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SHORT REPORT

Influence of bilingualism on memory generalization during infancy

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Abstract

Very few studies have examined the cognitive advantages of bilingualism during the first two years of development, and a majority of the studies examining bilingualism throughout the lifespan have focused on the relationship between multiple languages and cognitive control. Early experience with multiple language systems may influence domain-general processes, such as memory, that may increase a bilingual child's capacity for learning. In the current study, we found that bilingual, but not monolingual, infants were able to generalize across cues at 18 months. This is the first study to show a clear bilingual advantage in memory generalization, with more equal or balanced exposure to each language significantly predicting ability to generalize. A video abstract of this article can be viewed at http://www.youtube.com/watch?v=31QsMqYtGGo&feature=plcp

Introduction

Two-thirds of children around the world are raised in bilingual homes (Crystal, 1997) and according to the most recent US census data, 21% of (11.2 million) school-age children (5–17 years) in the United States spoke a language other than English at home (US Census Bureau, 2009). Cognitive advantages of bilingualism have been found as early as 7 months of age (Kovács & Mehler, 2009), suggesting that simply hearing the two languages contributes to the emerging cognitive advantage, and these advantages continue throughout the lifespan (Bialystok, Craik & Ryan, 2006; Costa, Hernández & Sebastián-Gallés, 2008).

The majority of studies reporting cognitive advantages of bilingualism early in development have been conducted with preschoolers (3 to 5 years) and have focused on executive functioning (Bialystok, Craik, Green & Gollan, 2009). Presumably, with the two languages 'active', the bilingual child constantly monitors the two language systems and may practice skills such as inhibition at an earlier age (Green, 1998). Having to learn different sets of rules for each language, while avoiding interference between the languages, provides the bilingual child with greater experience in learning from a mixed input. Studies have shown that this mixed input and awareness of different languages has led to a developmental advantage in nonlinguistic tasks that necessitate cognitive flexibility in children (Adi-Japha, Berberich-Artzi & Libnawi, 2010; Bialystok & Senman, 2004). Enhanced abilities in executive functioning may influence other domain-general processes, such as memory flexibility, that may increase a bilingual child's capacity for learning.

Memory flexibility is crucial to learning because it allows past experience to be applied to a range of future situations that are unlikely to be perceptually equivalent to the initial learning episode. The encoding specificity hypothesis, however, predicts that the memory of an event will only be retrieved if the cues at retrieval match the same cues seen during the original presentation (Tulving & Thomson, 1973). Although many studies are consistent with this hypothesis and show that changes in either stimuli or environmental context at the time of retrieval can disrupt memory performance, during adulthood these context changes often have to be quite extreme to exert a measureable effect (Godden & Baddeley, 1975).

The best evidence for the encoding specificity hypothesis has been obtained from infants (Hayne, 2006). During infancy, memory performance is initially highly context-specific, but becomes increasingly flexible across development. Memory specificity and flexibility during infancy has been documented in monolingual infants using a declarative measure of memory, the deferred imitation (DI) task (see Barr & Brito, in press; Hayne, 2006, for review). DI provides an optimal measure of memory in preverbal infants because it requires the infant to encode, retain, and retrieve a memory – all without the production of language. Memory retrieval is disrupted if infants are tested with different but functionally equivalent stimuli. Using the DI puppet task, Hayne and colleagues (1997) found that 6-month-old infants can imitate a sequence of actions when tested

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with the original objects, but fail to imitate if the objects change in color or shape. At first, this highly specific nature of memory may constrain learning, but generalization across cues emerges gradually around 12 months for changes in color (grey mouse to pink mouse), and 18 months for minimal changes in color and shape (grey mouse to pink rabbit) and 21 months for more drastic changes in color and shape (black and white cow to yellow duck). Test delay also influences memory flexibility with 12- to 18-month-olds exhibiting higher levels of generalization after shorter delays (immediate, 10 minutes) than after longer 24-hour delays (Hayne, McDonald & Barr, 1997; Herbert & Hayne. 2000; Jones & Herbert, 2008).

In the current study, we asked whether a bilingual infant's exposure to two languages could help them generalize across cues at 18 months after a 30-minute delay. Hayne and colleagues (1997) demonstrated that although 21-month-old monolinguals could generalize between two distinct puppets, 18-month-old monolinguals could not after a 24-hour delay. We hypothesized that bilingual infants would show a cognitive advantage in memory generalization, which would demonstrate the influence of early experience with multiple language systems on memory flexibility.

Method

Participants

Our final sample included 15 infants in the monolingual group (six male, nine female; *M* age = 18.53 months), 15 infants in the bilingual group (nine male, six female; *M* age = 18.68 months), and 12 infants in the baseline group (six monolingual, six bilingual; *M* age = 18.98 months). Eight additional infants (five monolinguals; three bilinguals) were excluded from the analyses because of parental interference ($n = 3$) or failure to touch the stimuli ($n = 5$). Parents were primarily Caucasian ($n = 23$) or mixed race ($n = 12$), were middle to high income, and well educated with no difference between the monolingual group, bilingual group, and baseline group on mean parental educational attainment ($F(2, 39) = .22$, $p = .81$) or mean rank of socioeconomic index ($F(2, 34) = 1.05$, $p = .36$).

