.12	1.50	.17	.23
2. Language	.03	.08	.18	2.04	.25	.11
3. Overall parent estimate of relative exposure	.002	.64	.05	1.57	.25	.19
4. LEAT calculation of relative exposure	.07	.008*	.27	2.81	.36	.02*

Note. * indicates significant value at $p < .05$

Table 3. Bivariate correlations for all predictor and outcome variables in regression analyses.

Measure	1	2	3	4	5
1. CCT relative vocabulary size					
2. MCDI relative vocabulary size	.12				
3. Age	-.02	-.14			
4. Maternal education	.13	-.11	-.04		
5. Overall parent estimate of relative exposure	.01	-.01	.08	.11	
6. LEAT estimate of relative exposure	.24*	.26*	.09	-.04	.23*

Note. * indicates significant value at $p < .05$

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