Bilingual infants were defined as those who (1) had a non-native English-speaking parent, (2) had a parent who predominantly spoke to them in a minority language at home, and who (3) had been exposed to two languages from birth. An infant's language exposure was measured by an adapted version of the Language Exposure Questionnaire (Bosch & Sebastián-Gallés, 1997) to obtain specific estimates of the infant's exposure to each language from all possible language partners (e.g. parents, grandparents). The average first language (L1) exposure for the monolingual group was 98% (some infants were minimally exposed to a second language via a secondary caregiver). In the monolingual group, 13 infants were exposed only to English, one to only Spanish and one to only Portuguese. Average L1 exposure for the bilingual group was 63%; range of second language (L2) exposure for the bilingual group was between 25% and 50%. L1 languages were English ($n = 10$), Spanish ($n = 4$), and Hebrew ($n = 1$). L2 languages were Spanish ($n = 9$), Portuguese ($n = 2$), Hebrew ($n = 2$), German ($n = 1$), and Cantonese ($n = 1$).

Apparatus

Two hand puppets (a black and white cow and a yellow duck with an orange bill) were 30 cm in height and made of soft acrylic fur. A removable felt mitten (8 cm × 9 cm) was placed over the right hand of each puppet and the mitten matched the color of the puppet. A large jingle was secured to the inside of the mitten. The bell was removed during the test session to avoid prompting memory retrieval.

The caregiver was asked to complete a general information questionnaire (assessing SES, parental education, childcare, and language) as well as the MacArthur Communicative Development Inventory: Words and Sentences Short Form (MCDI) to measure children's productive vocabulary (Fenson, Pethick, Renda, Cox, Dale & Reznick, 2000). For the bilingual infants, the caregiver was asked to fill out the same form for both languages. Due to the variety of languages, a language-appropriate MCDI was not feasible. Both a combined MCDI score (adding the number of words produced in each language) and English-only MCDI score were used in the analyses.

Procedure

The materials, study design, procedure, and analysis were identical to those described in Hayne *et al*. (1997) except that the test delay was shortened from 24 hours to 30 minutes to maximize generalization performance. Infants were assigned to the generalization or the baseline condition. During the demonstration, the infants in the generalization condition sat on their caregiver's lap and the parent held the infant firmly by his/her waist. The experimenter sat directly in front of the infant and held the puppet at the infant's eye level, approximately 80 cm away, out of the infant's reach. The experimenter performed the three target actions (pull off mitten, shake mitten to ring the bell, replace mitten) with one puppet (e.g. duck) three times in succession and the demonstration lasted approximately 60 s. The experimenter did not describe the target actions or the stimuli, and the infant was not allowed to touch the puppet. During the 30-minute delay, infants played with their own toys. Infants in the baseline condition were not shown the demonstration of the target actions. Rather, they were shown the test stimuli for the first time during the test session to assess the spontaneous production of the target actions. The test session was identical for the generalization and baseline conditions. During the test, the experimenter held the novel puppet in front of the infant (i.e. if the infant in the generalization condition was shown a demonstration with a duck puppet, the infant was tested with a cow puppet) within the infant's reach. The experimenter encouraged the infant to interact with the puppet for 90 s from the time the infant first touched the puppet.

Coding

One coder scored each videotaped test session for the presence of the three target behaviors: (1) remove the mitten, (2) shake the mitten, and (3) replace or attempt to replace the mitten. The number of individual target behaviors produced during the 90 seconds after the infant first touched the puppet was summed to calculate the imitation score (range = 0–3). A second independent coder scored 50% of the videos to determine reliability of the ratings; there was an inter-rater reliability kappa of 0.82.

Results

A preliminary ANOVA that investigated gender and stimuli yielded no main effects or interactions; therefore the data were collapsed across these variables in the following analyses. A one-way ANOVA was used to examine imitation performance across the three groups. Deferred imitation is operationally defined as performance that significantly exceeds a baseline control condition. Due to lack of homogeneity of variance, a Welch's correction was used. A significant main effect of group was found, *Welch's* $F(2, 25.16) = 4.32$, $p = .02$, adj. $\omega^2 = .20$. Post-hoc comparisons using the Games-Howell procedure showed that the bilingual group ($M = .93$, $SD = .96$) had significantly higher imitation scores than both the monolingual group ($M = .13$, $SD = .52$, $p = .02$) and baseline group ($M = .17$, $SD = .39$, $p = .03$). These means are typical and have previously been reported in other studies of memory generalization using the same stimuli (Hayne, Boniface & Barr, 2000; Hayne *et al.*, 1997; Herbert, 2011). To examine the effect sizes for these two significant pairs, the robust effect size measure, Glass' delta, was calculated by using the largest standard deviation of the three groups, and revealed effect sizes for the two significant comparisons of 0.83 and 0.80, respectively.

Nine of the 15 bilingual infants imitated the previously demonstrated actions with the novel puppet, compared to only one of the 15 monolingual infants. To test which individual factors predicted generalization, in a logistic regression model imitation (imitation score = 0 vs. imitation score > 0) was regressed on MCDI and percent L2 exposure. The full model was statistically significant ($\chi^2 = 12.08$, $p = .001$, with $df = 1$), but the Wald criterion demonstrated that only percent L2 exposure made a significant contribution to the prediction ($p = .006$, odds ratio Exp (B) = 1.10). A Nagelkerke's R^2 of .49 indicated a moderate relationship between prediction and grouping, and prediction success with the model was 85.7%. The results were the same whether the combined MCDI score or the English-only MCDI score was used for the bilinguals in the analyses. Using the logistic coefficients, we calculated the probability of generalization for an infant with 10% L2 exposure to be 11.67%, 34.43% for an infant with 25% L2 exposure, and 83.97% for a perfectly balanced bilingual with 50% L2 exposure.

Discussion

This is the first study to show a clear bilingual advantage in memory generalization, and one of the few studies examining bilingual cognitive advantages during the first two years of development. The finding that percent exposure to L2, but not vocabulary production as indexed by the MCDI score, predicted memory generalization suggests that the advantages of bilingualism occur well before the child is able to proficiently communicate in either language. A more equal or balanced exposure to each language may enhance these early cognitive abilities, as has been shown in past studies with both adults (Zied, Phillipe, Karine, Valerie, Ghislaine, Arnaud & Didier, 2004) and children (Bialystok & Majumder, 1998).

There are several possible explanations for the bilingual advantage in memory generalization found in this study. First, bilingual infants may have selectively attended to the mitten removal while ignoring the distracting novel perceptual cues. Bialystok and Shapero (2005) argued that a bilingual child's enhanced selective attention – being able to simultaneously ignore competing cues and focus on the relevant aspects of the stimuli – may have led to a bilingual advantage in the Embedded Figures Test, a test which requires 6-year-old children to find a simple visual pattern hidden in a larger complex drawing.

Another explanation could be that bilingual infants form hierarchical mental representations earlier than monolinguals. Within the memory development literature, it has been hypothesized that age-related changes in generalization may be due to an inability to form *relational representations*. Declarative memories are encoded in networks of representations that permit new memories to be connected to previous information (see Eichenbaum, 2002, for review). Thus, in order to successfully generalize across cues, infants must encode the details of the cue in a hierarchical manner, creating memories that are connected together by causal, logical, or temporal relationships (Eichenbaum, 2002; Jones & Herbert, 2006). Bilingual children may develop relational representation abilities earlier than monolinguals because they need to associate words from multiple languages and make connections at an abstract level between the two words and the same referent (Bialystok & Martin, 2004). Bialystok (1999) found that bilingual preschoolers have an advantage in the Dimensional Change Card Sort (DCCS) task – a task where children must conceptualize both the stimuli and the rules by constructing an appropriate mental representation. In the present study, bilingual infants may have been more likely to extract the hierarchical element of removing the mitten, independent of the perceptual differences between the two puppets.

The age at which infants can generalize across cues is believed to be the beginning of a hippocampus dependent higher-level memory system (Eichenbaum, 2002), but performance is likely to depend on brain systems in addition to the hippocampus. For example, during the demonstration phase of a DI task, infants encode both the elements of the target objects and the sequence of ordered events to build a relational representation, before selecting the appropriate motor response to a novel stimulus at test. This sequencing ability, selection, and motor planning have been reported to be dependent on the prefrontal cortex (Nelson & Webb, 2003). Richmond and Nelson (2007) posit that developmental changes in deferred imitation performance are directly related to hippocampal development, but acknowledge that due to the motoric capabilities needed for this task, explanations involving the development of the frontal cortex or the development of connectivity between the hippocampus and frontal brain regions cannot be excluded. Speculatively, if bilingual infants do indeed possess advantages in selective attention and mental representation, this may be associated with enhanced connectivity between frontal and hippocampal systems and may account for the reported differences in generalization performance between monolingual and bilingual infants in the present study. Utilization of imaging methods in future studies may be able to disentangle the neural underpinnings of memory flexibility during infancy.

Overall, these findings suggest that early exposure to multiple languages may influence domain-general cognitive processes, but more research is necessary to examine the connection between declarative memory development and bilingualism. The cognitive advantages of bilingualism are not just a phenomenon early in development – advantages have been reported throughout the lifespan (Bialystok *et al.*, 2006; Costa *et al.*, 2008) and may even delay the onset of dementia in older adults (Bialystok, Craik & Freedman, 2007). Studying these cognitive advantages early in development, while the infant is still becoming proficient with both languages, could lead to a better understanding of the behavioral and underlying neural mechanisms involved.

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